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T.V. Khmara, G.Ya. Stelmakh, O.V. Garvasiuk, I.G. Biriuk, V.M. Drachuk
Bukovinian State Medical University, Chernivtsi

PECULIARITIES OF INNERVATION OF MUSCLES AND SKIN OF THE ANTERIOR AND LATERAL ABDOMINAL WALLS IN HUMAN FETUSES

e-mail: khmara.tv.6@gmail.com

Considering theoretical and practical importance of data regarding fetal anatomical variability of intercostal nerves, iliopectas and inguinal nerves, the study was performed on 44 preparations of human fetuses of 231.0–375.0 mm parietococcygeal length using macromicroscopic preparation, superficial staining of dissected nerves, and morphometry. In some cases, in the innervation of the muscles and skin of the anterior and lateral abdominal walls took part VI (V)–XII intercostal nerves and iliohypogastric nerve, and in other – VII–XII intercostal nerves, iliohypogastric and ilioinguinal nerves. The formation of the intramuscular nerve plexus of the abdomen involves branches that begin directly from the main trunks of the intercostal nerves, and also from the lateral, anterior and additional musculocutaneous branches of the intercostal nerves, and the branches of the iliohypogastric and ilioinguinal nerves. In human fetuses, there are areas of overlap between the innervations of the muscles and skin of the anterior and lateral abdominal walls.

Key words: intercostal nerves, iliohypogastric nerve, ilioinguinal nerve, muscles of abdomen, skin of abdomen, fetus, human.

Т.В. Хмара, Г.Я. Стельмах, О.В. Гарвасюк, І.Г. Бірюк, В.М. Драчук

ОСОБЛИВОСТІ ІННЕРВАЦІЇ М'ЯЗІВ І ШКІРИ ПЕРЕДНЬОЇ І БІЧНИХ СТІНОК ЖИВОТА У ПЛОДІВ ЛЮДИНИ

З огляду на теоретичну і практичну важливість даних щодо фетальної анатомічної мінливості міжребрових нервів, клубово-підчеревного і клубово-пахвинного нервів дослідження проведено на 44 препаратах плодів людини 7–10 місяців 231,0–375,0 мм тім'яно-куприкової довжини за допомогою макромікроскопічного препарування, поверхневого забарвлення відпрепарованих нервів, а також морфометрії. У плодів людини встановлено, що в одних випадках, в іннервації м'язів та шкіри передньої і бічної стінок живота беруть участь VI(V)–XII міжреброві нерви і клубово-підчеревний нерв, а в інших – VII–XII міжреброві нерви, клубово-підчеревний і клубово-пахвинний нерви. М'язам передньої і бічних стінок живота притаманна сегментарна іннервація. В утворенні внутрішньом'язового нервового сплетення ділянки живота беруть участь гілки, які починаються безпосередньо від основних стовбурів міжребрових нервів, а також від бічних, передніх і додаткових м'язово-шкірних гілок міжребрових нервів, та гілки клубово-підчеревного і клубово-пахвинного нервів. У плодів людини існують зони перекриття іннервації м'язів і шкіри передньої і бічних стінок живота. Встановлені зв'язки між шкірними гілками суміжних міжребрових нервів вказують на відсутність чіткої метамерності в іннервації шкіри передньо-бічних стінок живота.

Ключові слова: міжреброві нерви, клубово-підчеревний нерв, клубово-пахвинний нерв, м'язи живота, шкіра живота, плід, людина.

The study is a fragment of the research project “Patterns of sexual and age structure and topographic anatomical transformations of organs and structures of the body at the pre- and postnatal stages of ontogenesis. Features of perinatal anatomy and embryotography”, state registration number 0120U101571.

Until now, the question of making incisions on the anterior abdominal wall in order to access the abdominal organs remains relevant. We have to mark that during laparotomy and lumbotomy are often damaged the intercostal nerves (IN) and their branches, and also the branches of the iliohypogastric and ilioinguinal nerves, which take part in the innervation of the muscles and skin of the abdominal wall. The above mentioned can lead to such complications as atrophy of the abdominal muscles, formation of postoperative hernias, development of trophic ulcers, pain syndrome, traumatic neuritis and neuroma of damaged nerves, etc. [9, 15].

In the area of the anterior abdominal wall, the number of IN varies from 1 to 4 pairs, but most often there are two pairs of IN (60 % of observations) [3]. INs penetrate the rectus abdominis muscles usually

through their outer edges (52 %) or through their posterior surface (39 %). In persons with posterior variant of penetration of the rectus abdominis muscles with IN, the posterior separation hernioplasty will be accompanied by a maximal risk of damage of nerve trunks and, consequently, by the occurrence of chronic pain syndrome in the postoperative period [1]. For morphologists and clinicians make an interest the information about the connections of IN with each other and with adjacent nerves, in particular, that accompany the inferior epigastric arteries, anterior and lateral musculocutaneous branches of IN [7, 13, 14]. Therefore, during operations on the abdominal wall (choosing the incision of the abdominal wall, muscle plasticity, neurectomy, etc.) it is necessary to take into account the peculiarities of nerve branching in the muscles and skin of the abdomen and to know their possible structure and topography.

Some researchers indicate the age and individual anatomical variability of IN and their musculocutaneous branches in human fetuses, as well as the numerous and varied forms of connections between the anterior and lateral musculocutaneous branches of VIII–XII IN in the anterior-lateral parts of the abdominal wall [5].

However, in the literary sources there are no complex studies on the fetal topography of the trunks of the IN, iliohypogastric and ilioinguinal nerves and their branches in the anterior and lateral abdominal walls.

Taking into account the theoretical and practical importance of the anatomical facts regarding the fetal anatomical variability of IN, iliohypogastric and ilioinguinal nerves, we consider it relevant to perform this study.

The purpose of the study was to determine the sources of innervation of the muscles and skin of the anterior and lateral abdominal walls at the end of the fetal period of human ontogenesis.

Material and methods. The study was performed on 44 preparations of human fetuses of 7–10 months 231.0–375.0 mm parietal-coccygeal length (PCL) without external signs of anatomical abnormalities or abnormalities of the skeleton of the chest, organs and structures of the thoracic and abdominal cavities using macromicroscopic dissection, superficial staining of dissected nerves, and morphometry. IN on the right and left sides were studied along their entire length from the site of origin to the final branches in the muscles and skin of the anterior-lateral parts of the trunk. Preparations of fetuses with mass of more than 500.0 g were studied directly at the Chernivtsi Regional Children's Pathological Bureau according to the cooperation agreement. For the study also were used the preparations of fetuses from the Museum of the Department of Human Anatomy named after MH Turkevich and the Department of Histology, Cytology and Embryology of Bukovinian State Medical University [4]. The research was performed in compliance with the basic bioethical provisions of the Council of Europe Convention on Human Rights and Biomedicine (April 4, 1997), the Helsinki Declaration of the World Medical Association on ethical principles of scientific medical research with human participation (1964–2013), the order of the Ministry of Health of Ukraine No. 690 dated 23.09.2009 and taking into account the methodological recommendations of the Ministry of Health of Ukraine “Procedure for removal of biological objects from deceased persons, whose bodies are subject to forensic examination and pathological examination, for scientific purpose” (2018). The Commission on Biomedical Ethics of Bukovinian State Medical University did not find any violations of bioethical, moral and legal norms during the research.

Results of the study and their discussion. It was found that IN (except I and XII) from the place of exit from the intervertebral foramen to the level of the middle axillary line branch out from 2 to 5 nerve trunks, which are connected by thin connecting branches that go in the ascending and descending directions. The ascending and descending connecting trunks of adjacent anterior musculocutaneous branches of VII–XII IN, in isolated cases connecting with each other, form additional anterior musculocutaneous branches.

The trunks of adjacent IN connect by connecting branches, here with numerous and varied in shape connections are observed between the anterior and lateral musculocutaneous branches of VIII–XII IN in the area of the anterior-lateral parts of the abdominal wall. It should be noted that the anterior musculocutaneous branches of the IN in the abdominal region are divided into several (2 to 5) convoluted trunks, which are connected by thin branches.

It has been found that in human fetuses the anterior musculocutaneous branches of VI–XII IN pass on the abdominal wall between the transverse and internal oblique muscles of the abdomen (fig. 1). The source of innervation of the internal oblique muscle of the abdomen are the anterior musculocutaneous branches of X–XII IN (in isolated cases of IX–XII IN), as well as branches of the iliohypogastric and ilioinguinal nerves. In this case, the branches of X–XII IN begin from the main trunks of IN at an acute angle, run parallel to each other, enter the thickness of the internal oblique muscle of the abdomen from the inner surface on the posterior margin, at an obtuse angle to the longitudinal axis of the muscle. The

anterior musculocutaneous branches of X–XII IN, iliohypogastric and ilioinguinal nerves in the thickness of the internal oblique muscle of the abdomen branch out and form an intramuscular plexus.

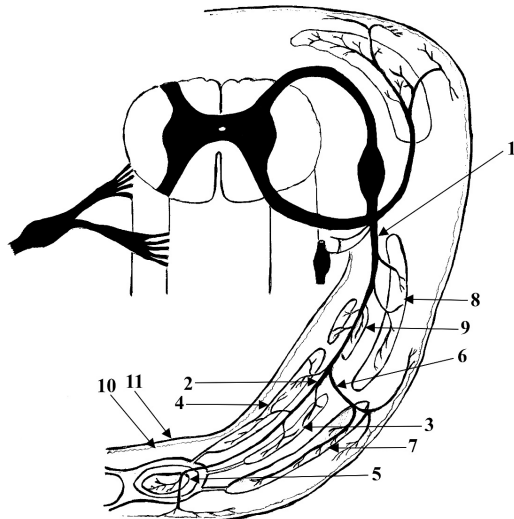


Fig.1. Branching of the intercostal nerve in the anterior-lateral abdominal wall area in the human fetus (scheme): 1 – trunk of the intercostal nerve; 2 – anterior musculocutaneous branch; 3 – internal oblique muscle of the abdomen; 4 – transverse abdominal muscle; 5 – rectus abdominis muscle; 6 – lateral musculocutaneous branch; 7 – external oblique muscle of the abdomen; 8 – external intercostal muscle; 9 – internal intercostal muscle; 10 – subperitoneal fascia; 11 – peritoneum.

The innervation of the transverse abdominal muscle is performed by the anterior musculocutaneous branches of VII–XII IN, and also the branches of the iliohypogastric and ilioinguinal nerves, which form the nerve plexus in the muscle thickness. The main trunks and branches of VII–XII IN, with iliohypogastric and ilioinguinal nerves before the entering to the transverse abdominal muscle, usually go parallel to each other, and then enter the muscle from the outer surface on the posterior edge at a right angle to its longitudinal axis.

It should be noted that the external oblique muscle of the abdomen is innervated by lateral musculocutaneous branches, as a rule, of VI–XII IN, and in isolated cases of V–XII IN, and with branches of iliohypogastric and ilioinguinal nerves. The branches of the above-mentioned nerves enter the thickness of the external oblique muscle of the abdomen from the inner surface in the area of the posterior edge and branch out mainly in trunk form. In the thickness of the external oblique muscle of the abdomen between the branches of the lateral musculocutaneous branches of V–XII IN, the connecting branches and the formation of the intramuscular nerve plexus are determined.

At the outer edge of the rectus abdominis or slightly medially from this edge, the anterior musculocutaneous branches of the IN are divided into muscular and cutaneous branches. The latter, as a rule in quantities of 2 to 5, penetrate together with the blood vessels through small fissures in the anterior wall of the sheath of the rectus abdominis muscle into the skin of the anterior abdominal wall. In this case, before entering the thickness of the rectus abdominis muscle, the musculocutaneous branches, branch out fan-shaped or, in the descending direction, go parallel to each other. It should be emphasized that into the skin parts covering the rectus abdominis muscle also penetrate the skin branches of additional anterior musculocutaneous branches, which appeared as a result of the connection of the descending and ascending nerve trunks of the anterior musculocutaneous branches of adjacent IN. It should be noted that in the skin, that covers the rectus abdominis muscle above the navel, branch out the skin branches of the anterior musculocutaneous branches of VI–IX IN, and in 6 fetuses – of V–IX IN. The skin branches of the anterior musculocutaneous branches of IX–X IN branch in the skin of the navel region. The terminal branches of the anterior musculocutaneous branches of XI–XII IN branch in the skin, covering the lower third of the rectus abdominis muscle. In this case, each anterior musculocutaneous branch of IN sends to the skin from 2 to 5 thin branches, each of which in turn is divided in the subcutaneous fat into 2–3 very thin stems. The latter, when connected, form the subcutaneous nerve plexus.

In the thickness of the rectus abdominis muscle, branch the anterior musculocutaneous branches of VI–XII IN and the iliohypogastric nerve, and in isolated cases – also of the ilioinguinal nerve (fig. 2). In this case, the branches of these nerves enter the rectus abdominis muscle from its posterior surface at a right angle to the longitudinal axis of the muscle and the direction of its muscle bundles.

In the late fetuses in the upper parts of rectus abdominis muscles, the formation of intramuscular nerve plexus is observed (fig. 3).

In the thickness of the lower parts of the rectus abdominis, single connecting branches are found between the anterior musculocutaneous branches of IX–XII IN and the iliohypogastric nerve. The anterior musculocutaneous branches of the XI and XII IN and the iliohypogastric nerve are directed mainly to the middle part of the pyramidal muscle and branch out in the thickness of the latter.

The sources of innervation of the skin of the anterior-lateral parts of the abdomen are the lateral and anterior musculocutaneous branches of the V–XII IN, as well as the cutaneous branches of the iliohypogastric and ilioinguinal nerves. The lateral musculocutaneous branches, after separation from the trunks of V–XII IN at the level of the mid-axillary line, innervate the external intercostal muscles and the external oblique muscle of the abdomen, and the cutaneous branches branch out in the skin of the lateral abdominal wall. In the skin of the hypochondrium, the anterior branches of the lateral cutaneous branches

of VII–IX IN branch out, and go in the caudo-ventral direction, while their end branches reach the lateral edge of the rectus abdominis muscle and in the subcutaneous fat form the connections between the cutaneous branches of adjacent IN. In the skin of the inguinal region and above the iliac crest, the lateral branches of the iliohypogastric and ilioinguinal nerves branch out.

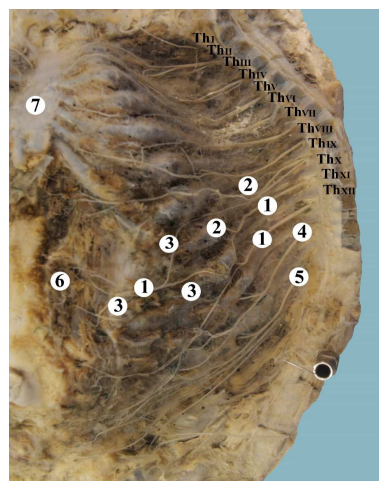


Fig. 2. Branching and connections of the intercostal nerves (Th I–XII) on the inner surface of the left half of the thoracic and abdominal walls in the fetus 345.0 mm PCL. Macropreparation. Mag. 2.4 \times : 1 – anterior musculocutaneous branches of intercostal nerves; 2 – lateral musculocutaneous branches of intercostal nerves; 3 – connecting branches of intercostal nerve; 4 – iliohypogastric nerve; 5 – ilioinguinal nerve; 6 – rectus abdominis muscle; 7 – sternum.



Fig. 3. Branching and connections of the intercostal nerves (Th VIII–XII) on the inner surface of the right half of the thoracic and abdominal walls and the formation of the intramuscular nerve plexus of the rectus abdominis muscle in the fetus 370.0 mm PCL. Macropreparation. Mag. 2.6 \times : 1 – rectus abdominis muscle; 2 – anterior musculocutaneous branches of intercostal nerves; 3 – lateral musculocutaneous branches of intercostal nerves; 4 – connecting branches of intercostal nerves; 5 – iliohypogastric nerve; 6 – ilioinguinal nerve.

The variability of the topography of the branches of the IN, iliohypogastric and ilioinguinal nerves and their number in the thickness of the muscles of the anterior and lateral walls of the abdomen was detected. In particular, in some cases, in the innervation of the muscles and skin of the anterior and lateral walls of the abdomen were involved VI (V)–XII IN and the iliohypogastric nerve, and in other observations – VII–XII IN, iliohypogastric and ilioinguinal nerves [5, 6, 12].

Into the external and internal oblique muscles of the abdomen and into the rectus abdominis muscle, the nerves usually enter from the posterior surface, and into the transverse abdominal muscle from the outer surface. Moreover, in the external and internal oblique muscles of the abdomen, the nerves enter mainly at an obtuse angle to

their longitudinal axis and at an acute angle relatively to the muscle bundles. Nerves usually enter the transverse abdominal muscle and rectus abdominis muscle at right angles to their longitudinal axis. The direction of the nerves at the entrance to the transverse abdominal muscle coincides with the course of the muscle bundles, and the nerves enter the rectus abdominis muscle at a right angle to them [2, 8, 10, 11].

Peculiarities of IN branching in the thickness of the muscles of the anterior and lateral abdominal walls should be taken into account during myoplastic operations.

The data on the fetal topography of the IN, iliohypogastric and ilioinguinal nerves in the region of anterior and lateral abdominal walls will help clinicians to solve the question of shape and direction of incisions in different parts of the abdominal wall.

The study indicates the need for further elucidation of the microscopic structure of IN, iliohypogastric and ilioinguinal nerves in fetuses and newborns.

Conclusions

1. In human fetuses it was determined the variability in the topography and number of branches of the intercostal nerves, iliohypogastric and ilioinguinal nerves, which provide innervation of the muscles and skin of the anterior and lateral abdominal walls. In some cases, in the innervation of the muscles and skin of the anterior and lateral abdominal walls are involved the VI (V)–XII intercostal nerves and iliohypogastric nerve, and in other observations – the VII–XII intercostal nerves, iliohypogastric and ilioinguinal nerve. In the thickness of the muscles of the anterior and lateral abdominal walls from the trunks of the intercostal nerves, iliohypogastric and ilioinguinal nerves depart the descending and ascending branches.

2. Into the external and internal oblique muscles of the abdomen and into rectus abdominis muscle the nerves mainly enter from the posterior surface, and into the transverse abdominal muscle – from its outer surface.

3. The muscles of the anterior and lateral abdominal walls are characterized by segmental innervation and the formation of intramuscular nerve plexus, the formation of which involves branches that begin directly from the main trunks of intercostal nerves, as well as lateral, anterior and additional musculocutaneous branches of intercostal nerves, and branches of iliohypogastric and ilioinguinal nerves.

4. In human fetuses, there are areas of overlap innervation of muscles and skin of the anterior and lateral abdominal walls, and there is the beginning of the formation in the subcutaneous tissue of the anterolateral abdominal wall of the nerve plexus by connection of branches of lateral and anterior branches of intercostal nerves. The connections between cutaneous branches of adjacent intercostal nerves that indicate a lack of clear metamerism in the innervation of the skin of the anterior-lateral abdominal walls were established.

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