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DEVELOPMENT AND FORMATION OF THE TOPOGRAPHY OF THE INFERIOR VENA CAVA AND PULMONARY VEINS DURING THE EIGHTH MONTH OF PRENATAL HUMAN ONTOGENESIS

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ABSTRACT

The aim: To determine the topographic features and morphometric parameters of the pulmonary veins and inferior vena cava in human fetuses during the eighth month of intrauterine development.

Materials and methods: A morphometric and histological research of 25 human fetuses in the eighth month of prenatal ontogenesis (271.0 – 310.0 mm parietal-coccygeal length) was conducted. The topographic features of the inferior vena cava and pulmonary veins during the eighth month of intrauterine development were established, and their length and diameter, as well as the change in the angle of their formation, were morphometrically determined. The formation of the topography of these veins is due to the formation of the chest and abdominal organs and continues throughout the entire fetal period of development.

Results: The inferior vena cava is formed at the level of the body of the IV lumbar vertebra in the eighth month of the intrauterine period of human development. The initial part of the trunk of the inferior vena cava obliquely "crosses" the common iliac artery from the left to the right. At this level, the vein is located to the right and slightly behind the aorta. In fetuses of the given age group, the right adrenal gland borders the inferior vena cava only at the level of the lower 2/3 of its medial edge. At the level of the subhepatic section of the inferior vena cava, 4–5 pairs of lumbar veins flow into it. In most cases, the ductus venosus flowed into the inferior vena cava independently between the middle and left hepatic veins. Compared to other sections of the inferior vena cava, the lumen of its diaphragmatic section, which passes through the opening in the dorsal part of the tendinous center of the diaphragm on the right, increases. During this period, it was established that the pulmonary veins lie completely in the heart cavity and are surrounded by a serous membrane. In all fetuses, two pulmonary veins flow from each lung into the left atrium. The level of confluence of the venous ducts of the pulmonary veins and their number varies individually. Pulmonary veins and their ducts lie more superficially and do not repeat the passage of the corresponding bronchi and arteries, lying, as a rule, within the limits of interlobular, intersegmental, and intersubsegmental connective tissue membranes.

Conclusions: In this age group, changes in venous vessels and complications in the structure of their walls and their ducts continue. The passage and branching of the bronchial tree and arterial branches (starting with the segmental branches) are almost completely identical. A significant increase in the number of small ducts was found in the system of pulmonary veins. There is an increase in the morphometric indicators of the size of the inferior vena cava in comparison with its other parts. In the wall of the pulmonary veins and inferior vena cava, all three tunics are clearly visible, which in structure are close to the definitive one.

KEY WORDS: human fetuses, pulmonary veins, inferior vena cava, parietal-coccygeal length, prenatal ontogenesis

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INTRODUCTION

Establishing the morphological regularities of human ontogenesis has not only theoretical value, but also important practical significance. The research of the peculiarities of the development of venous vessels is a morphological basis for understanding the mechanisms of the occurrence of variants, anomalies and malformations, as well as for the development of methods of antenatal prevention of some congenital diseases [1-8]. There are many scientific works that describe the morphological features of venous vessels in the age aspect [9-11]. However, despite the significant functional value of the inferior vena cava and pulmonary veins, their detailed and comprehensive morphological research in prenatal ontogeny was not conducted.

THE AIM

To determine the topographic features and morphometric parameters of the inferior vena cava and pulmonary veins in human fetuses during the eighth month of intrauterine development.

MATERIALS AND METHODS

The study of the pulmonary veins and inferior vena cava and also adjacent organs and structures was performed in compliance with the "Rules of Ethical Principles of Conducting Scientific Medical Research with Human Participation", approved by the Declaration of Helsinki (1964-2013), ICH GCP (1996), EU Directive No. 609 (from 24.11.1986), order of the Ministry of Health of Ukraine No. 680 from 23.09.2009.

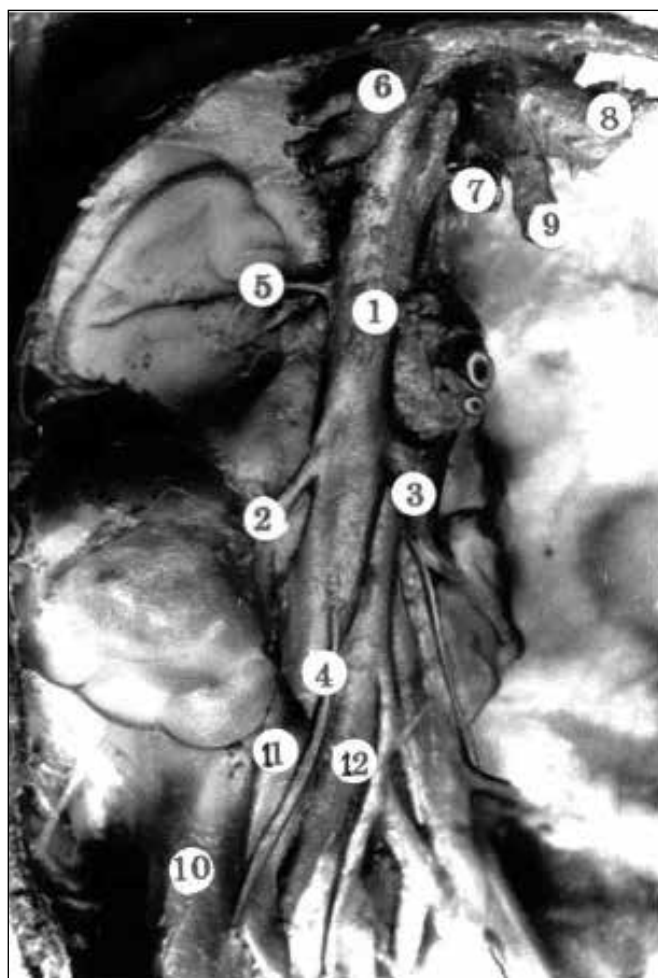


Fig. 1. Complex of organs of the abdominal cavity of a human fetus 348.0 mm parietal-coccygeal length (intestine and liver are removed). Macro photo. The photo is 2 times enlarged.

1 – inferior vena cava; 2 – right renal vein; 3 – left renal vein; 4 – right gonadal vein; 5 – central vein of the right adrenal gland; 6 – right hepatic vein; 7 – middle hepatic vein; 8 – left hepatic vein; 9 – venous duct; 10 – large lumbar muscle; 11 – right ureter; 12 – aorta.

The research was conducted on 25 corpses of human fetuses from 271.0 to 310.0 mm parietal-coccygeal length (PCL), which corresponds to the eighth month of prenatal ontogenesis. We also used histological preparations of fetuses from the archive of the department of human anatomy named after M.G. Turkevych, as well as the graphic reconstruction method used. The age of the object was determined according to the appropriate tables [12]. The length of the fetuses was measured after they were fixed in a 5% solution of neutral formalin for a day, which ensured the constancy of the shape of the gelatinous body and avoided mistakes in determining the age. Serial histological sections of fetuses with a thickness of 25 μ m were made in three planes – sagittal, frontal and horizontal, stained with hematoxylin-eosin. Morphometrically, the length and diameter of the pulmonary veins and inferior vena cava were determined

on histological sections and graphic reconstructions. The obtained morphometric parameters were processed statistically [13].

RESULTS

The morphogenesis and formation of the topography of the inferior vena cava and pulmonary veins and their ducts during the eighth month of intrauterine development were studied on the preparations of 25 fetuses 271.0 – 310.0 mm parietal-coccygeal length (PCL).

The end of the fetal period is characterized by a relative increase in morphometric indicators mainly in the diaphragmatic and intrapericardial sections of the inferior vena cava in comparison with its other sections and, thus, the vein acquires its final appearance. The inferior vena cava is formed at the level of the body of the IV lumbar vertebra. The left and right common iliac veins, with a diameter of 2.56 ± 0.11 mm and 3.13 ± 0.34 mm, respectively, in fetuses of the eighth month of development, merge at an angle of $47.63 \pm 0.40^\circ$. The initial part of the trunk of the inferior vena cava obliquely “crosses” from left to right the common iliac artery. At this level, the vein is located to the right and slightly behind the aorta. The right ureter is closely adjacent to it on the right, and the large lumbar muscle is attached to the back surface (Fig. 1).

The subrenal section of the inferior vena cava has an oval shape on cross-section, its transverse size is 4.49 ± 0.02 mm in fetuses of the eighth month of development.

At the level of the lower pole of the right kidney, the inferior vena cava is slightly more distant from the kidney, which is connected with the final formation of the position of the kidneys in the retroperitoneal space. On the left, the aorta closely adjoins the vein. Starting from the level of the kidney gate, the aorta takes a dorsal position in relation to the vein. The upper pole of the right kidney is separated from the inferior vena cava by the right adrenal gland, the caudal sections of which cover the anterior-medial surface of the upper third of the kidney. The renal section of the inferior vena cava has a rounded shape on cross-section, its diameter in eight-month-old fetuses is 4.69 ± 0.39 mm, and its length is 20.19 ± 0.32 mm, respectively.

The right renal vein, the diameter of which is 2.86 ± 0.11 mm, flows into the inferior vena cava at an angle of $60.0 \pm 1.14^\circ$. Its length in fetuses of the eighth month of development reaches 3.72 ± 0.08 mm. 3.0 mm below it, the right gonadal vein with a diameter of 2.17 ± 0.14 mm flows into the right anterior-lateral surface of the inferior vena cava.

The left renal vein flows into the inferior vena cava 3.0 mm above the level of the right renal vein. It has a tortuous passage, its diameter is 3.41 ± 0.07 mm, and at the point of confluence with the inferior vena cava it increases to 4.29 ± 0.05 mm. The central vein of the left adrenal gland with a diameter of 2.20 ± 0.14 mm flows into its upper semicircle. Lateral from it, the left gonadal vein with a diameter of 2.08 ± 0.12 mm flows into the lower semicircle of the left renal vein.

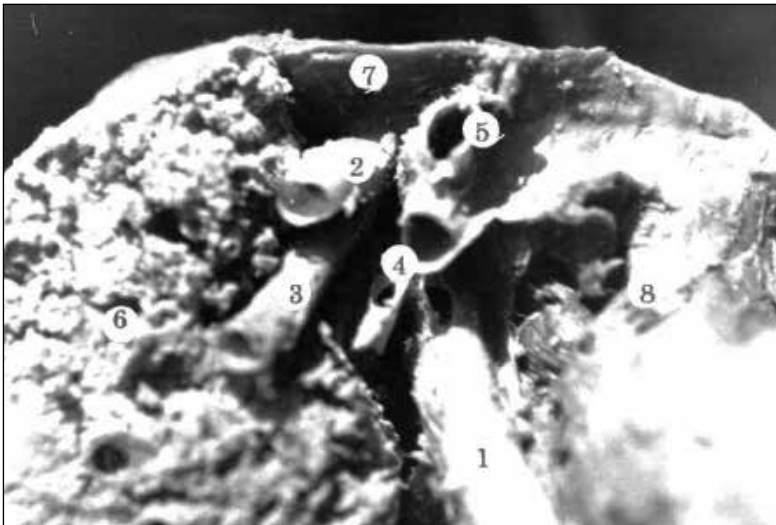


Fig. 2. Complex of organs of the upper part of the abdominal cavity (a part of the liver is removed) of a human fetus 320.0 mm parietal-coccygeal length (view from below). Macro photo. The photo is 4 times enlarged.
1 – inferior vena cava; 2 – right hepatic vein; 3 – middle hepatic vein; 4 – venous duct; 5 – left hepatic vein; 6 – liver; 7 – diaphragm; 8 – stomach.

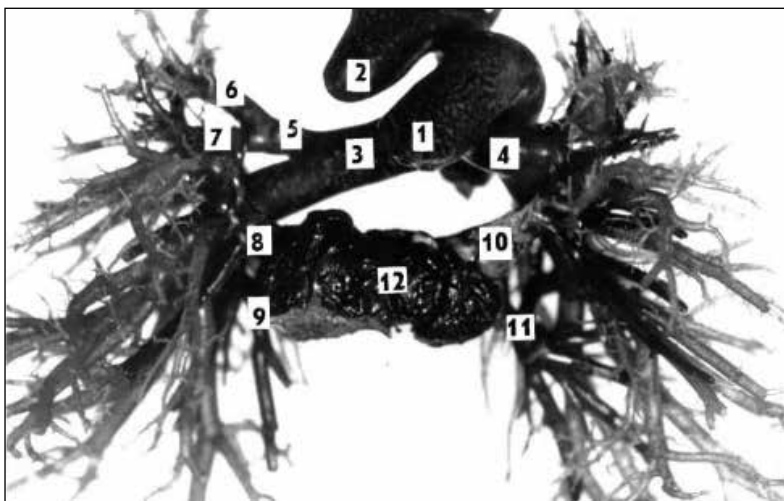


Fig. 3. Corrosive preparation of the pulmonary vessels of the fetus 280.0 mm parietal-coccygeal length. Front view. 36. x 2.4.
1 – pulmonary trunk, 2 – aorta, 3 – right pulmonary artery, 4 – left pulmonary artery, 5 – upper lobe branch of the right pulmonary artery, 6 – apical segmental artery, 7 – anterior segmental artery, 8 – right superior pulmonary vein, 9 – right lower pulmonary vein, 10 – left upper pulmonary vein, 11 – left lower pulmonary vein, 12 – left atrium.

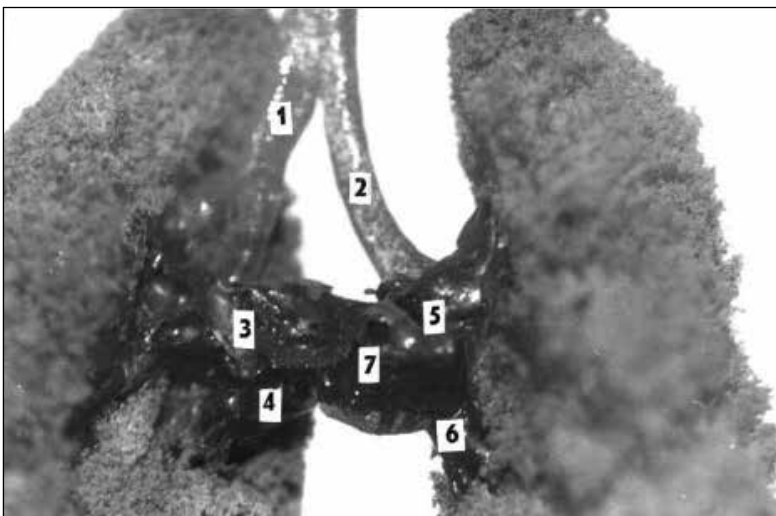


Fig. 4. Corrosive preparation of the bronchi and pulmonary vessels of the fetus 300.0 mm parietal-coccygeal length. Macro photo. Front view. 36. x 2.4.
1 – right main bronchus, 2 – left main bronchus, 3 – right upper pulmonary vein, 4 – right lower pulmonary vein, 5 – left upper pulmonary vein, 6 – left lower pulmonary vein, 7 – left atrium.

Fetuses of this age group, the right adrenal gland borders the inferior vena cava only at the level of the lower 2/3 of its medial edge. Within its upper third, the vein deviates ventrally and enters the liver parenchyma. At the level of the adrenal gland, the inferior vena cava borders the posterolateral surface of the descending part of the duodenum. The diameter of the suprarenal vein in fetuses of

the eighth month is 5.03 ± 0.06 mm of development, the length is 11.06 ± 0.39 mm. The central vein of the right adrenal gland, which emerges from the anterior surface of the gland near its medial edge, flows into the inferior vena cava. Its diameter is 2.33 ± 0.11 mm.

At the level of the subhepatic section of the inferior vena cava, 4-5 pairs of lumbar veins with a diameter of 1.58 ± 0.16

mm flow into it. The lower lumbar veins fall 2.0 mm above the place of formation of the trunk of the inferior vena cava, and the upper ones – at the level of the upper third of the right adrenal gland. The left lumbar veins are located slightly higher than the right. Lumbar veins in fetuses of the eighth month are at a distance of 6.8 – 7.1 mm from each other.

In the liver, the inferior vena cava lies in its sulcus. Adjacent to the posterior surface of the vein is the right adrenal gland and the right *crus* of the diaphragm. At the level of the liver, the vein is slightly compressed from the sides, its transverse size in fetuses of the eighth month of development is 4.41 ± 0.09 mm. The length of the hepatic part of the inferior vena cava during this period increases by 1.83 ± 0.03 mm. When the vein comes out the sulcus, the three main hepatic

The right and middle hepatic veins, which head to the inferior vena cava from the side of the right lobe of the liver, are the same in diameter on almost all preparations, which is 2.94 ± 0.13 mm in fetuses of the eighth month of development. The diameter of the left hepatic vein during this period increases from 2.5 ± 0.54 mm to 3.1 ± 0.38 mm. The ductus venosus, which connects the umbilical vein to the inferior vena cava, flew into the left hepatic vein in one case (340.0 mm parietal-coccygeal length in a fetus), and in all other cases it flew into the inferior vena cava independently between the middle and left hepatic veins. The length of the ductus venosus increases during the eighth month of fetal development, and its diameter increases until the ninth month. The length of the venous duct gradually increases in eight-month-old fetuses. During this period, the diameter of the duct at the level of the umbilical opening decreases from 3.7 ± 0.48 mm to 2.1 ± 0.24 mm, and the diameter of its caval opening remains almost unchanged (between 4.0 and 4.2 mm). This fact is explained by the gradual exclusion of the venous duct from the circulatory system.

Compared to other sections of the inferior vena cava, the lumen of its diaphragmatic section, which passes through the opening in the dorsal part of the tendinous center of the diaphragm on the right, increases. During this period, the length of the diaphragmatic vein reaches 11.21 ± 1.40 mm.

The heart cavity at the end of the fetal period is already clearly formed. The diameter of the intra-pericardial part of the vein in its expanded part in fetuses of the eighth month of development is 6.01 ± 0.07 mm [14].

Pulmonary veins in fetuses of this age group lie completely in the cavity of the heart and are surrounded by a serous membrane. In all these fetuses, four pulmonary veins flow into the left atrium (two from each lung). However, the number of venous ducts that form the pulmonary veins, as well as the level of confluence of these ducts varies individually (Fig. 3).

Therefore, in twenty-two preparations (88.0%), the right upper pulmonary vein (length – 3.1 ± 0.64 mm, diameter – 2.92 ± 1.02 mm) is formed by the fusion of the apical branch and the branch of the middle lobe. In sixteen cases (64.0%), the apical branch of the right upper pulmonary vein is formed from two branches – intrasegmental and intersegmental. The length of the apical branch of the

vein is 2.6 ± 0.09 mm, the diameter is 1.78 ± 0.17 mm. It is located in front of the right pulmonary artery and bronchus. The ducts of the apical branch lie superficially and are clearly visible on the medial surface of the lungs. The diameter of intersegmental branches is 1.4 ± 0.18 mm, intersubsegmental – 0.57 ± 0.12 mm.

The vein of the middle lobe, as a rule, is formed as a result of the fusion of two trunks – lateral and anterior branches. In three cases (12.0%), the named trunks flow into the apical branch separately. In these cases, the branch of the middle lobe does not exist as an independent trunk. The length of the branch of the middle lobe is 2.34 ± 0.15 mm, the diameter is 1.41 ± 0.08 mm. It is located below and medial to the artery and bronchus of the same name. Its passage is directed somewhat in the upward direction, where it merges at an acute angle with the apical branch [15-16].

The right lower pulmonary vein collects blood from the lobe of the lung of the same name and is formed in 50% of cases from two or three (42.5%) of venous trunks.

In the first version, it is formed by the upper branch and the common main vein, in the second – by the upper venous branch and two intersegmental veins. In five cases (20.0%), the upper branch flows not into the lower one, as usual, but into the upper pulmonary vein, “crossing” its back wall near the point of confluence of the latter into the left atrium. The right lower pulmonary vein in these cases is a direct continuation of the common main vein and flows into the left atrium in the area of its right lower lateral corner.

The length of the right lower pulmonary vein at this stage of development is 3.0 ± 0.09 mm, the diameter is 3.19 ± 0.08 mm; upper branch – 3.88 ± 0.2 mm and 2.07 ± 0.13 mm, respectively; the common main vein – 3.82 ± 0.16 mm and 3.09 ± 0.87 mm, respectively. The diameter of the intersegmental veins is 2.07 ± 0.11 mm.

The left upper pulmonary vein collects blood from the lobe of the lung of the same name and is formed as a result of the fusion of three (50%), two (25%), and sometimes four (5.8%) of venous trunks.

The length of the left superior pulmonary vein is 4.77 ± 0.21 mm, and its diameter is 3.07 ± 0.12 mm. In the first case, it is formed by apical-posterior, anterior and lingual branches, in the second – by apical-posterior and lingual branches, in the third – by apico-posterior and anterior branches.

The length of the apical-posterior branch is 2.41 ± 0.17 mm, the diameter is 2.0 ± 0.2 mm, the lingual branch is 3.72 ± 0.26 mm and 1.69 ± 0.14 mm, respectively. The diameter of the intersegmental ducts of the above-mentioned veins is 1.71 ± 0.08 mm and 1.39 ± 0.12 mm. Their passage and relation to the bronchial and arterial branches are the same as in fetuses of the previously described age groups.

The lower pulmonary vein collects blood from the lobe of the lung of the same name. Its length is 3.88 ± 0.11 mm, its diameter is 3.17 ± 0.14 mm, and in most cases this vein is formed as a result of the fusion of two veins (upper branch and common main vein). The principle of formation, pas-

sage and topography of veins are similar to those of fetuses of 6-7 months of prenatal development [17-18].

The length of the upper branch is 2.92 ± 0.04 mm, the diameter is 1.91 ± 0.07 mm, the common main vein is 4.22 ± 0.16 mm and 2.35 ± 0.13 mm, respectively.

In three fetuses (12.0%), the left lower pulmonary vein as a separate trunk is almost absent, because the trunks that form it merge with each other near the wall of the atrium, opening into its cavity through one common mouth (Fig. 4).

DISCUSSION

Scientific works that would discuss the development and formation of the lower vena cava and pulmonary veins during the eighth month of prenatal embryogenesis are not found. Ji Hyun Kim¹ (2014) emphasizes that the variants of formation of the topography of the lower vena cava do not always depend on the period of development, but partly on the individual differences [18]. Blom N.A. (2001) indicates that the common pulmonary vein develops in segments of the venous sinus, and later – between the venous sinus in the right atrium [19]. Some authors confirm such a formation of pulmonary veins [20].

According to the results of our research, it was established that the eighth month of the fetus ontogenesis of a person is characterized by a change in the morphometric indicators of veins, both in thoracic and also abdominal cavities. During this period, the length, diameter, and angle of formation of the inferior vena cava relatively increase in the diaphragmatic and intrapericardial sections. A gradual distance of the lower vena cava from the lower pole of the right is observed. In fetuses of this age group, this vein partially borders the adrenal gland from the medial edge and the descending part of the duodenum. The length of the hepatic section of the inferior vena cava increases significantly. The ductus venosus is gradually excluded from the circulatory system.

Two pulmonary veins from each lung flow into the left atrium in all fetuses of this age group. At the same time, they lie completely in the cavity of the heart. Changes in morphometric parameters are characterized by some increase in both the length and diameter of the pulmonary veins, but not as pronounced as in the inferior vena cava. In the wall of the veins, all three membranes are almost completely formed, which in terms of histological structure are close to the definitive ones.

CONCLUSIONS

During the eighth month of the fetal period of human ontogenesis, the inferior vena cava and its tributaries undergo significant changes that lead to the formation of its final state. This concerns the level and indicators of the angle of formation of the inferior vena cava, its length and diameter. The passage and branching of the bronchial tree and arterial branches (starting with the segmental branches) are almost completely identical. Veins and their branches lie more superficially and do not repeat the passage of

the corresponding bronchi and arteries, lying, as a rule, within the limits of intersegmental, intersegmental, and intersubsegmental connective tissue membrane.

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