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The features of the intrafascicular structure of the thoracodorsal nerve trunk in terms of restoring afferent innervation in breast reconstruction

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Abstract

Aim. To study of anatomical and topographic features and the intrafascicular structure of the thoracodorsal nerve trunk in the brachial plexus.

Methods. The study was performed on the brachial plexus preparations of 80 male and female corpses. Short and long branches, secondary bundles, primary trunks, spinal nerves, anterior and posterior roots of the spinal cord were layer-by-layer anatomically prepared from brachial plexus. The angles of inclination from the arising site of the thoracodorsal nerve, the topography throughout and after entering the latissimus dorsi muscle were studied. The length and thickness of the thoracodorsal nerve, including the extramuscular and intramuscular parts, were measured. After isolation and fixation of the preparations, intrafascicular dissection of the thoracodorsal nerve was performed throughout the brachial plexus, by using microsurgical instruments and a binocular magnifier.

Results. The length of the thoracodorsal nerve consists of extramuscular and intramuscular parts and was equal to 17.9 cm, of which the extra-muscular part was three-quarters of the total length of the nerve. The nerve trunk dissection revealed that the thoracodorsal nerve consists of 1–4 nerve fascicles and most frequently, in 46.2% of preparations, the thoracodorsal nerve arises from the C_7 nerve root. The presence of motor and sensory portions of nerve fibers in the thoracodorsal nerve was found. In 90.2% of the preparations, the motor portion was located in the posterior-lateral part of the nerve and sensory in the anterior-medial. In most cases, both the sensory and motor fascicles arose from C_7, or motor fascicle from C_7 and sensory from C_8.

Conclusion. The intrafascicular dissection of the thoracodorsal nerve revealed microtopography of the sensitive and motor portions of nerve fibers in the nerve and along the entire length of the brachial plexus; in breast reconstruction, after mastectomy with thoracodorsal flap for the preservation of afferent innervation, it is recommended to cross only motor fibers of the thoracodorsal nerve.

Keywords: brachial plexus, thoracodorsal nerve, intrafascicular structure, sensitive innervation, thoracodorsal flap.

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Background. With the development of reconstructive surgery, microsurgical grafts (autografts) have become widely used to replace skin and soft tissue defects, particularly after radical mastectomy for breast cancer. The restoration of the reconstructed breast's volume and symmetry and the creation of its aesthetic shape have become possible [1]. Currently, special attention is paid to the restoration of the afferent innervation of the transplanted grafts. Therefore, scientific research is actively being conducted to develop and improve the technique of graft transplantation, which is based on anatomy [2,3].

The thoracodorsal flap (TD-flap) based on the latissimus dorsi muscle (LDM) remains one of the most reliable methods of breast reconstruction since it has the least amount of complications compared with other grafts [4]. The flap comprises

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skin, subcutaneous adipose tissue, LDM, and in the case of a non-free flap, also a neurovascular pedicle, which is represented by the thoracodorsal vessels and nerve.

According to several studies, the thoracodorsal nerve provides the exclusive motor innervation of the muscle and does not implement afferent innervation [5, 6]. For this reason, when transferring a non-free flap, most surgeons transect the trunk of the thoracodorsal nerve to avoid muscle twitching in the long-term period. However, this approach leads to the denervation of the flap [7, 8]. The information has been published on the start of work on intraoperative verification of the thoracodorsal fascicles for selective excision of only the motor fibers innervating the LDM and identification of the sensory fibers [9].

Aim. Considering the relevance of issues related to the use of the thoracodorsal nerve in reconstructive surgery, the ambiguity of studies, and the lack of complete information about the intra-trunk structure, this work aimed to study the anatomical and topographic aspects and the intra-trunk structure of the thoracodorsal nerve within the brachial plexus.

Material and methods. The study was conducted on preparations of the brachial plexus of 80 corpses of the male (52 cadavers, 65%) and female (28 cadavers, 35%) gender. In all cases, death was caused by widespread somatic diseases without injuries to the upper limbs, chest, neck, and head.

Anatomical dissection of the brachial plexus was performed with layer-by-layer isolation of the short and long branches, secondary bundles, primary trunks, spinal nerves, and anterior and posterior roots of the spinal cord. The angle of inclination from the place of the thoracodorsal nerve formation, topography along the length, and after entering the LDM were analyzed. A detailed sequential measurement of the thoracodorsal nerve's length and thickness, including the extra- and intramuscular parts, was performed. The nerve's length in total before and after branching was considered, including the branches before the muscle. After isolation and fixation in a 10% solution of neutral formalin, the brachial plexus was placed in a 10% solution of acetic acid for further intra-trunk dissection of the nerves of the sternum. The isolation of the thoracodorsal nerve bundles along the entire length of the brachial plexus was implemented using a microsurgical set of instruments and a Carl Zeiss × 2.5 binocular loupe.

Statistical processing was performed using the Statistica 10 software package. The normality of distribution was determined using the Kolmogorov-Smirnov test. Characterization of quantitative indicators with nonparametric distribution is presented using the median (*Me*) and interquartile range [P_{25}; P_{75}].

Ethical principles and norms during the study were observed in full (extract from the minutes of the meeting of the local ethics committee of the Krasnoyarsk State Medical University No. 91, dated 09/11/2018).

Results. The thoracodorsal nerve's total length consists of extramuscular (77.9%) and intramuscular (22.1%) parts equal to 17.9 cm, with a variance from 15.3 to 20.5 cm within the $P_{25;\ 75}$ interquartile range. The length of the extramuscular part of the thoracodorsal nerve is 13.6 cm with a variance from 12.0 to 15.2 cm within the $P_{25;\ 75}$ interquartile range and the thickness in the proximal section is 1.6 [1.6; 1.9] mm, and 2.1 mm [1.8; 2.4] in the distal section. Differences in thickness were significant ($p < 0.001$).

Initially, the thoracodorsal nerve is located behind the axillary vein. Below it becomes superficial and medial to the thoracodorsal artery (lateral) and vein (central). Next, a crossover occurs, and the thoracodorsal nerve is located laterally, and the artery and vein are located medially. Further, the thoracodorsal nerve is divided into independent branches.

In 58% of cases, the thoracic spinal nerve is divided into two branches: central and lateral. The central branch is 4.0 [2.9; 4.4] cm long and is a continuation of the nerve. The lateral branch is also 4.0 [3.2; 4.8] cm long and branches laterally at an angle of 30°–50°. In 30.4% of cases, the thoracodorsal nerve is not divided into branches, has a length of 11.0 [10.2; 12.5] cm, and penetrates the LDM with its one trunk.

In 7.5% of cases, the thoracodorsal nerve separates into three branches, namely the lateral one of 4.3 [3.5; 6.0] cm, the central one is 4.3 [3.5; 6.0] cm, and the medial branch is 4.3 [3.4; 5.5] cm. In 4.1% of cases, it splits into four branches, namely the lateral one of 4.8 [4.0; 5.2] cm, the lateral intermediate one is 4.8 [4.0; 5.2] cm, the central one of 4.8 [4.0; 5.2] cm, and the medial branch is 4.8 [4.0; 5.2] cm (Fig. 1). The total length of the thoracodorsal nerve's extramuscular part is significantly ($p=0.021$) longer since it has more branches.

The intramuscular part of the thoracodorsal nerve is represented by its branches of the first- and second-orders, which extend either from its main branches (75.7%) or from a common trunk (24.3%). There are two to seven intramuscular branches of the first- and second-orders. Intramuscular branches have a total thickness of 4.2 [3.5; 4.7] mm, length of 4.6 [3.2; 6.5] cm, and terminate in their own fascia. Consequently, the thoracodorsal nerve

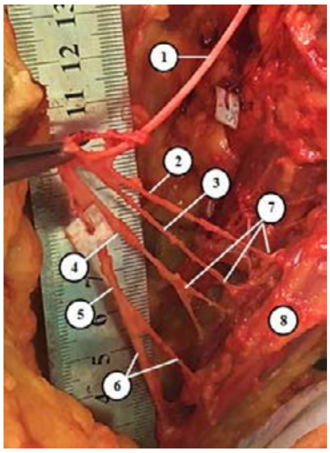

Fig. 1. The formation of extra- and intra-muscular branches of the thoracodorsal nerve (a variant of the division into four branches): 1—thoracodorsal nerve; 2—extramuscular (medial) branch of the thoracodorsal nerve; 3—extramuscular (central) branch; 4—extramuscular (lateral intermediate) branch; 5—extramuscular (lateral) branch; 6—(dissected) intramuscular branches to the outer section of the latissimus dorsi muscle (LDM); 7—(dissected) intramuscular branches to the internal section of the LDM; 8—LDM.

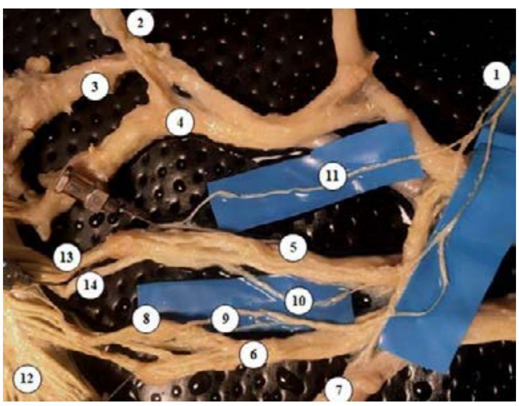

Fig. 2. The formation of the thoracodorsal nerve bundles, their microtopography in the spinal nerves (posterior view): 1—thoracodorsal nerve; 2—spinal nerve C4; 3—C5; 4—C6; 5—C7; 6—C8; 7—Th1; 8—spinal ganglion; 9—a sensory bundle of the thoracodorsal nerve in the posterior root of the spinal nerve C8; 10—a motor bundle of the thoracodorsal nerve in the anterior root of the spinal nerve C7; 11—a sensory bundle of the thoracodorsal nerve in the posterior root of the spinal nerve C7; 12—spinal cord; 13—the posterior root of the spinal cord; 14—the anterior root of the spinal cord.

thickness is significantly ($p < 0.001$) less than the total thickness of its branches of the first- and second-orders. Fine dissection of the intramuscular branches enabled the area of LDM innervation by the thoracodorsal nerve to be determined, which is 159.4 cm^2, with fluctuations from 117.8 to 201.0 cm^2 within the interquartile range of $P_{25;\,75}$.

The intra-trunk dissection revealed that most often, in 46.2% of cases (37 plexuses), the thoracodorsal nerve is formed from one spinal nerve C_7, in 37.5% of cases (30 plexuses). It is formed from two nerves (C_7, C_8), in 7.5% of cases (6 plexuses), it is formed from one nerve (C_8), in 5.0% of cases (4 plexuses), it is formed from two nerves (C_6, C_7), and in 3.8% of cases (3 plexuses), it is formed from three nerves (C_6, C_7, C_8).

Dissection of the thoracodorsal nerve bundles along the secondary bundles, primary trunks, and spinal nerves of the brachial plexus revealed the aspects of the formation of this nerve. First, the thoracodorsal nerve consists of 1–4 bundles of nerve fibers. It comprises two bundles in 72.5% of cases, three bundles in 23.8% of cases, one bundle in 2.5%, and four bundles in 1.2% of cases. Second, it was revealed that one thin bundle with a two-bundle structure is only sensory, and the other thick one is motor. With a three-bundle structure, one thick bundle is motor, and the other two thin ones are sensory. In the case of a four-bundle structure, one thick bundle is also motor, and three thin ones are sensory. It is impossible to identify sensory and motor fibers with a single-bundle structure of the thoracodorsal nerve (2.5% of cases) because of the intra-bundle entanglement of nerve fibers.

The formation of the bundles of the thoracodorsal nerve is also variable. In 68% of cases, sensory and motor bundles are formed from C_7, or a motor bundle is formed from C_7, and a sensory bundle is formed from C_8. In 24.7% of cases, with a multi-bundle structure of the thoracodorsal nerve, the motor portion always corresponds predominantly to C_7, and only in 7.3%, the sensory and motor portions correspond to C_8 only.

Fine intra-trunk bundle dissection of the thoracodorsal nerve along its entire length enabled the discovery of the microtopography of the sensory and motor portions of nerve fibers in the nerve, in the posterior secondary bundle, primary trunks, spinal nerves C_6–C_8 of the brachial plexus, as well as in the spinal ganglia, anterior and posterior roots of the spinal cord (Fig. 2).

Thus, in 90.2% of cases, the fibers' inter-bundle relationship of in the thoracodorsal nerve is presented as follows: the motor segment is located in the posterolateral part, and the sensory segment is in the anteromedial part. In 7.3% of cases, the nerve fibers' motor segment is located in the posterior medial part, and the sensory segment is located in the anterolateral part. In 2.5% of cases, it was impossible to determine the location of the sensory and motor bundles.

In the posterior secondary bundle, the sensory and motor portions of the thoracic spinal nerve are located in the posterior inferior part in 87.6% of cases, in the anteroinferior part in 7.4%, and the mid-posterior part in 5.0% of cases. In the primary trunks of the brachial plexus, the sensory and motor bundles of the thoracodorsal nerve are located unequally. In 46.2% of cases, they are located in the posterior inferior part of the middle primary trunk. In 37.5% of cases, they are in the posterior inferior part of the middle and posterior superior part of the lower primary trunk. Less often, the sensory and motor bundles have a different location in the primary trunks of the brachial plexus, namely in the posterior superior part of the lower trunk in 7.5% of cases, in the posterior inferior part of the upper and middle trunks in 5.0%, in the posterior inferior part of the upper and middle trunks and the posterior superior part of the lower trunk in 3.8% of cases.

In the spinal nerves C_6, C_7, and C_8, the motor and sensory bundles correspond to a location in the upper, middle, and lower primary trunks, respectively. Further, the motor bundle is directed to the anterior root, and the sensory bundle is directed to the spinal ganglion and the posterior root. Inside the roots, the nerve fibers' location of the thoracodorsal nerve is impossible to determine because of the dense interweaving of the nerve fibers.

Discussion. As a result of the study, the thoracodorsal nerve's anatomical aspects were revealed concerning its use in the transplantation of a thoracodorsal flap for breast reconstruction after a radical mastectomy. One main advantage of the thoracodorsal flap is the least number of complications [4, 10]. In the postoperative period, surgeons often register such complications as motor-muscular activity in the area of the reconstructed breast when the arm was abducted, which caused the patients discomfort. So, they started to cross the trunk of the thoracodorsal nerve during thoracodorsal flap transplantation. However, flap denervation results in a loss of its original volume.

According to the study results, the thoracodorsal nerve comprises both motor and sensory nerve fibers. It should be noted that previously no such information was available in the scientific literature. Nevertheless, there were judgments about the sensory function of the thoracodorsal nerve [9]. According to our data, the thoracodorsal nerve must be partially preserved during flap transplantation. Also, the differences in the number, thickness, and microtopography of the sensory and motor portions of nerve fibers in the thoracodorsal nerve, should be considered using electroneuromyography, if possible. This is to verify the bundles of nerve fibers and transect the motor portion after the nerve divides into branches and as close to the LDM as possible.

In light of the need to preserve the thoracodorsal nerve, the length of its extramuscular part, which is 13.6 cm, was investigated. This length is sufficient to displace the musculocutaneous graft to the area of the reconstructed breast without tension. The area of LDM innervation by the thoracodorsal nerve is 159.4 cm^2. This size allows the use of a large volume of the musculocutaneous graft for breast reconstruction while maintaining afferent sensitivity.

CONCLUSIONS

1. Intra-trunk dissection of the thoracodorsal nerve enabled the discovery of the microtopography of the sensory and motor portions of the nerve fibers in the nerve and along the entire length of the brachial plexus.
2. During breast reconstruction after mastectomy with a thoracodorsal graft, it is recommended to transect only the motor fibers of the thoracodorsal nerve as close as possible to the LDM to maintain the afferent innervation.
3. While maintaining a sensory portion of nerve fibers, the length of the thoracodorsal nerve allows the transplantation of a non-free thoracodorsal graft without tension.

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