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Research Article
Published: 11 Feb, 2019

Journal of Anatomy Forecast

Structural Features of the Branches of the Pulmonary Arteries of the Fetus

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Abstract

The lungs of 17 fetuses from 29–32 weeks of gestation (late fetal period) were studied. For the first time, the formation of additional muscle structures in the intraorgan branches of the pulmonary arteries under conditions of a non-functioning small circle of blood circulation has been established. Adaptive formations are represented by longitudinally oriented smooth myocytes of the inner lining, which form muscle sphincters and intimate muscles.

Regulatory complexes are localized in the arteries of the muscular-elastic and muscular type, as a rule, in the area of blood flow dividers. These elements are genetically determined formations that provide after the birth of a child and the beginning of active blood flow to the lungs, adequate hemodynamics and organ activity.

Keywords: Intraorgan pulmonary arteries; Regulatory structures; Human fetal period

Abbreviations

PA: Pulmonary Artery; SM: Smooth Myocytes; MES: Muscular-Elastic Sphincters; IM: Intimate Musculature; MSU: Moscow State University; MOS: Micrometer Ocular Screw

Introduction

The study of patterns of intraorganic hemodynamics in human antenatal ontogenesis is one of the urgent problems of modern morphology and pathomorphology [1,2]. It should be borne in mind that the lungs have only their inherent features of morphofunctional prenatal formation [3]. Anatomical feature is the vascularization of the organ from the pulmonary circulation of the pulmonary arteries (PA) and the large circle - branches of the bronchial arteries extending from the aorta [4], while the latter are constantly active from the beginning of their development [5]. In embryogenesis, the main volume of blood, bypassing the small circle, passes through the ducts of the duct and the oval hole in the left heart and the large circle, after the birth of a child with the first breath, the PA branches begin to play a major role in the blood supply to the lungs [4,5]. For neonatologists, morphological criteria for the readiness of organs, in particular, lungs for birth and release of the fetus into the new environment, are important; pathologists obtain important information on the structure of organs, which is necessary for analyzing the causes of fetal death [1]. In the available literature, information about adaptation formations in the wall of the intraorgan branches of the PA in the prenatal development of man is scarce and contradictory.

The purpose of the work is to identify and establish patterns of localization and structural features of the tunica intima regulatory structures of the intraorganic pulmonary arteries in the late fetal period of human development.

Materials and Methods

The lungs of 17 fetuses of both sexes were studied for 29–39 weeks of intrauterine development. The material was obtained from the maternity homes of Yaroslavl during pregnancy complicated by chronic placental insufficiency that caused antenatal fetal death. Pathomorphological study performed in the clinical hospital. NV Solovyov, Yaroslavl. Pieces of the organ were fixed in 10% neutral formalin or Carnoy fluid. Paraffin serial sections 4-5 microns thick were stained with hematoxylin-eosin, according to Van Gieson, Mason, Hart, Schiff reagent according to MacManus. The glycogen content in smooth myocytes (SM) of the arteries was analyzed on a MIF-K cytometer (MGU) at a wavelength of 518 nm. It was determined at what level of bronchial branching there

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Received Date: 04 Jan 2019
Accepted Date: 06 Feb 2019
Published Date: 11 Feb 2019

Citation: Gansburgsky AN, Yal'tsev AV. Structural Features of the Branches of the Pulmonary Arteries of the Fetus. J Anat Forecast. 2019; 2(1): 1006.

ISSN 2643-7090

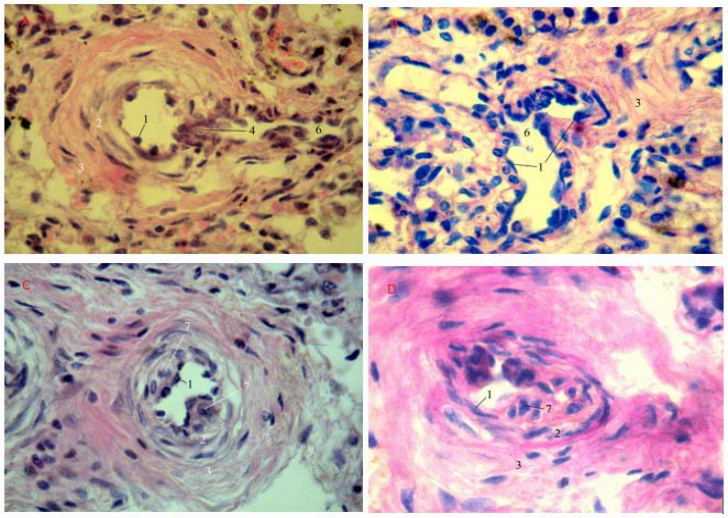

Figure 1: Adaptive structures of the tunica intima of the branches of the pulmonary arteries of the muscular type of the fetus (A: Muscular sphincter of the first and B types of the second type in the mouth of the outgoing side branch; C,D: The intimal muscles:
1: Inner; 2: Middle; 3: Outer shell; 4: Sphincter of the first type; 5: Sphincter of the second type; 6: Lateral branch; 7: Longitudinal bundles of SM in tunica intima. Stained with hematoxylin and eosin (A, B, C), CHIC reaction (D). About 40, ok.10.

are PAs that have additional smooth muscle structures in tunica intima. Screw eyepiece micrometer MOS -1-15x measured the inner and outer diameter, the thickness of the middle shell of the branches of the aircraft. Quantitative data were processed by the method of variation statistics. The significance of the differences was judged by the value of t Student criterion.

Research Results

Large intraorgan PA are arteries of a mixed muscular-elastic type more than 1 mm in diameter; tunica media, depending on the caliber, accounts for 8–17% of the internal cross section. Muscular small arteries have a size less than 1 mm, a narrow lumen, the average sheath is 12-35% of the outer diameter. In the order of branching of the bronchial tree, which is accompanied by branches of the aircraft, the muscular arteries correspond to the small bronchi, terminal and respiratory bronchioles.

Muscle-elastic sphincters (MES) are found predominantly in arterial vessels at the level of the middle (subsegmental) bronchi, the histological feature of which is the location of the elastic cartilage in the form of "struts" at the site of their branching. MEA are also found in vessels at the level of the small bronchi (Figure 1). The study of the spatial organization of MES in serial sections allowed us to identify two variants of the structure. The sphincters of the first type in cross section of the orifice of the outgoing arterial branches have the form of a closed smooth muscle ring in the inner shell, and in the longitudinal one they are two valves arranged at an angle to each other (Figure 1A). In the sub-endothelial layer of these areas of the vessels there are bundles of smooth myocytes (SM), surrounded by a network of elastic fibers (Figure 2). The sphincters of the second type represent the SM roller in tunica intima, partially covering the vessel and forming one valve in longitudinal section (Figure 1B). Separate intimal myocytes are enclosed in a weakly pronounced elastic framework. It should be noted that the sphincters of the first type are found in the arterial vessels at the level of the medium, and the second - are more common in the PA accompanying the small bronchi. As a rule, the place of localization of MEA is vascular branches.

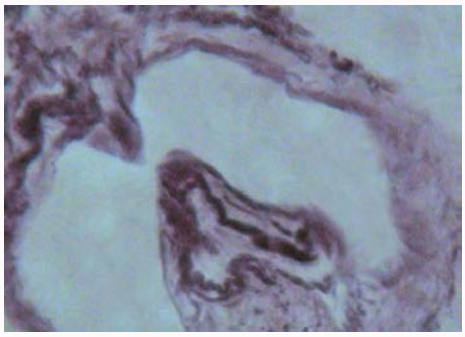

Figure 2: Elastic fibers in the sphincter of the pulmonary artery of the muscular type of the fetus. Fukselin coloring according to Hart. 40, ok.20.

Intimate smooth myocytes (intimal muscles - IM) are detected in PA only at the level of the small bronchi. In some cases, IM is represented by individual SMs located longitudinally and obliquely, and in others it forms bundles in tunica intima and has the form of rollers protruding into the vessel lumen (Figure 1C and 1D). In contrast to the localization of the muscular-elastic sphincters, myocardial infarction is more common outside the flow dividers in the arterial bed. A high concentration of glycogen is found in the SM intimal muscles (Figure 1d). A cytophotometric study showed an increase of 38% in the amount of glycogen in myocardial infarction t. intima, including sphincters ($P < 0.05$ relative to the level of glycogen in the GM medium shell).

Results and Discussion

It has been established that in the small circulation of blood of the lungs of the human fetus, the PA branch is characterized by a narrow lumen and relatively thick walls due to a significant development of the muscular layer. This is confirmed by a number of studies [3,6]. It is indicated [7] that in large PAs of adult animals (bulls, mice) the population of the SM tunica media is heterogeneous. In particular, the muscle cells of the middle membrane at the border with the inner one do not perceive typical SM markers and have low myofibrils density,

while smooth muscle α-actin is detected immunocytochemically at its outer edge.

The development of PA branches is affected by growth, exchange rate in the respiratory parenchyma, as well as hemodynamic factors and fetal respiratory movements [5,6]. The formation of intraorgan blood vessels - provides normal organ and histogenesis [6,8]. By the time of birth, all the structural components of the human lung are formed [3].

In the late fetal period, when the differentiation and maturation of the internal organs of the fetus was completed [1], in the non-functioning branches of PA, we found additional longitudinally oriented SM in the form of MES and IM. Such additional smooth muscle structures in tunica intima are commonly referred to as adaptive due to their ability to quickly correct blood flow in normal and pathological conditions [9]. Regulatory adaptive elements involved in changing the lumen of the arteries, are divided into three types: polypoid pillows, sphincters, intimate muscles [9]. In favor of the fact that myocardial infarction is predisposed to the active regulation of regional blood circulation, it is evidenced by the high concentration of glycogen in SM, which provides energy for muscle contraction, revealed in the work [10].

The study showed that the site of adaptation structures in the inner shell PA of the aircraft are blood flow dividers. This is consistent with materials indicating the presence of intimate pillows in the area of bifurcation of the arterial vessels of the cerebral brain in people of different ages [11]. Such zones of the vascular bed are of considerable interest to pathologists and clinicians, as they are characterized by increased permeability of the endothelium [12] and the maximum effects of the latter on SM [13]. In the analysis of intercellular communications, it should be borne in mind that the internal elastic membrane of the PA (rats and mice) has “coordination gaps” that allow for “bi-directional” signaling between endothelial cells and SM [7].

It is known that the prenatal development of mammals, including humans, proceeds in a hypoxic environment [1]. In the present observation, fetal hypoxia was aggravated by placental insufficiency (in the history of pregnant women). Early adaptive reactions to hypoxia simultaneously serve as a powerful stimulus for morphogenesis [1]. Hypoxia stimulates the proliferation and migration of SM [14] and, thus, initiates the formation and differentiation of adaptive smooth muscle complexes of intima.

Mechanisms that support heart balance during intrauterine life are completely adapted to rebalance the load on a different postnatal basis, without a sudden reload of the inactive parts of the vascular system [15]. One of the most striking phenomena in embryology is the complete readiness of the body to abruptly terminate the placental circulation and immediately take over the pulmonary cycle of the function of gas exchange.

Conclusion

Based on the conducted studies, it can be concluded that the muscle-elastic sphincters and intimal muscles identified in the non-functioning pulmonary arteries of the human fetus are genetically determined formations that are ready to actively influence the regional blood flow in the organ after the birth of a child.

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