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FETAL ANATOMICAL VARIABILITY OF MUSCLES AND NEUROVASCULAR BUNDLES OF THE ANTERIOR BRACHIAL REGION

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Abstract

Introduction. Performing surgical manipulations and interventions on neurovascular bundles located in the anterior brachial region of human fetuses and newborns requires comprehensive knowledge of their topographical and anatomical features.
The objective of the study was to establish the fetal topography peculiarities of both nerves and vessels in the anterior brachial muscle region.
Materials and methods. The study was carried out on 32 human fetuses of 4-8 months with 81.0-310.0 mm crown-rump length (CRL) using macro microscopic dissection, vascular injections and morphometry.
Results. We describe the main and additional sources of muscle blood supply and innervation of the anterior brachial region in human fetuses. Two to 4 branches of the musculocutaneous nerve take part in the innervation of both coracobrachialis and brachialis muscles, as well as the biceps brachii muscle. Some fetuses possess additional sources of innervation: for the coracobrachialis muscle there is a branch of the lateral bundle of the brachial plexus, the biceps brachii muscle has median nerve and for the brachialis muscle there is radial nerve. The largest number of arterial and nerve branches goes to the proximal and middle

Résumé

Variabilité anatomique fœtale des muscles et des faisceaux neurovasculaires de la région brachiale antérieure

Introduction. La réalisation de manipulations chirurgicales et d'interventions opératoires sur des faisceaux neurovasculaires situés dans la région brachiale antérieure de fœtus et de nouveau-nés humains nécessite une connaissance approfondie de leurs caractéristiques topographiques et anatomiques.
L'objectif de l'étude. Établir les particularités de la topographie fœtale des nerfs et des vaisseaux dans la région du muscle brachial antérieur.
Matériaux et méthodes. L'étude été réalisée sur 32 sujets de fœtus humains de 4 à 8 mois de 81,0 à 310,0 mm de longueur couronne-croupe (CRL) en utilisant la dissection macro microscopique, les injections vasculaires et la morphométrie.
Résultats. Chez les fœtus humains, les sources principales et supplémentaires d'approvisionnement en sang musculaire et d'innervation de la région brachiale antérieure sont décrites. De 2 à 4 branches du nerf musculo-cutané participent à l'innervation des muscles coraco brachial et brachial, ainsi que du muscle

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parts of the coracobrachialis and brachialis muscles, as well as the biceps brachii muscle.
Conclusions. The established neurovascular correlations and features of the fetal anatomy of the anterior brachial muscle region determine the presence of relatively favourable conditions for cutting muscle flaps that are well innervated and supplied with blood.

Keywords: anterior brachial region, musculocutaneous nerve, brachial artery, anatomical variability, fetus

biceps brachial. Certains fœtus possèdent des sources d'innervation supplémentaires : pour le muscle coracobrachial il y a une branche du faisceau latéral du plexus brachial, le muscle biceps brachial a le nerf médian et pour le muscle brachial il y a le nerf radial. Le plus grand nombre de branches artérielles et nerveuses va aux parties proximale et médiane des muscles coracobrachial et brachial, ainsi qu'au muscle biceps brachial.
Conclusion. Les corrélations neurovasculaires établies et les caractéristiques de l'anatomie fœtale de la région du muscle brachial antérieur déterminent, en général, la présence de conditions relativement favorables pour couper des lambeaux musculaires bien innervés et alimentés en sang.

Mots-clés: région brachiale antérieure, nerf musculo-cutané, artère brachiale, variabilité anatomique, fœtus

Introduction

Today, among the areas of practical medicine, the field of fetal surgery would be impossible without comprehensive knowledge of the age-related and individual anatomical variability of organs and structures in human fetuses of different ages. At the same time, transplantation of muscles and tendons without knowledge of topographical and anatomical relationships of their vessels and nerves is problematic and almost impossible. In this regard, it is appropriate to cite the statement of the famous orthopedist Pauwels, who was involved in developing the theoretical grounds of biomechanics: „First of all, in operative orthopedics, responsible purposeful actions are impossible without fundamental anatomical knowledge, especially without penetration into functional relationships." Performing surgical manipulations and interventions on myofascial and neurovascular formations and bundles of the upper limb, and especially in the anterior brachial region, in human fetuses and newborns requires comprehensive knowledge of their topographical and anatomical features[1]. The anterior brachial region is characterized by age-related and individual anatomical variability of neurovascular bundles, which is a frequent cause of complications during operations[2-6].

Movement loss associated with damage to the nerve trunks of the brachial plexus often does not fit into the known innervation patterns of the upper limb muscles. This can be explained by the fact that some muscles are innervated by two nerves, so even with a complete integrity loss of the large nerve trunk, there is a slight impairment of motor function evident. It should also be noted that due to the presence of a developed network of anastomoses between the nerves, the motor function of the affected nerve may slightly suffer[7-8]. Ruptures of blood vessels inside or outside the nerves also lead to some decrease in the function of directly unaffected nerves, which makes it much more difficult to recognize the true picture of peripheral nerve damage. Degenerative changes develop in nerve trunks as well as atrophic sclerotic processes in muscles as a result of impaired blood circulation and reflex spasm of blood vessels[9-10].

It is known that damage to the musculocutaneous nerve causes an inconsistency in forearm flexion. However, partial flexion at the elbow joint with simultaneous adduction will remain possible due to the brachialis muscle, which is innervated by the radial nerve, and the abductor teres and flexor carpi radialis muscles, which are innervated by the median nerve, and partly as a result of the double innervation of the biceps brachii muscle due mainly to the musculocutaneous and, less often, the median nerves[3,11]. In case of detecting the weakened muscle strength, absence or limitation to the above mentioned movements, decrease or absence of the biceps brachii muscle reflex, hypotonia or atrophy of the anterior brachial muscle region, sensitivity decrease in the skin innervation area of the nerve, as well as changes in normal electrical excitability establish a diagnosis of branchial damage of the musculocutaneous nerve. At the same time, the isolated paralysis of the musculocutaneous nerve should be noted to be a rare occurrence[12-13]. The main etiological factors of musculocutaneous nerve lesions in the postnatal period of human ontogenesis are the following: gunshot wounds, stab wounds, dislocation of the shoulder joint, shoulder fracture, compression of the nerve during sleep and infectious diseases[14-16].

However, in the scientific literature, the peculiarities of intramuscular distribution and correlations between blood vessels and nerves in the anterior branchial muscle region in human fetuses are not covered.

The research is a part of the planned comprehensive work of both Department of Human Anatomy named after M.G. Turkevych and Department of Anatomy, Clinical Anatomy and Operative Surgery of Bukovinian State Medical University (Ukraine) „Regularities of gender-age structure and topographic and anatomical transformations of organs and structures of the body at the pre- and postnatal stages of ontogenesis. Peculiarities of perinatal anatomy and embryo topography", state registration number 0120U101571).

The objective of the study was to establish the fetal topography peculiarities of both nerves and vessels in the anterior brachial muscle region.

Materials and methods

The study of fetal anatomical variability of the neurovascular structures in the anterior brachial region was carried out on 32 specimens of human fetuses of 4-8 months, 81.0-310.0 mm crown-rump length (CRL) using macro microscopic dissection, vascular injection, and morphometry. The fetal corpses were first measured, vascular injection was performed, and they were mobilized on a special frame to maintain the shape of the subjects during fixation in a 10% neutral formalin solution for 3 weeks. The subjects were stored in a 5% formalin solution between research stages. The vascular injection of the upper limbs was performed for further macro microscopic examination. The use of polychromic radiopaque substances (mixture for artery injection consists of lead suric, alcohol and glycerin; mixture for vein injection consists of barium, glycerin, alcohol, and methylene blue), polymers in the composition of injection masses, allows the use of several research methods on one subject, namely: macro microscopy, radiography, computer tomography, reconstruction, etc.)[17-19]. The arterial vessel injection of the upper limb was carried out through a catheter inserted into the subclavian artery; vein injection was performed on unfixed fetal cadavers, while the radiopaque mixture was injected through a catheter inserted into the superior vena cava. The fetal topography and anatomical variability of the nerves and blood vessels that go to the muscles of the anterior brachial group were determined during the macro microscopic subject dissection of the fetal upper limbs, the main and additional sources of innervation and blood supply of the latter, the departure and entry angle of muscular neural branches and arteries into the biceps brachii, coracobrachialis and brachial muscles, features of their intramuscular branching were studied.

The study was conducted in compliance with the requirements of bioethics and the main provisions of the Council of Europe Convention on Human Rights and Biomedicine (from April 4, 1997), the Helsinki Declaration of the World Medical Association on the Ethical Principles of Scientific Medical Research with Human Participation (1964-2013), the order Ministry of Health of Ukraine No. 690 dated September 23, 2009 and taking into account the methodological recommendations of the Ministry of Health of Ukraine „Procedure for the extraction of biological objects from deceased persons, whose bodies are subject to forensic medical examination and pathological examination, for scientific purposes" (2018). The Commission on Biomedical Ethics of the Bukovinian State Medical University did not find any violations of moral and legal norms during the conduct of medical scientific research.

Results and discussion

In the studied fetuses, the long and short heads of the biceps brachii muscle are placed under the deltoid and pectoralis major muscles, below they are connected, forming a common muscle belly. The long head of the biceps brachii muscle begins with a tendon from the supraglenoid tubercle of the scapula; its tendon passes through the shoulder joint in the inter tuberous groove of the humerus. The short head of the biceps brachii muscle together with the coracobrachialis muscle begins from the coracoid process of the scapula. It should be noted that in human fetuses, the proximal part of the coracobrachialis muscle belly is tightly connected to the short head of the biceps brachii muscle. The distal end of the belly belonging to the biceps brachii narrows and turns into a tendon that attaches to the humerus of the radius. A small tendinous bundle departs from this tendon of the biceps brachii muscle, which goes caudo-medially and connects to the fascia of the forearm. In a fetus of 170.0 mm CRL, the left biceps brachialis muscle was divided into two independent muscles.

The coracobrachialis muscle is attached to the medial surface of the humerus slightly below its middle. In most of the examined fetuses, the following occurrences were established: insignificant sizes of the coracobrachialis muscle belly and close topographical and anatomical correlations with the neurovascular bundle of the shoulder and the axillary cavity. Considering the above-mentioned features of the fetal anatomy of the coracobrachialis muscle, as well as the fact that the main trunk of the musculocutaneous nerve passes through the thickness of the belly in most of the studied fetuses, therefore, the use of the coracobrachialis muscle in plastic surgery is unfounded. Only in one observation (fetus 95.0 mm CRL) the musculocutaneous nerve did not pass through the thickness of the coracobrachialis muscle and closely to the middle part of the muscle belly gave off 2 nerve branches to it, which makes it possible, if necessary, to cut out the flap with the distal pedicle.

However, in a fetus of 205.0 mm CRL, the distribution of the right coracobrachialis muscle was established into two parts: upper and lower. The latter was independently attached to the medial epicondyle of the humerus.

In human fetuses, most of the shoulder muscle is covered by the biceps brachii muscle. The brachial muscle originates from the anterior surface of the inferior half of the humerus, and both intermuscular septa, runs along the anterior surface of the elbow joint and, as a rule, is attached to the humerus of the ulna. In three cases (fetuses 90.0, 115.0, and 190.0 mm CRL), an attachment of the brachial muscle to the coronoid process of the ulna was observed.

In all studied fetuses, the innervation of the coracobrachialis muscle is provided by 2-4 branches of the musculocutaneous nerve, which enter the middle part of the belly from the inside and branch out in the thickness of the belly of the coracobrachialis muscle in a loose form. Usually one, sometimes two branches, with the neural branches from the musculocutaneous nerve go together from the anterior circumflex artery of the shoulder to the middle part of the muscle belly.

The anterior circumflex brachial artery passes laterally behind the coracobrachialis muscle and the short head of the biceps brachii, wraps around the surgical neck of the humerus anteriorly and anastomoses with the posterior circumflex brachial artery. In three observations, an additional independent neural branch from the lateral bundle of the subclavian part of the brachial plexus was found, which went to the proximal part of the belly of the coracobrachialis muscle, entered the latter isolated from blood vessels, passed along the entire muscle, parallel to its muscular bundles and branched in the thickness of the muscle according to the main form. From the back circumflex artery of the shoulder to the middle belly part of the coracobrachialis muscle, mainly one branch goes, which branches out in the thickness of the muscle belly in the transverse direction in relation to the muscle bundles. Single anastomoses between the branches of the anterior and posterior circumflex brachial arteries were found in the studied fetuses. It should be emphasized that the intramuscular branching of the anterior and posterior circumflex brachial arteries in the coracobrachialis muscle occurs, as a rule, according to the trunk form. The outflow of blood from the coracobrachialis muscle occurs through the veins of the same name, which accompany the arterial trunks. In isolated cases, 1-2 muscular branches of the brachial artery took part in the blood supply of the coracobrachialis muscle in human fetuses. It is worth mentioning that the topography of blood vessels and nerves in the thickness of the coracobrachialis muscle does not always coincide.

In cases of localizing residual bone cavities on the anterior-medial surface of the upper third part of the humerus and, if necessary, to use the coracobrachialis muscle which is directly adjacent to the bone, flaps from the latter can be cut with a longitudinal incision that coincides with the course of the main intramuscular nerves, not above the border of the upper and middle thirds of the muscle belly, i.e. the entry level of its neurovascular bundle into the muscle.

In the innervation of both long and short heads of the biceps brachii muscle, 2-4 branches of the musculocutaneous nerve are preferably involved, which together with the vessels enter the middle part of the muscle belly and further branch out into ascending and descending trunks (Fig. 1).

The study has established the magistral form of intramuscular distribution of the above-mentioned nerve trunks of the musculocutaneous nerve, which are placed in parallel to the muscle beams of the biceps brachii muscle. The early fetuses should be noted to have a variable number of bonds between the branches of the musculocutaneous nerve. In 4 observations in the innervation of the biceps brachii muscle only 1-2 branches of the median nerve participated.

The blood supply sources to the biceps brachii muscle are the muscular branches of the brachial and axillary arteries, the superior and inferior elbow bypass and the radial rotary arteries (Fig. 2).

It's worth noting that the number of muscle branches in the brachial artery involved in the blood supply to the biceps brachii muscle in human fetuses usually consists of 3 or 4. However, a number variability of muscle branches of the brachial artery has been established and it ranges from 1 to 9. Thus, in the human fetus with 280.0 mm CRL, the blood supply to the left biceps brachii muscle was provided only by the muscle branch which before entering the muscle belly on the verge of proximal and middle parts branched out to the ascending and descending parts (Fig. 3). In one case (fetus with 190.0 mm CRL) in the blood supply of the left biceps brachii muscle, 9

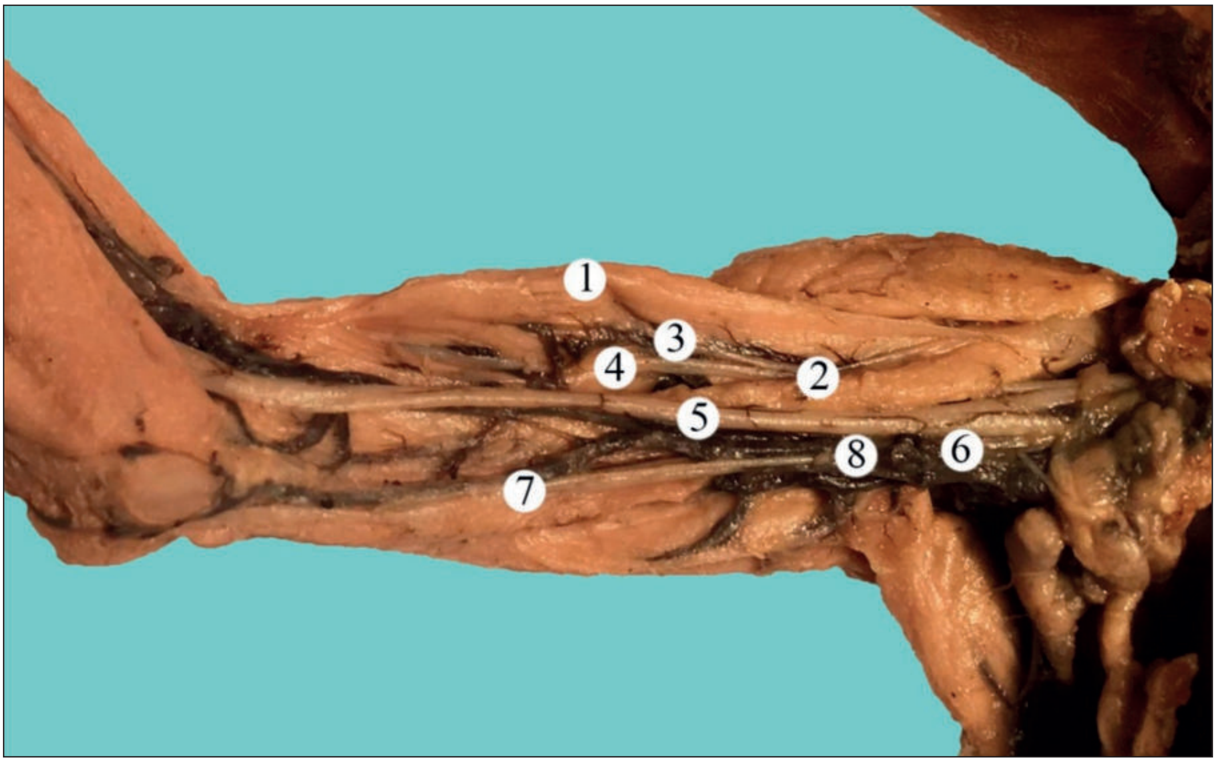

Fig. 1. Structures of the right anterior brachial region of a fetus of 170.0 mm CRL.
Photo of macro subject. Magnification 2.1^{x}:
1 – biceps brachii muscle; 2 – musculocutaneous nerve; 3 – ascending trunk; 4 – descending trunk; 5 – median nerve; 6 – medial cutaneous nerve of the shoulder; 7 – ulnar nerve; 8 – brachial artery.

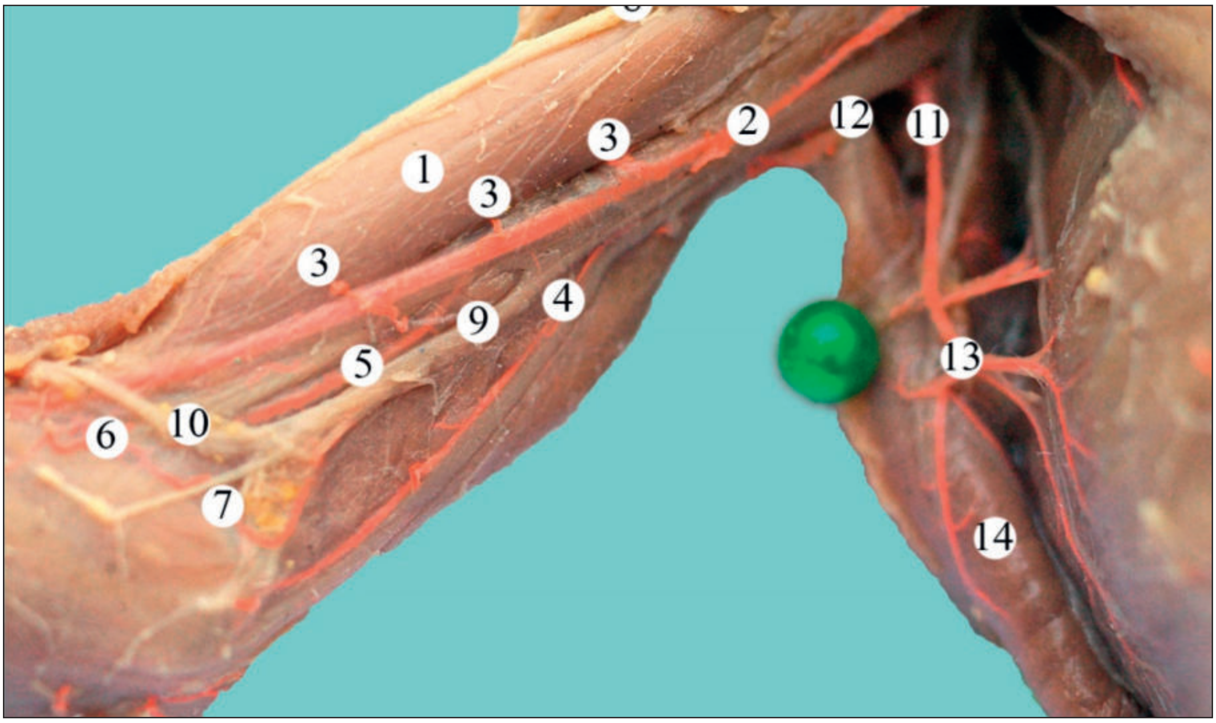

Fig. 2. Structures of the right anterior brachial region of a fetus of 255.0 mm CRL.
Photo of macro subject. Magnification 2,3^{x}:
1 – biceps brachii muscle; 2 – brachial artery; 3 – muscular branches of the brachial artery; 4 – upper bypass ulnar artery; 5 – lower bypass ulnar artery; 6 – radial rotary artery; 7 – anterior branch of the ulnar rotary artery; 8 – cephalic vein; 9 – main vein; 10 – middle vein of the elbow; 11 – subscapular artery; 12 – circumflex artery of the scapula; 13 – thoracodorsal artery; 14 – the widest muscle of the back.

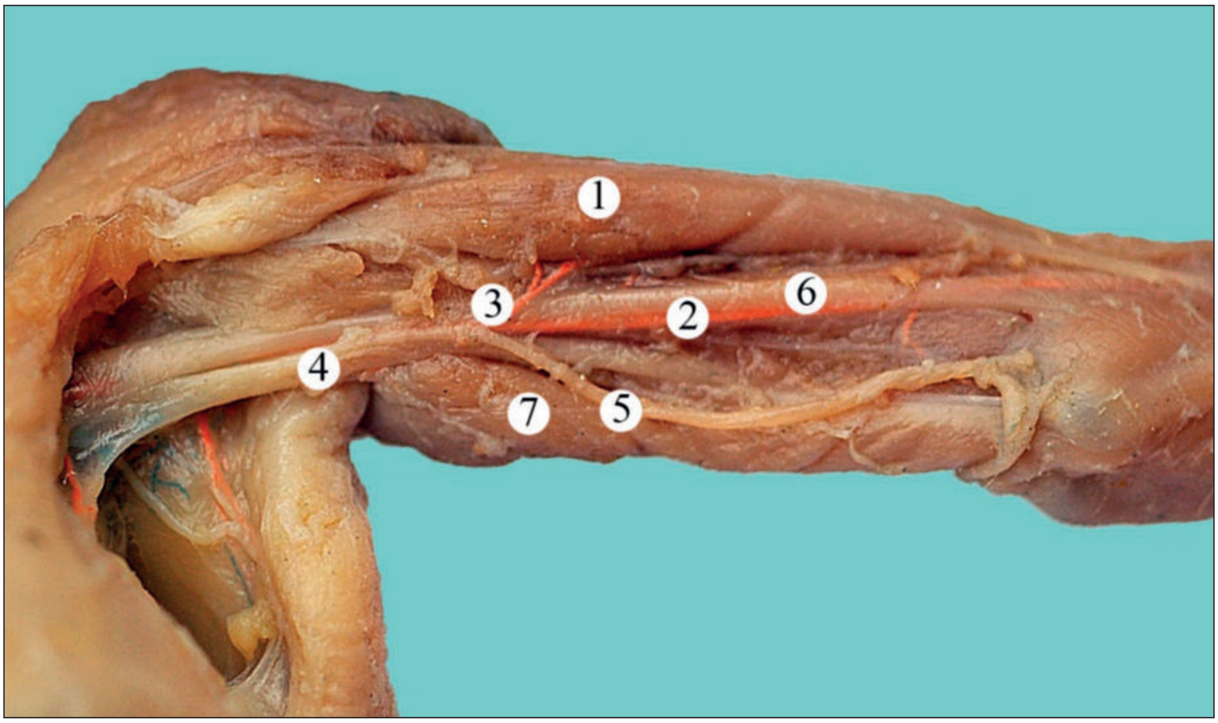

Fig. 3. Structures of the left anterior brachial region of a fetus of 280.0 mm CRL.
Photo of macro subject. Magnification 2,6^x:
1 – biceps brachii muscle; 2 – brachial artery; 3 – muscular branches of the brachial artery; 4 – brachial vein; 5 – main vein; 6 – median nerve; 7 – middle head of the triceps brachii muscle.

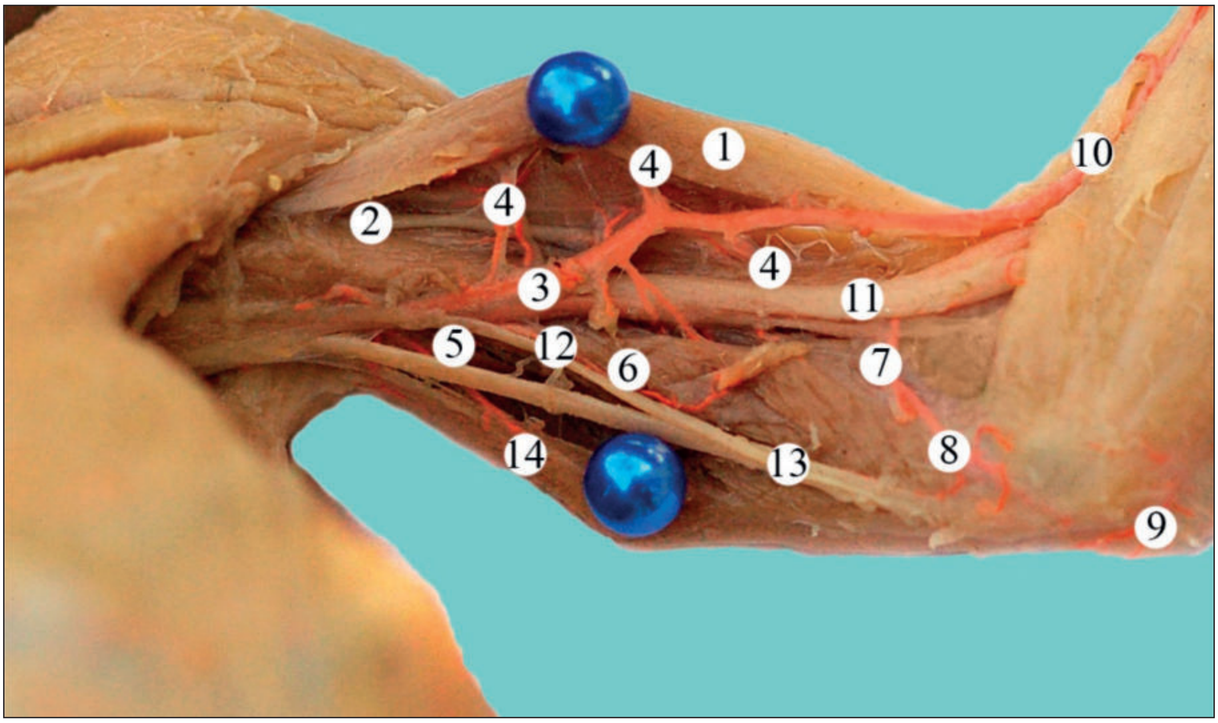

Fig. 4. Structures of the left anterior brachial region of a fetus of 205.0 mm CRL.
Photo of macro subject. Magnification 2,1^x:
1 – biceps brachii muscle; 2 – musculocutaneous nerve; 3 – brachial artery; 4 – muscular branches of the brachial artery; 5 – deep brachial artery; 6 – upper bypass elbow artery; 7 – lower bypass elbow artery; 8 – anterior branch of the elbow rotary artery; 9 – posterior branch of the elbow rotary artery; 10 – radial artery; 11 – middle nerve; 12 – medial cutaneous brachial nerve; 13 – ulnar nerve; 14 – triceps brachii muscle.

muscle branches of the brachial artery were involved, which entered the thickness of its belly over the entire length of the muscle (Fig. 4).

Some fetuses have the branch of the anterior bypass brachial artery participating in the blood supply to the biceps brachii muscle. Arterial branches, in number from 3 to 6, are included in the biceps brachii muscle within the proximal, middle and distal parts. Moreover, in the middle part of the biceps brachii muscle belly, the vessels enter with the nerves, head in parallel with respect to the nerve trunks and branch in the magistral form. While the muscular arteries enter the proximal and distal parts of the biceps brachii muscle isolated from the nerve branches and are distributed in their thickness in the loose form.

The outflow of blood from the biceps brachii muscle occurs through the companion veins of the same name. It is noteworthy that arterial branches of 1-2 orders are mostly accompanied by two veins.

The neurovascular correlations of the biceps brachii muscle established in fetuses, as well as the proximity to the neurovascular bundle of the shoulder, create less favourable conditions for manipulation of this muscle. However, if necessary, the use of the lateral side of its long head is quite acceptable. At the same time, considering the topography of the intramuscular arteries and nerves, longitudinal cuts that coincide with the direction of muscle bundles and are performed no higher than the middle of the shoulder, that is, close to the lower border of the neurovascular gate of the biceps brachii muscle, are more justified. It can be assumed that with the segmental form of vascular entry, when the arteries penetrate the muscle belly in the transverse direction, longitudinal cuts are more traumatic than with the magistral form of branching, when the arteries of a larger diameter and in much smaller numbers enter in the longitudinal direction, tangentially. However, given the large number of blood supply sources and vascular anastomoses of the biceps brachii muscle, longitudinal incisions are preferred in all cases because they spare the more vulnerable intramuscular nerve ligaments and network. The separation of the innervation of the long and short heads of the biceps brachii allows relatively free movement of the muscle flaps that are cut out during myoplastic operations.

Innervation of the brachial muscle is usually provided by 2-4 branches of the musculocutaneous nerve. Branching of the nerve trunks in the proximal and middle parts of the belly of the brachial muscle should be noted to occur in a loose form, and in its distal part, mainly in a magistral form. It is noteworthy that the nerve branch, which goes to the distal part of the brachial muscle belly, is not accompanied by arteries.

Also, some fetuses possessed 1-2 branches of the radial nerve, which entered the brachial muscle from the side of the lateral edge and branched out in the middle and distal parts of the muscle belly, as a rule, are in a loose form. At the same time, connections between the branches of the musculocutaneous and radial nerves were established in the thickness of the brachial muscle belly.

The sources of blood supply to the brachial muscle are the upper and lower ulnar bypass arteries, the deep brachial artery, and the radial rotary artery (Fig. 5). Arterial branches, numbering from 2 to 5, enter the proximal and middle parts of the brachial muscle belly, mostly together with nerves and afterwards branch out in a loose form. Three ulnar bypass arteries were found in a 210.0 mm CRL fetus: upper, middle, and lower, which were involved in blood supply to the brachial muscle (Fig. 6).

The outflow of venous blood from the brachial muscle occurs through the veins accompanying the arterial branches. Considering the fetal topography features of the arteries and nerves of the brachial muscle, its partial use for myosurgery can be assumed, with the exception of the medial part of the muscle belly, close to the neurovascular bundle of the brachial muscle. At the same time, the longitudinal cuts of the brachial muscle are not higher than the border level of the middle and lower third of the anterior brachial area fully meet the requirements for cutting muscle flaps. The same requirements do not allow cutting out muscle flaps with a distal pedicle in all cases, because denervation and deterioration of the blood supply conditions of the flap may occur. Only if there is an additional source – innervation from the radial nerve, and if it is possible to make sure of this during the operation, it is possible to use the lateral part of the brachial muscle for the flap with the distal pedicle.

Thus, during the anatomical study, fetal anatomical variability of the muscles, arteries and nerves in the anterior brachial region was discovered. As a result of correlation study vessels and nerves in the thickness of the muscles belonging to the anterior brachial region in human fetuses of 4-8 months, it was established that the places of entry („gates") of arteries and nerves, as well as their topography and the branching form, do not always coincide. The largest number of arterial and nerve branches goes to the proximal and middle parts of the belly of the coracobrachialis and brachialis muscles, as well as the biceps brachii muscle. In some fetuses, additional sources of muscle innervation of the anterior brachial region were found. Thus, the coracobrachialis muscle received

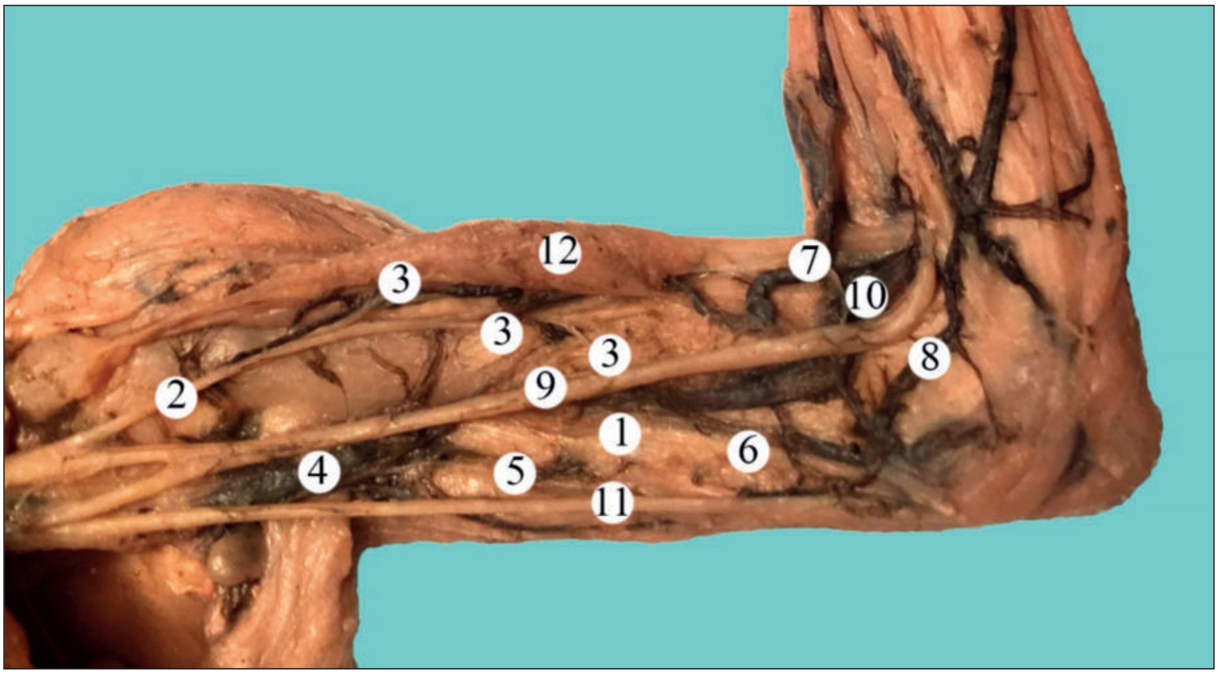

Fig. 5. Structures of the left anterior brachial region of a fetus of 170.0 mm CRL.
Photo of macro subject. Magnification 2,1^{x}:
1 – brachial muscle; 2 – musculocutaneous nerve; 3 – muscle branches of the musculocutaneous nerve; 4 – deep brachial artery; 5 – upper bypass elbow artery; 6 – lower bypass elbow artery; 7 – radial rotary artery; 8 – anterior branch of the elbow rotary artery; 9 – median nerve; 10 – accompanying artery of the median nerve; 11 – ulnar nerve; 12 – biceps brachii muscle.

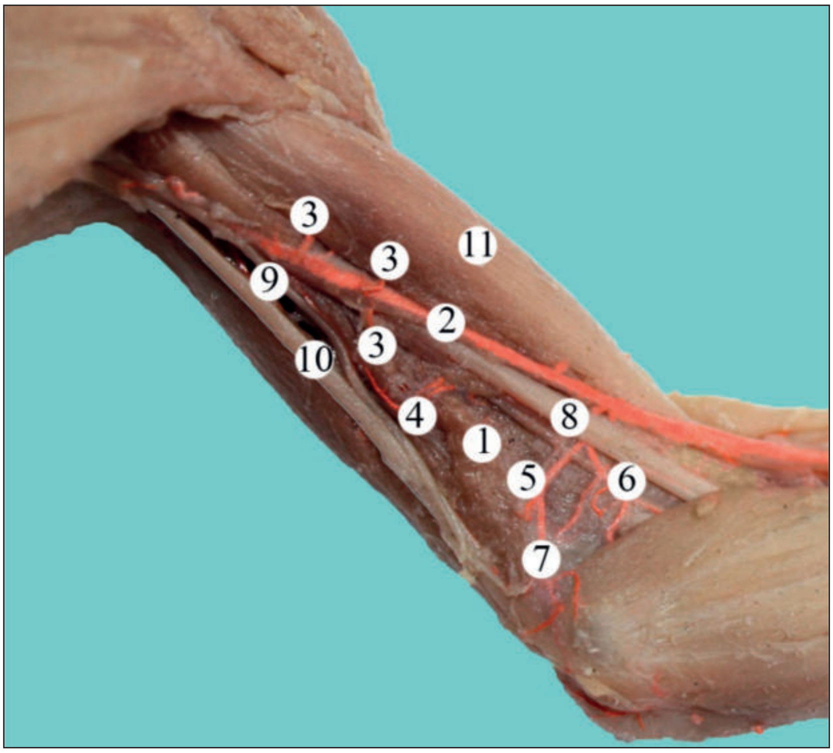

Fig. 6. Structures of the left anterior brachial region of a fetus of 210.0 mm CRL.
Photo of macro subject. Magnification 2,1^{x}:
1 – brachial muscle; 2 – brachial artery; 3 – muscle branches of the brachial artery; 4 – upper bypass elbow artery; 5 – median bypass elbow artery; 6 – lower bypass elbow artery; 7 – anterior branch of the elbow rotary artery; 8 – median nerve; 9 – medial cutaneous brachial nerve; 10 – ulnar nerve; 11 – biceps brachii muscle.

additional innervation from the lateral bundle of the brachial plexus, the biceps brachii muscle – from the median nerve, and the brachial muscle – from the radial nerve. Also, in one case, an additional branch of the brachial artery was described – the middle bypass ulnar artery, which, together with the upper and lower arteries of the same name, participated in the blood supply of the brachial muscle.

The main and additional sources of blood supply and innervation of the anterior brachial muscle region in human fetuses are described, as well as the peculiarities of the intramuscular branching of nerves and arteries, the presence of anastomoses should be considered when performing myoplastic operations at the stages of the postnatal period of human ontogenesis. At the same time, the utmost attention should be placed to the nerves, which, compared to the vessels, do not have such developed opportunities to compensate for the lost parts.

Conclusions

Fetal anatomical variability of the muscles, arteries, and nerves of the anterior brachial area has been revealed in human fetuses, and the places of entry of arteries and nerves, as well as their topography and the form of branching in the muscles of the anterior brachial area, do not always coincide.

The largest number of arterial and nerve branches goes to the proximal and middle parts of the belly of the coracobrachialis and brachial muscles, as well as the biceps brachii muscle.

In human fetuses, the loose form of intramuscular neural branching and the magistral form of arterial branching in the thickness of the coracobrachialis muscle have been established.

The magistral form of the intramuscular distribution of nerve trunks in the biceps brachii muscle was revealed, while the vessels enter the middle part of the muscle belly together with the nerves and branch out according to the magistral form. Muscular arteries enter the proximal and distal parts of the biceps brachii separately from the nerve branches and are distributed in their thickness in a loose form.

Branching of the nerve trunks in the proximal and middle parts of the brachial muscle belly occurs in a loose form, and in its distal part, as a rule, in a magistral form. Arterial branches enter the proximal and middle parts of the brachialis muscle belly, mostly together with the nerves and therefore branch out in a loose form. The nerve branch that goes to the distal part of the brachial muscle's belly is not accompanied by arteries.

In addition to the main source of muscle innervation of the anterior brachial region, i.e. the musculocutaneous nerve in human fetuses, additional sources of their innervation were found in individual fetuses. Thus, the coracobrachialis muscle received additional innervation from the lateral bundle of the brachial plexus, the biceps brachii muscle – from the median nerve, and the brachialis muscle – from the radial nerve.

When performing rational incisions to cut completely viable muscle flaps on the pedicle, it is necessary to consider not only the extra-, but also the intramuscular distribution of nerves and arteries of each individual muscle of the anterior brachial area, considering possible variants of the branch topography of the subclavian part in both the brachial plexus and the brachial arteries.

The established neurovascular correlations and the fetal anatomy features of the anterior brachial muscle area determine, in general, the presence of relatively favourable conditions for cutting muscle flaps that are well innervated and supplied with blood, on a pedicle of various lengths, thicknesses and directions, necessary for the treatment of motor disorders, as well as for filling residual bone cavities in osteomyelitis in the postnatal period of a person. Due to the distribution peculiarities of intramuscular nerves, flaps that include areas from the central parts of the anterior brachial muscle area, where the nerves are more concentrated, may turn out to be quite viable. At the same time, on the shoulder, flaps with a proximal pedicle, cut from the entire thickness of the muscles, are preferable.

Author Contributions:

T.V.K. is responsible for the conception the manuscript. O.A.K. is responsible for the data acquisition, anatomical investigations and data analyzing, design and writing the manuscript. V.V.I. and M.I.K. aided to the design, reviewed, and edited the manuscript. All authors contributed equally to the present work. All authors contributed to the critical revision of the article for valuable intellectual content. All the authors have read and agreed with the final version of the article.

Compliance with Ethics Requirements:

„The authors declare no conflict of interest regarding this article"

„The authors declare that all the procedures and experiments of this study respect the ethical standards in the Helsinki Declaration of 1964, as revised in 2013, as well as the national law"

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