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Topographic anatomy of the brachial plexus and possibilities with endoscopic approach (cadaveric study)

E.A. Belyak[1,2]✉, D.L. Paskhin[2], F.L. Lazko[1,2], A.P. Prizov[1,2], M.F. Lazko[1,2], N.V. Zagorodniy[1], S.A. Asratyan[2], M.A. Belash[1,2]

[1] Peoples' Friendship University of Russia, Moscow, Russian Federation
[2] Moscow City Clinical Hospital in honor of V.M. Buyanov, Moscow, Russian Federation

Corresponding author: Evgeniy A. Belyak, belyakevgen@mail.ru

Abstract

Relevance The brachial plexus is a complex anatomical structure the passes through three narrow anatomical spaces including the interscalene space, the space between the first rib and the clavicle (thoracic aperture), the space between the anterior chest wall and the pectoralis minor muscle. Compression of the brachial plexus and the vascular band can occur at the sites. Endoscopic approach to the brachial plexus is a promising surgical trend to allow neurolysis and decompression of the plexus with minimal trauma and blood loss and a good cosmetic result. The purpose was to explore topographic anatomy of the brachial plexus and surrounding structures and determine the possibility of endoscopic approach to the brachial plexus. **Material and methods** The shoulder and neck were dissected in 5 fresh cadavers. The study was performed at Trauma and Orthopaedics department of the Russian Peoples Friendship University and Department of pathological anatomy at the Buyanov's Moscow State City Hospital between 2021 and 2022. **Results** The pectoralis minor muscle was detached from the coracoid process to endoscopically approach to the subclavian part of plexus. The lateral aspect of the subclavian muscle was detached from the clavicle to endoscopically approach to the thoracic aperture. Portals were produced at the supraclavicular fossa to endoscopically approach to the supraclavicular part of the plexus in the interscalene space considering the topographic anatomy of the jugularis external vein and accessory veins. The mean distance from the coracoid tip to the penetration point of the musculo-cutaneous nerve to the conjoint tendon was 3 cm. The mean distance between the anterior chest wall and the clavicle (width of thoracic aperture) was 1.86 cm. The mean distance between the sternal end of the clavicle to the point of passage of the subclavian artery under the clavicle was 5.7 cm. The mean width of the interscalene space was 1.4 cm. **Discussion** Aspects of topographic anatomy of the brachial plexus were examined in cadaveric studies of Sidorovich R.R. (2011), Chembrovich V.V. (2019), Anokhina Z.A. (2021), but endoscopic approach to the brachial plexus and possibility with endoscopic surgery were not discussed in the studies. Foreign cadaveric studies of Akaslan I. (2021), Koyyalamudi V. (2021), Costabeber I. (2010), Akboru (2010) were performed to examine topographic anatomy of the brachial plexus. The only study reporting the possibility of endoscopic approach to the brachial plexus and endoscopic anatomy was performed by Lafosse T. (2015). Our cadaveric series reported the possibility of endoscopic approach to the brachial plexus at the three levels for the first time in Russian literature. **Conclusion** Topographic anatomy of the supraclavicular and infraclavicular portions of the brachial plexus was examined in our series. The study showed the possibility of endoscopic approach to the brachial plexus at the interscalene space, thoracic aperture and subclavian area.

Keywords: endoscopic neurolysis, decompression, neuropathy, plexopathy, brachial plexus, cadaveric study, anatomy

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INTRODUCTION

The brachial plexus is a complex anatomical structure the passes through three narrow anatomical spaces including the interscalene space, the space between the first rib and the clavicle (thoracic aperture), the space between the anterior chest wall and the pectoralis minor muscle [1-4]. Compression of the brachial plexus and the vascular band can occur at the sites [5-7]. Due to compression of the plexus, plexopathy develops, which manifests itself in the form of a pain syndrome and neurological symptoms (impaired sensitivity and motor activity) [8-10]. If a conservative treatment fails, a surgical intervention would be indicated with decompression and neurolysis. It is normally performed with an open surgical approach [11-15]. Endoscopic approach to the brachial plexus is a promising surgical trend to allow neurolysis and decompression of the plexus with minimal trauma and blood loss and a good cosmetic result.

Research objectives were to:

1) explore topographic anatomy of the brachial plexus and surrounding structures and determine the possibility of endoscopic approach to the brachial plexus;

2) dissect the cadaveric material, explore topographic anatomy of the interstitial space, the space of the thoracic aperture and the region of the pectoralis minor muscle;

3) measure the distances being significant in our opinion:

a) from the top of the coracoid process to the entry of the musculocutaneous nerve into the joint tendon (distance A);

b) between the first rib and the clavicle (thoracic aperture width) (distance B);

c) from the sternal end of the clavicle to the passage of the subclavian artery (distance C);

d) the width of the interstitial space (distance D);

4) determine the direction of endoscopic channels and structures located along the route, identify dangerous areas and zones for endoscopic access;

5) determine the approximate projection of the location of the skin endoscopic ports for access to the brachial plexus.

MATERIAL AND METHODS

Dissection of 5 fresh cadavers was performed at the Pathological Anatomy Department of the Buyanov's Moscow State City Hospital between 2021 and 2022. There were four female and one male cadaveric materials. There were left (n = 2) and right (n = 3) dissection sides. Dissection was performed using general surgical and special endoscopic instruments. Statistical data processing was performed using Microsoft Excel (mean value, standard deviation).

Ethical review

The study protocol was approved by the Ethics Committee of the Medical Institute of the Russian Peoples' Friendship University (No. 7 dated April 21, 2022).

Dissection technique

The shoulder was examined before a skin incision and major bone landmarks identified and palpated distinguishing the clavicle, coracoid process, and humeral head (Fig. 1). An L-shaped flap was excised, the shoulder area and the shoulder girdle exposed and the subcutaneous structures and the superficial muscle group were visualized (Fig. 2). The deltoid and pectoralis major muscles were dissected, and the deep layer of muscles and the coracoid process were visualized (Fig. 3). The musculocutaneous nerve at the site of entry into the combined tendon of the short head of the biceps brachii and the coracobrachial muscle could be visualized at the stage of dissection. We measured the distance from the top of the coracoid process to the point of entry of the musculocutaneous nerve into the joint tendon (distance A). The pectoralis minor muscle was the main anatomical structure that covered the neurovascular bundle and limited access to it. Then we cut it off from the medial edge of the coracoid process and retracted it inwards. We could visualize fatty tissue with the vascular bundle and the brachial plexus Under the pectoralis minor muscle (Fig. 4).

The adipose tissue was removed and the neurovascular bundle dissected and the brachial plexus visualized. The lateral bundle of the brachial plexus with continuation in the musculocutaneous nerve was the most superior and lateral structure. The peculiarities of the entry of the musculocutaneous nerve into the joint tendon were observed in 2 cases with the split into two branches, the superior (smaller) and the inferior (larger) that entered the joint tendon at different levels. Medial to the lateral bundle was the axillary artery with the upper and lower branches of the median nerve being anterior and located also anterior to the axillary artery. Medial to the artery was the medial bundle of the brachial plexus with the continuation to the ulnar nerve. The axillary vein was located even more medially (Fig. 5).

Fig. 1 The main bone landmarks: (1) the humeral head; (2) coracoid process of the scapula; (3) clavicle

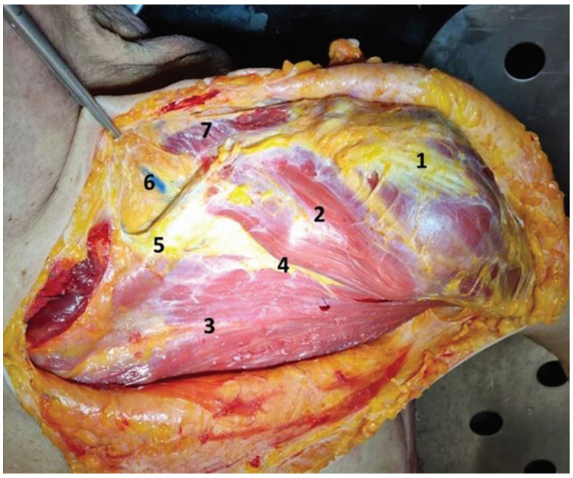


Fig. 2 Superficial muscles and subcutaneous anatomical structures: (1) lateral bundle of the deltoid muscle; (2) anterior bundle of the deltoid muscle; (3) pectoralis major muscle; (4) delto-pectoral gap; (5) clavicle; (6) external jugular vein; (7) trapezius muscle

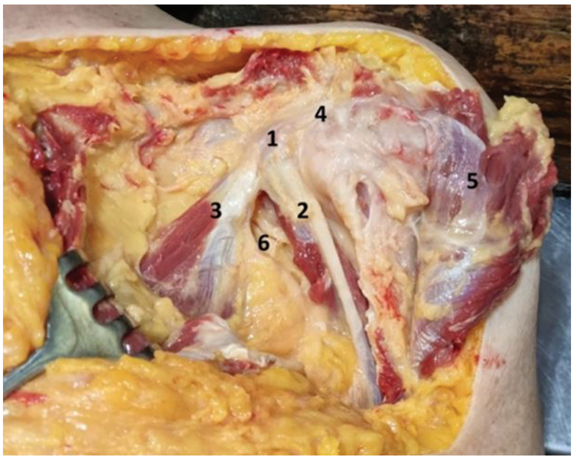


Fig. 3 Deep muscles of the shoulder: (1) coracoid process; (2) the combined tendon of the short head of the biceps brachii and the coraco-brachial muscle; (3) small pectoral muscle; (4) coraco-acromial ligament; (5) anterior bundle of the deltoid muscle (abducted); (6) musculocutaneous nerve

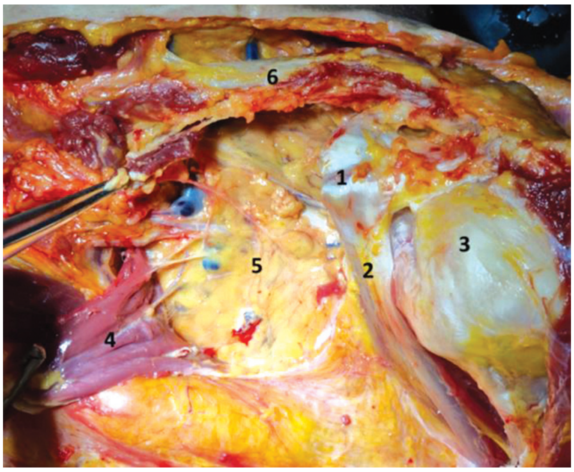


Fig. 4 Topographic and anatomical picture with the pectoralis minor muscle cut off: (1) coracoid process; (2) joint tendon; (3) humeral head; (4) the small pectoral muscle cut off and retracted inside; (5) fatty tissue at the site of the neurovascular bundle; (6) clavicle

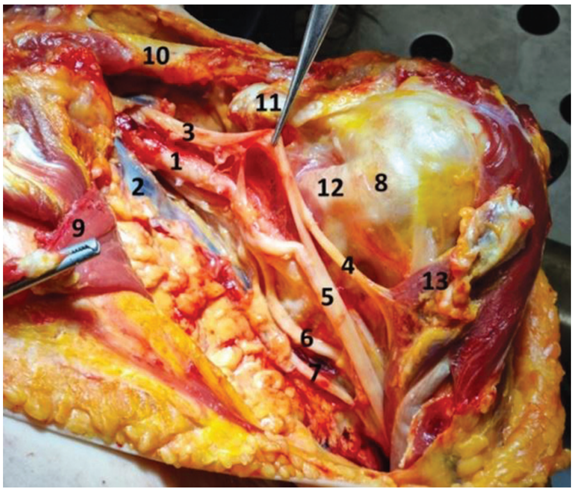


Fig. 5 Topographic anatomy of the subclavian part of the brachial plexus: (1) axillary artery; (2) axillary vein; (3) lateral bundle of SN; (4) musculocutaneous nerve; (5) median nerve; (6) ulnar nerve; (7) sensory nerve of the brachial plexus; (8) head of the humerus; (9) small pectoral muscle; (10) clavicle, (11) coracoid process; (12) tendon of the subscapularis muscle; (13) joint tendon

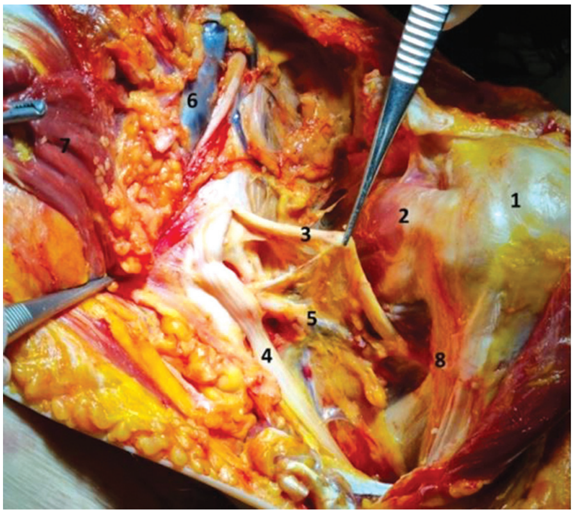


Fig. 6 Topographic anatomy of the subclavian part of the brachial plexus: (1) head of the humerus; (2) subscapularis muscle; (3) axillary nerve; (4) radial nerve; (5) posterior circumflex artery and vein; (6) axillary vein; (7) pectoralis minor muscle (retracted inside); (8) four-sided hole

The posterior bundle passed behind the artery with the axillary nerve running towards the quadrilateral foramen. The radial nerve, the largest nerve of the brachial plexus was the continuation of the posterior bundle (Fig. 6). Then the direction of the endoscopic instrument (trocar with an obturator) was determined to access the brachial plexus at the coracoid process (Fig. 7). Next, the lateral part of the subclavian muscle was dissected from the clavicle and the width of the thoracic aperture measured (distance from the anterior chest wall to the clavicle, distance B). Then the distance from the sternal end of the clavicle to the passage of the subclavian artery under the clavicle was measured (distance C). The direction of the endoscopic instrument (trocar with an obturator) was determined to access the brachial plexus at the thoracic aperture (Fig. 8).

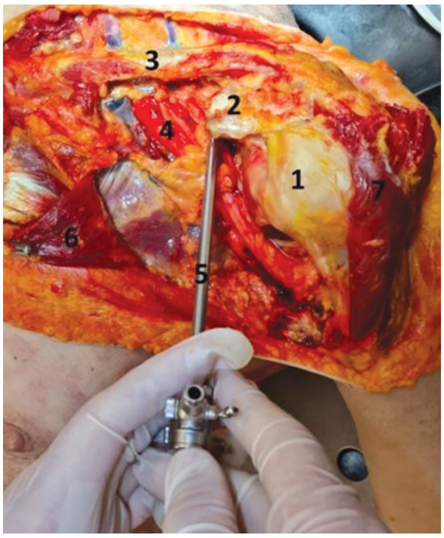


Fig. 7 The direction of the endoscopic instrument (trocar with an obturator) to access the brachial plexus at the coracoid process: (1) the head of the humerus; (2) coracoid process; (3) clavicle; (4) neurovascular bundle; (5) trocar; (6) small pectoral muscle (cut off and retracted inside); (7) anterior bundle of the deltoid muscle (cut off and retracted outwards)

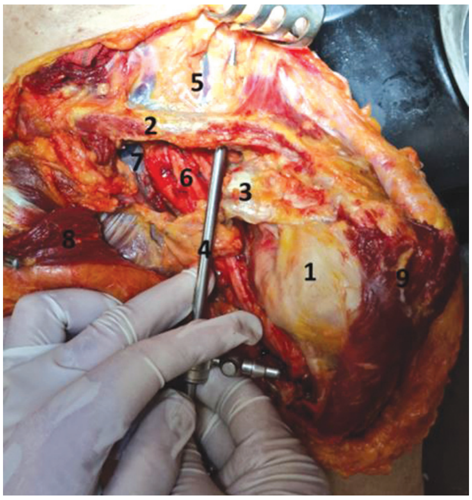


Fig. 8 The direction of the endoscopic instrument (trocar with an obturator) to access the thoracic aperture and supraclavicular region: (1) the head of the humerus; (2) clavicle; (3) coracoid process; (4) trocar; (5) adipose tissue in the supraclavicular fossa; (6) brachial plexus; (7) subclavian vein; (8) small pectoral muscle (cut off and retracted inside)

Then the supraclavicular region was dissected. The skin was separated and the superficially located structures at the supraclavicular fossa were determined, the fat pad developed at the site was identified (Fig. 9). An additional jugular vein was found at the supraclavicular fossa in some cases. Adipose tissue and superficial veins were removed. The scapular-hyoid muscle being located along the access to the interstitial space was an essential anatomical structure at the site that passed diagonally. The scapular-hyoid muscle was cut off from the hyoid bone and displaced outwards for better visualization. Then the interstitial space was reached with 3 trunks of the brachial plexus (superior, medium and inferior), the subclavian artery and the branch of the descending artery of the scapula passing between the middle and lower bundles were exposed (Fig. 10). The width of the interscalene gap was measured as a distance between the anterior and middle scalene muscles (distance D).

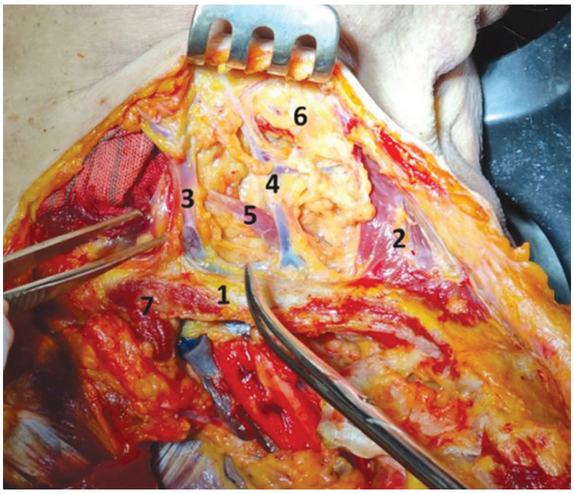


Fig. 9 Supraclavicular region: (1) clavicle; (2) trapezius muscle; (3) external jugular vein; (4) additional jugular vein; (5) scapular-hyoid muscle; (6) fat pad; (7) subclavian muscle (cut off and retracted inside)

Fig. 10 Topographic anatomy of the interstitial space: (1) upper trunk; (2) middle trunk; (3) lower trunk; (4) descending artery of the scapula; (5) subclavian artery; (6) clavicle; (7) anterior scalene muscle; (8) trapezius muscle

The trunks of the brachial plexus were relatively vertical, no large vessels were found at the superior and middle trunks with small venous branches located in the adipose tissue around the trunks (Fig. 11). The direction and position of the endoscopic instrument was determined accessing the supraclavicular part of the SN. This can be performed using the subclavian space with the trocar passing under the clavicle in the proximal direction (Fig. 12). The access to the supraclavicular part of the brachial plexus could also be performed with ports at the supraclavicular fossa. The approximate position of the endoscopic instrument to access the supraclavicular part of the brachial plexus is shown in Figure 13. The space outside and behind the brachial plexus was relatively safe with no arteries and large veins there.

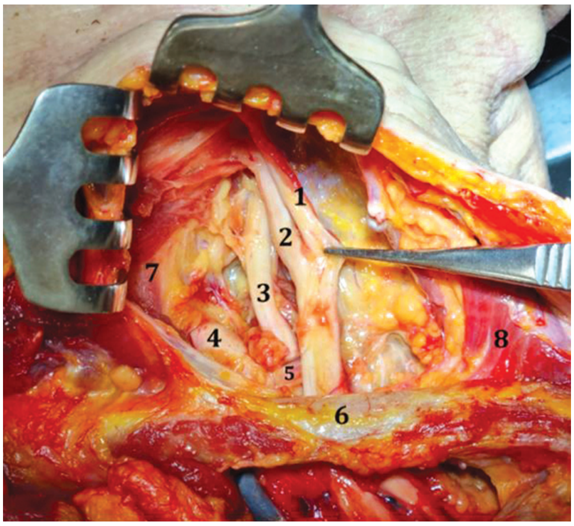


Fig. 11 Topographic anatomy of the interstitial space: (1) upper trunk of the SN; (2) middle trunk of the SN; (3) the lower trunk of SN; (4) subclavian artery; (5) descending artery of the scapula; (6) clavicle; (7) anterior scalene muscle; (8) trapezius muscle

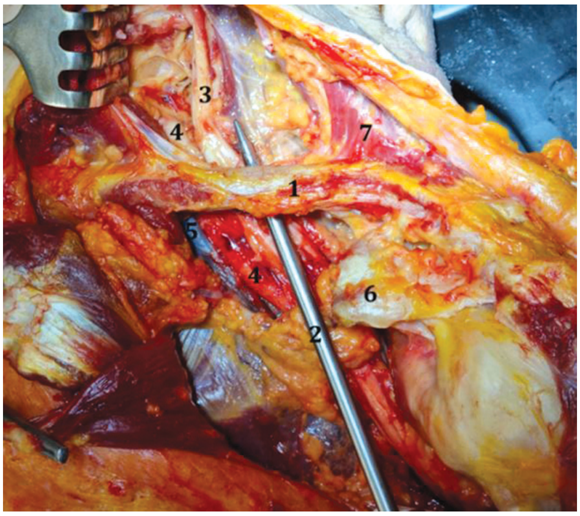


Fig. 12 The direction of the endoscopic instrument (trocar with an obturator) to access the supraclavicular region from the subclavian space: (1) clavicle; (2) trocar with obturator; (3) the upper trunk of the brachial plexus; (4) subclavian artery; (5) subclavian vein; (6) coracoid process; (7) trapezius muscle

Fig. 13 The direction of the endoscopic instrument (trocar with an obturator) to access the supraclavicular region from the supraclavicular fossa: (1) clavicle; (2) trocar with obturator; (3) the upper trunk of the brachial plexus; (4) subclavian artery; (5) subclavian vein; (6) coracoid process; (7) trapezius muscle

RESULTS

Topographic anatomy of the coracoid process

The area outward from the brachial plexus was relatively safe, as no significant vascular structures was required to access to the plexus. Our findings showed an average distance of 3 cm from the top of the coracoid process to the musculocutaneous nerve entering the joint tendon to be taken into account cutting off the pectoralis minor muscle. Cutoff of the pectoralis minor muscle is a routine procedure in the Latarjet operation, and is common in the treatment of anterior instability of the shoulder joint.

Cutoff of the muscle cause no dysfunction and muscle deficiency in the shoulder area, and does not manifest itself clinically [16, 17, 18, 19, 20]. A standard anterior port to the shoulder joint at the rotator interval can be used to perform additional ports at the coracoid process both laterally and medially for endoscopic access to the plexus. An approximate location of endoscopic instruments is shown on the model in Figure 14.

Fig. 14 Location of endoscopic instruments to access to the brachial plexus at the pectoralis minor muscle

Topographic anatomy of the thoracic outlet

The average width of the thoracic aperture was 1.86 cm and was sufficient for endoscopy (location of the camera and the instrument). The subclavian muscle occupied a significant part of the aperture and the cutoff of the lateral part of the subclavian muscle from the clavicle was needed to allow endoscopic instrumentation. The arthroscope and the instrument were placed outward of the brachial plexus with no major vessels at the site (only small venous branches were present), and the subclavian artery was at an average distance of 5.7 cm from the sternal end of the clavicle providing a safe zone. The artery and the vein were located medially off the brachial plexus. Standard anterior and anterolateral ports could be used considering the direction and location of the neurovascular bundle. The supraclavicular part of the brachial plexus could also be approached at the thoracic aperture. An approximate location of endoscopic instruments is shown on the model in Figure 15.

Topographic anatomy of the interstitial space

The width of the interstitial space averaged to1.4 cm. The supraclavicular part could be accessed from the subclavian region by placing the instrument under the clavicle in the proximal direction and was facilitated by cutting off the lateral bundle of the subclavian muscle. The standard anterior shoulder port could be used for the maneuver and additional ports could be created medial to the coracoid process. The supraclavicular part of the plexus could be accessed with ports made in the supraclavicular fossa; close location and projection of the external jugular vein and accessory veins were to be considered to prevent injury creating the ports.

An approximate location of endoscopic instruments is shown on the model in Figure 16.

The space outside and behind the brachial plexus at the interstitial space was relatively safe with no arteries and large veins at the site. The descending artery of the scapula passed between the middle and lower trunks of the plexus. The subclavian artery was located anterior to the brachial plexus. The measurements of the cadaveric topographic and anatomical parameters are presented in Table 1.

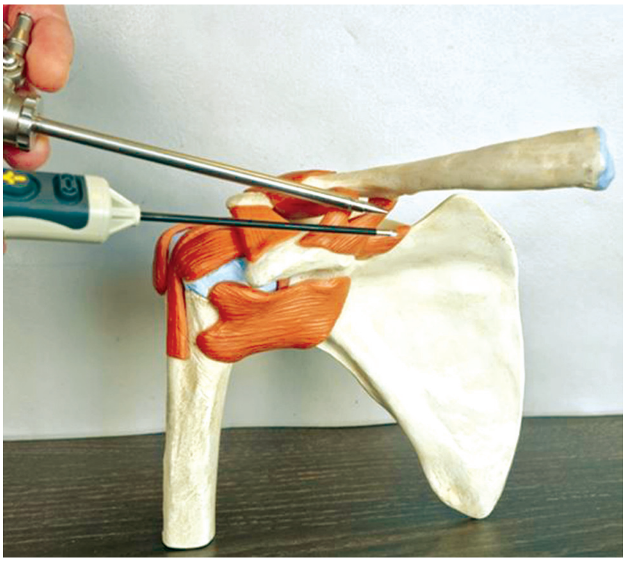
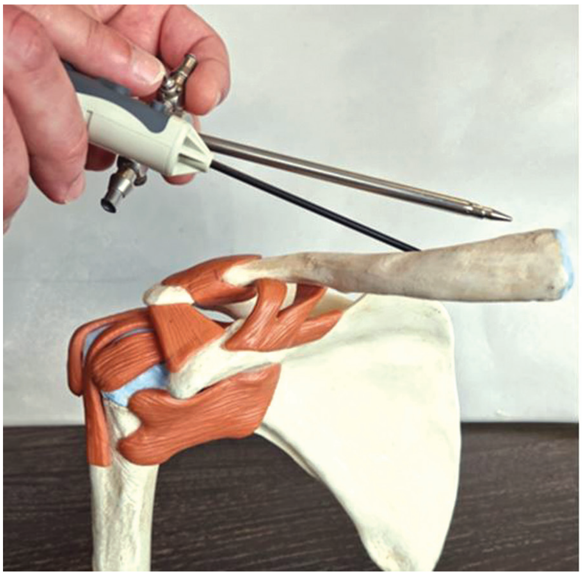


Fig. 15 Location of endoscopic instruments to access to the brachial plexus at the thoracic outlet



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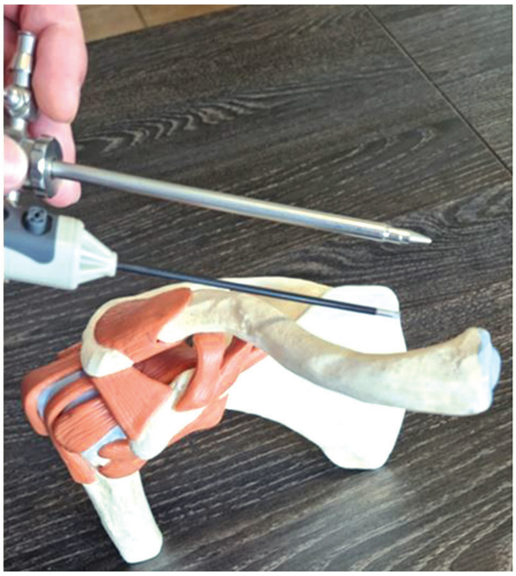

b

Fig. 16 Location of endoscopic instruments to access the brachial plexus in the supraclavicular region: *a* front view; *b* top view

Table 1

Measurements of topographic and anatomical distances

	Distance A, cm	Distance B, cm	Distance C, cm	Distance D, cm
Cadaver 1 (F)	2	2	6	1.5
Cadaver 2 (F)	3.5	1.5	5	1.5
Cadaver 3 (F)	3	1.5	4.5	1
Cadaver 4 (F)	4	1.8	5.5	1.5
Cadaver 5 (M)	2.5	2.5	7.5	1.5
The mean	3 ± 0.8	1.86 ± 0.3	5.7 ± 0.84	1.4 ± 0.16

Notes: F, female; M, male.

DISCUSSION

There are publications in the Russian and foreign literature reporting topographic anatomy of the brachial plexus. In 2005 and 2011, R.R. Sidorovich et al. examined the brachial plexus using cadaveric material (10 autopsies) and reported the variability of the structure, presence of anastomoses at the levels of spinal nerves, primary and secondary trunks and proximal portions of long nerves [21, 22]. In 2019, V.V. Chembrovich reported the results of a cadaveric study (13 cadavers) and which he studied the features, established differences in the parameters of the brachial plexus on the right and left upper limbs [23]. Specific features of the brachial plexus anatomy were examined by Zh.A. Anokhina et al., 2021 [24]. In 2021, I. Akaslan et al. reported a cadaveric study (11 cadavers) featuring topographic anatomy and approaching posteriorly to the brachial plexus at the neck [25]. In 2021, V. Koyyalamudi et al. reported a block of the brachial plexus performed under ultrasound control at the site of the thoracic aperture to be followed by an anatomical dissection [26]. The study showed a high efficiency of ultrasound assistance. S. Leung et al. examined topographic anatomy of the supraclavicular part of the brachial plexus using 8 cadavers [27]. I. Costabeber et al. (2010) and I.M. Akboru (2010) explored the topographic anatomy of the brachial plexus, relationship of trunks, divisions and bundles [28, 29]. T. Lafosse et al. (2015) reported endoscopic dissection of the brachial plexus performed on 13 cadavers, followed by an open dissection and verification of the anatomical structures [30]. Our study was the first in Russian literature reporting the possibility of endoscopic access to the brachial plexus at the three levels using the cadaveric material.

CONCLUSION

Topographic anatomy of the supraclavicular and subclavian parts of the brachial plexus were examined in our series. The study showed the possibility of endoscopic access to the brachial plexus. Access to the subclavian plexus required the pectoralis minor muscle to be cut off from the coracoid process. Cutoff of the lateral part of the subclavian muscle from the clavicle facilitated access to the thoracic aperture. Ports were located in the supraclavicular fossa to access the supraclavicular part of the plexus and the interscalene space considering the topographic anatomy of the external jugular vein and accessory veins.

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Information about the authors:

1. Evgeniy A. Belyak – Candidate of Medical Sciences, belyakevgen@mail.ru, https://orcid.org/0000-0002-2542-8308, SPIN: 7337-1214;
2. Dmitriy L. Paskhin – yas-moe@mail.ru, https://orcid.org/0000-0003-3915-7796, SPIN: 8930-1390;
3. Fedor L. Lazko – Doctor of Medical Sciences, fedor_lazko@mail.ru, https://orcid.org/0000-0001-5292-7930, SPIN: 8504-7290;
4. Aleksey P. Prizov – Candidate of Medical Sciences, aprizov@yandex.ru, https://orcid.org/0000-0003-3092-9753, SPIN: 6979-6480;
5. Maksim F. Lazko – Doctor of Medical Sciences, maxim_lazko@mail.ru, https://orcid.org/0000-0001-6346-824X;
6. Nikolay V. Zagorodniy – Doctor of Medical Sciences, zagorodniy51@mail.ru, https://orcid.org/0000-0002-6736-9772; SPIN: 6889-8166;
7. Sarkis A. Asratyan – Candidate of Medical Sciences, dr.sako@mail.ru, https://orcid.org/0000-0001-8472-4249; SPIN: 1037-4232;
8. Mikhail A. Belash – mickeybelash@gmail.com, https://orcid.org/0000-0003-1505-4661.

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