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Anatomical aspects of the use of the thoracodorsal nerve as a donor in musculocutaneous nerve injury

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Abstract

Aim. To assess the anatomical possibility of the use of the thoracodorsal nerve as a donor for nerve transfer to the musculocutaneous nerve.

Methods. Anatomical dissection of the brachial plexus with layer-by-layer dissection of secondary bundles, short and long branches was performed in 121 male and female corpses. The localization of the origin of thoracodorsal and musculocutaneous nerves relative to the clavicle, the takeoff angle (degrees) from the secondary bundle, the length (in centimeters) of the nerves from the site of origin to the latissimus dorsi muscle entry point and the perforation of the coracobrachialis muscle, respectively, were investigated. The length of the thoracodorsal nerve with and without extramuscular branches was studied separately.

Results. It was revealed that, in 58.7% of cases, the thoracodorsal nerve has the optimal length required for transposition to the musculocutaneous nerve. The excess length of the thoracodorsal nerve was between 0.1 and 9.1 cm. In 41.3% of cases, the length of the thoracodorsal nerve is not enough for transposition. Of these, in 17.4% of cases, the shortage of the length of the thoracodorsal nerve was –2 cm or less, which categorically does not allow its transfer to the musculocutaneous nerve. Only in 5% of cases, the length of the nerve was not enough for transposition in the use of the thoracodorsal nerve with extramuscular branches.

Conclusion. Due to tension in many cases, the thoracodorsal nerve transfer to the musculocutaneous nerve can be performed with difficulty, and in some cases it is impossible, solving the problem in this category of people dictates the development of new surgical techniques with the thoracodorsal nerve or the use of another nerve as a donor.

Keywords: brachial plexus, thoracodorsal nerve, musculocutaneous nerve, nerve transposition, injury.

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Background. Damage to the structures (spinal nerves, trunks, and fascicles) of the brachial plexus is considered a severe condition. It is accompanied by a loss of peripheral nerve function and leads to patient disability. With this type of injury, the nerve transposition technology is especially effective, as it restores nerve conduction to the denervated muscle as close as possible [1]. Nerve transposition technology implies that the less needed donor nerve is transected near the muscle innervated and transported to the more important distal segment of the recipient nerve. Thus, the proximal injury at the brachial plexus level is transformed into a distal one, which enables to shorten the path of nerve fiber regeneration [2].

Currently, surgeries are performed to transpose the thoracodorsal nerve (TDN) to the musculocutaneous nerve (MCN), whose function is impaired when the spinal nerves C_5, C_6 or the superior primary trunk of the brachial plexus are damaged [3]. It should be noted that the brachial plexus is most often damaged precisely in the supraclavicular region with the separation of the upper primary trunk [4]. When the upper primary trunk is damaged, the TDN remains intact, since the TDN nerve fibers are mainly formed from the spinal nerves C_7 and C_8, which enables to use the nerve as a donor case of damage to the MCN [5].

To perform the transfer of the donor nerve to the position of the recipient nerve, an optimal length of the donor nerve is a necessary condition [6]. Since the introduction of TDN transposition surgeries, there have been cases in which the TDN length was not enough, and other nerves were used as donors during the surgery, which were inferior in characteristics to the TDN [7]. Such cases are rare, but

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they require a longer surgery time, and also are associated with an attempt to match the ends of the nerves with tension, development of complications, and this generally does not enable to plan an optimal surgical technique.

It is obvious that in order to understand the approach of patient management and the development of surgeries for the neurotization of damaged nerves using the nerve transposition technology, a detailed study of the anatomical characteristics of donor and recipient nerves is necessary [8]. TDN has already been described in anatomical and clinical studies when comparing donor nerves using a latissimus dorsi flap in reconstructive surgery [9, 10]. A number of clinical studies on the results of transferring the TDN to the MCN position have been published, but there are still no anatomical studies in this field [7, 11].

This study aimed to assess the anatomical possibility of using the TDN as a donor nerve when transferring to the MCN recipient nerve position.

Materials and methods. The study was conducted on preparations of the brachial plexus of 121 male and female corpses. Most of the subjects were the corpses of men (76, 63%), with fewer corpses of women (45, 37%). The criterion for inclusion in the study was the absence of injuries to the upper limb, chest, neck and head.

Anatomical preparation of the brachial plexus was performed with the layer-by-layer isolation of secondary fascicles, including short and long branches. The TDN and MCN were studied in detail as a donor nerve and a recipient nerve. The TDN was dissected from the posterior secondary fascicle throughout to the entry of the latissimus dorsi muscle. The localization of the place of TDN origin relative to the clavicle, length (centimeters) of the nerve, angle (degrees) of divergence from the secondary fascicle, number of extramuscular branches, and length of each branch were determined.

MCN was also isolated along the entire length from the lateral secondary fascicle to the point of penetration into the coracobrachialis muscle. The localization of the MCN origin relative to the clavicle, length (centimeters) of the nerve, and angle (degrees) of divergence from the secondary fascicle were determined.

Based on the length of the two nerves, two indicators were determined, namely the difference in length between the TDN and MCN (centimeters) and the difference in length between the TDN with extramuscular branches and MCN (centimeters).

Data analysis was performed using the Statistica 10 software package. The indicators were tested for normality of distribution using the Kolmogorov–

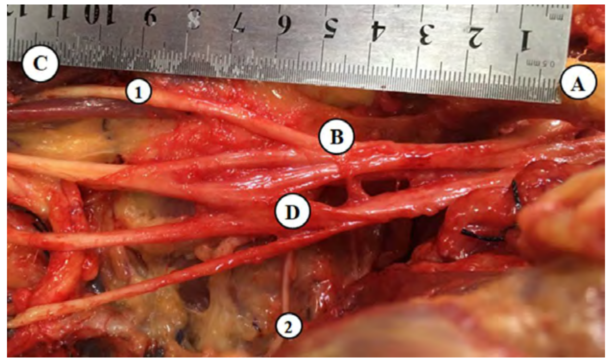

Fig. 1. Formation of the thoracodorsal nerve (TDN) and musculocutaneous nerve (MCN): A—clavicle; B—the place of origin of the MCN from the lateral secondary fascicle of the brachial plexus; C—the place of MCN entry into the coracohumeral muscle; D—the place of origin of the TDN from the posterior secondary fascicle of the brachial plexus; 1—MCN; 2—TDN; 3—median nerve; 4—radial nerve; 5—ulnar nerve; 6—axillary nerve.

Smirnov test. Characterization of the quantitative traits with a nonparametric distribution was presented using the median (Me) and interquartile range [P_{25}; P_{75}]. The determination of the significance of intergroup differences in quantitative traits was performed using the Wilcoxon nonparametric test. The lower limit of significance p was 0.05.

Ethical principles and norms were observed during the study (extracts from the minutes of the meeting of the local ethical committee of the Krasnoyarsk State Medical University No. 91 dated November 09, 2018).

Results. In 94.2% of cases (n = 114), the TDN departed from the posterior secondary fascicle of the brachial plexus at a distance of 5.0 [4.5; 6.0] cm from the clavicle, and an angle of 130 [120; 135]° downwards to the anterolateral surface of the latissimus dorsi. In 5.8% of cases (n = 7), the TDN was formed from the axillary nerve at a distance of 6.0 [5.5; 6.3] cm from the clavicle, and at an angle of 115 [110; 133]° (Fig. 1).

The TDN length to the entrance of the latissimus dorsi was composed of the length of the TDN itself (9.5 [8.0; 11.0] cm) and that of its longest branch (4.6 [3.5; 5.2] cm). As a result, the length of the TDN was 14.1 cm with variations from 11.5 to 15.5 cm [P_{25}; P_{75}]. Most often, in 62.0% of cases (n = 75), the TDN divided into two branches with a length of 4.0 [2.8; 4.5] cm each; In 27.3% of cases (n = 33), it did not divide into branches, but penetrated with a length of 11.0 [10; 12.5] cm the latissimus dorsi muscle with one trunk; in 8.2% of cases (n = 10), it divided into three branches with a length of 4.3 [3.5; 6.0] cm; and in 2.5% of cases (n = 3), the nerve divided into four branches of 4.8 [4.0; 5.2] cm each.

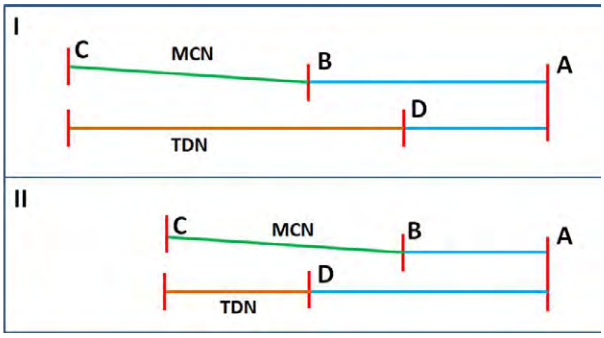

Fig. 2. The value of the level of origin of the thoracodorsal nerve (TDN) and musculocutaneous (MCN) nerve during transposition: A—clavicle; B—MCN origin from the lateral secondary fascicle; C—MCN entry into the coracohumeral muscle; D—origin of the TDN from the posterior secondary fascicle; I—with a low MCN origin relative to the TDN, greater length of the TDN is required for transposition; II—with a high MCN origin relative to the TDN, shorter TDN is required for transposition

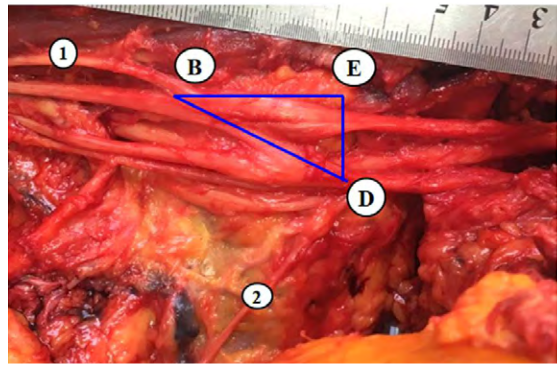

Fig. 3. Calculation of the additional length of the thoracodorsal nerve (TDN) during transplantation into the position of the musculocutaneous nerve (MCN): B—the place where MCN originates from the lateral secondary fascicle of the brachial plexus; E—the upper point of the lateral secondary fascicle of the brachial plexus, opposite to the place of origin of the TDN; D—the place of origin of the TDN from the posterior secondary fascicle of the brachial plexus; 1—MCN; 2—TDN.

In 96.7% of cases (n = 114), MCN departed from the lateral secondary fascicle of the brachial plexus at a distance of 8.0 [7.0; 9.5] cm from the clavicle, and an angle of 10 [10; 20]° in the anterolateral direction and, perforating the coracobrachial muscle, it entered the biceps brachii muscle. In 3.3% of cases (n = 4), the MCN was absent, and the branches of the median nerve innervated the anterior muscle group of the shoulder. The MCN length before the perforation of the coracohumeral muscle was 6 cm with variations from 4.5 to 7.8 cm [P25; P75] (Fig. 1).

Regarding the transfer of the TDN to the MCN position, in addition to the sufficient length of the TDN, it is necessary to match the level of origin of these nerves. It was showed that the clavicle serves as an important reference point relative to which the correspondence between the levels of the MCN and TDN origin can be determined. This indicator is of great importance for nerve transposition; if the distance AB is greater than the distance AD, this will require an additional length of the TDN, and vice versa. A greater distance AD allows the shorter TDN to be transferred to the MCN position (Fig. 2).

A comparative study showed that the median value of the distance from the clavicle to the place of origin of the TDN was 5.0 [4.5; 6.0] cm, and that of the MCN was 8.0 [7.0; 9.5] cm. Consequently, the place of MCN origin was farther from the clavicle, while that of TDN was closer (differences are significant, $p = 0.00001$). The pairwise comparison of these indicators in each brachial plexus revealed that in 93.4% of cases (n = 113), the distance from the clavicle to the MCN origin was greater than the distance from the clavicle to the TDN origin (Fig. 3). The difference in length ranged from 0 to 13.5 cm, and the median was 2.9 [1.5; 4.0] cm. In 5.8% of cases (n = 7), the distance from the clavicle to the site of MCN formation was less than the distance from the clavicle to the site of TDN formation, and it was equal in 0.8% of cases (n = 1).

During transposition, this difference must be taken into account when calculating the TDN length. In this regard, a more detailed measurement of the difference in length between the two nerves was made (see Fig. 3).

It was found that the brachial plexus thickness at the level of the TDN origin (DE distance) ranged from 1.0 to 2.9 cm, with a median of 1.7 [1.3; 2.5] cm. The difference from the TDN and MCN places of origin (BE distance) ranged from 0 to 10.7 cm, and the average value was 2.7 [0; 4.7] cm. Therefore, the additional length of the TDN (BD hypotenuse) ranged from 0 to 10.8 cm, and the average value was 3.3 [1.9; 4.3] cm.

Thus, to transfer the TDN to the MCN position, the length of the first one must correspond to the following:

– The length of the second (from the origin from the lateral secondary fascicle of the brachial plexus to the point of entry into the coracobrachial muscle);

– Additional distance from the origin of the first to the origin of the second nerve (hypotenuse).

The MCN length was 6.0 [4.5; 7.8] cm, and that of the TDN was greater than 9.5 [8.3; 11.0] cm, the differences were statistically significant ($p = 0.00000$). Considering that the additional length (hypotenuse) accounts for 3.3 [1.9; 4.3] cm, the length of the TDN (9.5 [8.3; 11.0] cm) is sufficient to perform the transplantation to the MCN position (6.0 [4.5; 7.8] cm + 3.3 [1.9; 4.3] cm).

However, a pairwise comparison revealed significant differences in the length of the nerves. It was revealed that the TDN length was sufficient for transposition to the MCN position in only 58.7% of cases (n = 71). The excess length of the nerve ranged from 0.1 to 9.1 cm, and the average value was 2.9 [1.4; 4.3] cm. In 41.3% of cases (n = 50), the length of the TDN was insufficient for transposition. The difference in length ranged from –0.1 to –8.9 cm, and the average value was –1.5 [–3.3; –0.5] cm. Among these, in 17.4% of cases (n = 21), the lack of the TDN length was –2.1 cm and less, which already totally prevents its transfer to the MCN position.

With a lack of the TDN length, its lower intersection together with the extramuscular branches is possible. The length of the TDN with extramuscular branches ranged from 5.5 to 18.9 cm, and the median was 12.5 [11.5; 14.3] cm, which was significantly greater than the length of the nerve without branches (p = 0.000). Pairwise comparison revealed that in 13.2% of cases (n = 16), the length of the TDN with extramuscular branches was still not sufficient to be transferred to the MCN position. The difference in length ranged from –0.1 to –5.8 cm, and the median was –1.3 [–2.5; –0.7] cm. In 5.0% of cases (n = 6), the difference in length was –2.1 cm or less, which prevents the transposition of the TDN with extramuscular branches to the MCN position, even with tension

Discussion. This study was the first to assess the anatomical possibility of transferring the TDN to the MCN position. According to our data, in 58.7% of cases, if the length of the TDN nerve is used before it is divided into extramuscular branches, then this length will be sufficient to transpose the TDN to the MCN position. In a clinical study by F. Soldado et al., the use of the TDN length without extramuscular branches also provided the optimal nerve length required for the transposition to the MCN position [7].

In 23.9% of cases, the length of the TDN is not sufficient, since the diastasis between the TDN and MCN ranges from 0.1 to 2.0 cm, but this allows the transposition with an acceptable tension of the nerves. In 17.4% of cases, transposition of the TDN is impossible, since the diastasis between the TDN and MCN is > 2.1 cm.

According to several authors, when suturing the nerves, the maximum permissible tension is considered to be that at which the nerve segments can be matched with the simultaneous tying of two 8/0 threads, which corresponds to a diastasis of up to 2.0 cm [12,13]. According to the study results, the use of the TDN with extramuscular branches can increase the length of the nerve required for transposition to the MCN and reduce the risk of ineffective surgery from 17.4 to 5.0%.

CONCLUSION

Due to the discrepancy in the length of the nerves in 13.2–41.3% of cases, the transfer of the thoracic nerve with and without extramuscular branches to the position of the musculocutaneous nerve can be performed with tension, and this is impossible in 5.0–17.4% of cases. Solving the problem in this category of patients necessitates the development of new surgical techniques with the transposition of the thoracodorsal nerve or the use of another nerve as a donor. In any case, it is advisable for the surgeon to have information about the length of the donor nerve, the length of the recipient nerve of the patient and, especially, about the difference in the length of the two nerves with and without extramuscular branches.

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Conflict of interest. The authors declare no conflict of interest.

REFERENCES

1. Chuang D.C. Distal nerve transfer: Perspective of reconstructive microsurgery. *J. Reconst. Microsurg.* 2018; 34 (9): 675–677. DOI: 10.1055/s-0038-1639369.

2. Griffin M.F., Malahias M., Hindocha S., Khan W.S. Peripheral nerve injury: Principles for repair and regeneration. *Open Orthop. J.* 2014; 8: 199–203. DOI: 10.2174/1874325001408010199.

3. Samardzić M., Rasulić L., Lakićević N., Bascarević V. Collateral branches of the brachial plexus as donors in nerve transfers. *Vojnosanit. Pregl.* 2012; 69 (7): 594–603. DOI: 10.2298/VSP110301007S.

4. Kaiser R., Waldauf P., Haninec P. Types and severity of operated supraclavicular brachial plexus injuries caused by traffic accidents. *Acta. Neurochir. (Wien).* 2012; 154 (7): 1293–1297. DOI: 10.1007/s00701-012-1291-7.

5. Kober K.V., Gorbunov N.S., Sindeeva L.V., Chikun V.I. Macro-anatomic and intrainal structure of the thoracodorsal nerve. *Modern problems of science and education*. 2019; (3): 133. (In Russ.)

6. Foroni L., Siqueira M.G., Martins R.S., Oliveira G.P. The intercostobrachial nerve as a sensory donor for hand reinnervation in brachial plexus reconstruction is a feasible technique and may be useful for restoring sensation. *Arq. NeuroPsiquiatr.* 2017; 75 (7): 439–445. DOI: 10.1590/0004-282x20170073.

7. Soldado F., Ghizoni M.F., Bertelli J. Thoracodorsal nerve transfer for elbow flexion reconstruction in infra-

clavicular brachial. *J. Hand. Surg. Am.* 2014; 39 (9): 1766–1770. DOI: 10.1016/j.jhsa.2014.04.043.

8. Malalasekera A., Beneragama T., Kanesu S. et al. Extra and intramuscular distribution of the thoracodorsal nerve with regard to nerve reconstruction surgeries. *J. Reconstr. Microsurg.* 2016; 32 (5): 358–360. DOI: 10.1055/s-0036-1579541.

9. Schreiber J.J., Byun D.J., Khair M.M. et al. Optimal axon counts for brachial plexus nerve transfers to restore elbow flexion. *Plas. Reconstruct. Surg.* 2015; 135 (1): 135e–141e. DOI: 10.1097/prs.0000000000000795.

10. Patel R., Oberhofer H., O'Neill D. et al. Is thoracodorsal nerve transection needed in latissimus dorsi breast reconstruction? *Ann. Plast. Surg.* 2020; 84 (6S, suppl. 5): S393–S395. DOI: 10.1097/SAP.0000000000002281.

11. Novak C.B., Mackinnon S.E., Tung T.H.H. Patient outcome following a thoracodorsal to musculocutaneous nerve transfer for reconstruction of elbow flexion. *Br. J. Plast. Surg.* 2002; 55 (5): 416–419. DOI: 10.1054/bjps.2002.3859.

12. Novikov M.L., Torno T.E. Traumatic injuries of brachial plexus: present methods of surgical treatment. Part II. Treatment policy for brachial plexus injuries. *Neuromuscular diseases.* 2013; (1): 18–26. (In Russ.)

13. Millesi H. The nerve gap: theory and clinical practice. *Hand. Clin.* 1987; 2: 651–663. PMID: 3539948.