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MORPHOMETRIC CHANGES AND ADAPTIVE PROCESSES IN RABBIT LUNG TISSUE FOLLOWING LEFT-SIDED PNEUMONECTOMY

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Abstract

Introduction. Left-sided pneumonectomy, a surgical intervention for treating severe lung conditions, requires significant bodily adaptation to maintain lung function. Understanding the adaptive processes based on morphometric studies of lung tissue can help develop new treatment and rehabilitation strategies to improve outcomes and quality of life for patients undergoing this surgery.

The aim. This study aims to analyze morphometric changes in lung tissue in rabbits following left-sided pneumonectomy using standard methods, and to explore the compensatory and adaptive processes occurring in the remaining lung tissue.

Materials and Methods. Thirty adult, mixed-breed rabbits of both sexes, weighing between 2 to 4 kg, were divided into two experimental series. Series I involved standard left-sided pneumonectomy on 10 rabbits, while Series II involved left-sided pneumonectomy with pre-arteriovenous shunting of the small circulation on 15 rabbits. A control thoracotomy was performed on 5 rabbits for comparison. Morphometric analysis of alveoli, capillaries, terminal arterioles, and precapillaries was conducted at various time points: 1, 3, 6, 12 hours, and 1, 3, 7, 15, and 30 days post-operation.

Results. Significant morphometric changes were observed in the alveoli, capillaries, terminal arterioles, and precapillaries of the remaining lung tissue. In the first hours after pneumonectomy, there was a notable increase in the true size of alveoli and specific alveolar area, indicating compensatory hyperinflation. Capillary diameter and cross-sectional area significantly increased within the first 12 hours post-surgery, suggesting compensatory vasodilation. Terminal arterioles exhibited increased outer radius, lumen radius, and vessel diameter, indicating active vasodilation and improved perfusion. Precapillary changes were most significant in the first hours and days, stabilizing by 30 days post-operation.

Conclusion. The study demonstrates that left-sided pneumonectomy in rabbits leads to significant morphometric changes in the remaining lung tissue, driven by compensatory and adaptive processes aimed at maintaining adequate ventilation and perfusion. These findings contribute to a better understanding of lung tissue adaptation mechanisms and may inform the development of new therapeutic and rehabilitative strategies for patients undergoing pneumonectomy.

Keywords: left-sided pneumonectomy, morphometric analysis, lung tissue adaptation, compensatory processes, rabbits, vascular remodeling

Introduction. Left-sided pneumonectomy is a significant surgical intervention used for treating various lung diseases, including cancer, severe infection, and trauma. This type of

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surgery involves the removal of a substantial portion of lung tissue, necessitating the body's adaptation to a new functional state. To ensure adequate gas exchange and blood supply, the remaining lung tissue must undergo numerous morphological and functional changes (Fehrenbach et al., 2008, Konerding et al., 2012). Studying these adaptive processes is crucial for understanding compensation mechanisms and developing new treatment and rehabilitation methods for patients after pneumonectomy.

After pneumonectomy, the body must compensate for the loss of lung tissue volume, leading to hypertrophy and hyperplasia of alveoli, remodeling of capillaries and arterioles, and improvement of microcirculation. These processes help maintain normal respiratory function and adequate gas exchange. In particular, the increase in alveolar volume and surface area enhances gas exchange efficiency (Mentzer S.J., 2018). These changes are accompanied by the adaptation of the capillary network, including an increase in capillary diameter and blood flow, which ensures improved oxygen delivery and carbon dioxide removal (Ackermann et al., 2014).

Vascular remodeling after pneumonectomy plays a key role in the adaptation of lung tissue. The increase in the medial thickness of arterioles and precapillaries, as well as the improvement in their reactivity to vasoactive substances, indicate significant changes in the structure and function of vessels aimed at maintaining adequate perfusion of lung tissue (Eldridge and Wagner, 2019; Ciurea and Gil, 1996). These changes are necessary to ensure adequate blood supply and prevent hypoxia in the remaining lung tissue.

Numerous studies conducted on various animal models confirm the presence of significant morphometric changes in lung tissue after pneumonectomy. For example, studies on mice and rats have shown that after partial lung removal, compensatory hyperinflation and restructuring of the remaining tissue occur to maintain normal respiratory function (Voswinckel et al., 2004; Katz et al., 2019). These adaptive processes include increased alveolar volume, improved microcirculation, and increased blood flow in the remaining lung tissue.

Moreover, studies indicate that inflammation plays an important role in adaptive processes after pneumonectomy. An increase in the number of alveolar macrophages and the expression of vascular growth factors, such as VEGF (vascular endothelial growth factor), suggests the involvement of inflammatory processes in lung tissue remodeling (Takeda et al., 1999; Matsui et al., 2015). These processes contribute to the restoration of lung tissue structure and function, ensuring adequate ventilation and perfusion.

Despite the significant volume of research conducted on various animal models, data on the morphometric changes of alveoli, capillaries, arterioles, and precapillaries in rabbits after left-sided pneumonectomy remain limited. Rabbits are an important model for studying these processes due to their lung anatomy and physiology being similar to humans. The aim of this study is to analyze morphometric changes in lung tissue in rabbits after left-sided pneumonectomy using standard methods, as well as to study compensatory and adaptive processes occurring in the remaining lung.

In this study, we aim to expand the understanding of lung tissue adaptation mechanisms after pneumonectomy, which may contribute to the development of new therapeutic approaches to improve treatment outcomes for patients with lung diseases. Additionally, the results of our study may be useful for developing new methods of rehabilitation and recovery of lung function after surgery. We also hope that our data will help develop new strategies for managing complications associated with pneumonectomy and improve patients' quality of life.

Materials and methods

Thirty adult, mixed-breed rabbits of both sexes, weighing between 2 to 4 kg, were selected for this study. The experimental work was divided into two series, including a control thoracotomy on 5 animals for comparison with the experimental animals. The general characteristics of the conducted experiments are presented in Table 1.

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Table 1. Characteristics of Conducted Experiments

Experiment Type	Series	Operated Animals (number)
Control thoracotomy	-	5
Left-sided pneumonectomy using standard method	I	10
Left-sided pneumonectomy with pre-arteriovenous shunting of the small circulation	II	15
Total	-	30

Anesthesia and Surgical Techniques

Standard Left-sided Pneumonectomy

In series I, standard left-sided pneumonectomy was performed on 10 rabbits. In series II, left-sided pneumonectomy with pre-arteriovenous shunting of the small circulation was performed on 15 rabbits. The animals were observed for 1, 3, 6, 12 hours, and 1, 3, 7, 15, and 30 days post-operation.

For the surgeries, the following methods of anesthesia and surgical techniques were used. Premedication was administered subcutaneously with 0.1% atropine sulfate at a dose of 0.01 mg/kg and intravenously with droperidol at 1 mg/kg body weight, 15-20 minutes before the operation. Induction anesthesia was achieved by intravenous administration of ketamine at 15 mg/kg body weight, and basic anesthesia was maintained with hexobarbital (or thiopental sodium) intravenously at 14 mg/kg body weight. After intubation, the animals were transferred to mechanical ventilation using a respiratory apparatus.

The standard left-sided pneumonectomy was performed through a posterolateral approach at the 7th-8th intercostal space on the left, with an incision length of 7-8 cm. The wound edges were separated using a Mikulicz retractor. After thoracotomy, 7-10 ml of 0.5% novocaine solution was injected subpleurally into the lung root for blocking the perihilar nerve plexuses. The pulmonary ligament was ligated and cut closer to the lung tissue. All lobes of the left lung were mobilized externally.

The elements of the lung root were separated individually, starting with the ligation and subsequent suturing of the left pulmonary artery trunk, followed by the identification of the pulmonary veins (upper, lower, and posterior cardiac lobes). Bronchial arteries, numbering 2 to 5, were ligated at the lung root. The main bronchus trunk was sutured with 2-3 silk ligatures, and the left lung was removed as a single specimen. After thorough hemostasis, pleurization of the lung root stump, 1.5 million units of penicillin were introduced into the pleural cavity. The ribs were approximated using catgut sutures through the intercostal spaces. The thoracic cavity was sutured in layers to achieve airtight closure, and air was aspirated from the pleural cavity using an injection needle.

Left-sided Pneumonectomy with Pre-arteriovenous Shunting

The model of the arteriovenous shunt for left-sided pneumonectomy was developed by V.V. Morozova, A.Kh. Kainazarov, and Y.A. Almabaev in an experiment (patent No. 78 from 03.01.78). In pneumonectomy with pre-arteriovenous shunting, anesthesia and incision procedures were similar to those used for standard left-sided pneumonectomy. However, the subsequent course of the operation had significant differences. The previously isolated vessels (artery and vein of the lower lobe of the left lung) were dissected from the surrounding lung parenchyma for 4-5 cm, with ligation of the side branches of the artery and vein. The isolated vessels closer to the lung parenchyma were clamped and cut.

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The prepared vessels were rinsed with warm saline containing an anticoagulant (heparin). An anastomosis was then created between the proximal end of the artery and the distal end of the vein using a vascular suturing apparatus ASC-80. After removing the vascular suturing apparatus, the anastomosis was checked for tightness and patency, and the outer diameter of the anastomosis was measured. With the functioning shunt, the lower lobe, constituting 27% of the total lung parenchyma, was removed. The bronchus of the lower lobe was sutured with a thick ligature and tied on both sides. The remaining lobes of the left lung were removed with individual handling of the root elements of each lobe, as in standard pneumonectomy. The thoracic cavity was sutured airtight, and air was aspirated from the pleural cavity.

Observations

During the observation period, the respiratory rate (RR) and heart rate (HR) of the animals were determined. The animals were euthanized at the observation time points according to the "Rules for Conducting Work with the Use of Experimental Animals," approved by the Ministry of Health of the USSR Order No. 755 from 12.08.1977. The euthanasia of anesthetized animals was performed by the intravenous administration of 10-15 ml of 25% potassium chloride solution and 2% hexobarbital solution.

The object of the study was the remaining lung. After re-thoracotomy, the macroscopic condition of the remaining lung and the entire thoracic cavity organs was examined. For histological examination, lung parenchyma samples of 2x3 cm size were cut out. The fixation was performed in 10% neutral formalin for 24 hours. Subsequently, the lung parenchyma samples were dehydrated in ethanol solutions of increasing concentrations and embedded in paraffin. Histological sections 5-7 μm thick were stained using standard methods: hematoxylin-eosin and picrofuchsin according to Van Gieson. Van Gieson staining was necessary to distinguish smooth muscle tissue from connective tissue.

Morphometric and Stereological Methods

The study is based on morphometric methods described by several authors. Using an ocular micrometer, morphometry was performed on arterioles, terminal bronchioles, precapillaries, capillaries, postcapillaries, and venules. Vessels were measured on sections taken in three mutually perpendicular planes. At magnifications of 280 and 630 times, the outer radius of the vessels (Ro), the radius of the lumen (Rnp), the diameter of the vessels (d), the thickness of the media (t), and the cross-sectional area of the middle vessel layer (S) were determined. To assess the functional state of arterioles and venules, the Kerogan index, the ratio of media thickness (t) to vessel diameter (d), was calculated, which allows differentiating dynamic changes in vessel tone from structural remodeling.

The cross-sectional area of the media was determined using the formula:

$$S = \frac{3t}{4}(ab - a1b1)$$

where:

t is a constant equal to 3.14;
a is the long diameter of the outer vessel contour;
b is the short diameter of the outer vessel contour;
a1 is the long diameter of the lumen axis;
b1 is the short diameter of the lumen axis.

The Kerogan index was calculated using the formula:

$$\text{ИК} = \frac{m}{d}$$

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where:
t is the thickness of the muscle wall (media),
d is the vessel diameter.

When analyzing capillaries, the following parameters were considered: the number of capillaries per 0.1 mm of the alveolar septum, the average capillary diameter (d), and the cross-sectional area of the capillary bed per 0.1 mm of the alveolar septum. The cross-sectional area of the capillaries was determined using the formula:

$$S = \frac{\pi D^2}{4} = \pi r^2$$

where:
π\piπ is a constant equal to 3.14,
D is the vessel diameter,
r is the vessel radius.

To obtain the true average size of the alveolus in the prepared state, the following formula was used:

True alveolar size=(A+r)×1.2

where:
A is the depth of the alveolus,
r is the radius of the alveolus,
1.2 is the shrinkage correction factor due to lung fixation.

Using stereological methods, the volume-structural relationships of various lung tissues were studied. Particular attention was paid to studying the air content in the remaining lung after surgery. On preparations for studying the air content in the remaining lung, a calibrated square-grid Autandilov mesh with 100 points was used to determine the specific area of the alveoli (S) and the width of the entrance (R) into the respiratory alveolus.

Statistical Methods

The obtained numerical data were processed using the Fisher-Student variation statistical method, calculating the arithmetic mean (M), the mean error (t), the standard deviation (σ), and the Student's t-test criterion (t). Differences were considered significant at p<0.05p < 0.05p<0.05.

Results

Morphometric Characteristics of Alveoli in Left-sided Pneumonectomy Using the Standard Method:

During the study, the morphometric characteristics of lung alveoli in rabbits subjected to standard left-sided pneumonectomy were analyzed. Changes in the true size of the alveolus, specific area of the alveolus, and the width of the entrance to the respiratory alveolus depending on the study period are presented in Table 2.

Table 2. Morphometric Characteristics of Alveoli in Left-sided Pneumonectomy Using the Standard Method

Study Period	**True Alveolar Size, mm²**	**Specific Alveolar Area (S), µm²**	**Width of the Entrance to the Respiratory Alveolus (R), mm**
Control	0.057±0.004	0.40±0.01	0.013±0.001
1 hour	0.096±0.003*	0.76±0.05*	0.051±0.004*

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3 hours	0.080±0.088*	1.28±0.02*	0.048±0.008*
6 hours	0.136±0.097*	1.54±0.05*	0.053±0.006*
12 hours	0.118±0.065*	0.83±0.06*	0.039±0.003*
1 day	0.185±0.036*	1.90±0.04*	0.057±0.001*
3 days	0.138±0.067*	1.28±0.06*	0.054±0.005*
7 days	0.131±0.077*	1.59±0.05*	0.050±0.003*
15 days	0.119±0.058*	0.83±0.06*	0.042±0.006*
30 days	0.125±0.035*	1.06±0.01*	0.050±0.004*

significant differences at p<0.05p < 0.05p<0.05

As seen from Table 2, animals subjected to pneumonectomy exhibit significant changes in the morphometric characteristics of the alveoli. The most significant changes occur within the first day after surgery, followed by stabilization of the indicators at later stages.

Morphometric Characteristics of Lung Capillaries in Left-sided Pneumonectomy Using the Standard Method:

The changes in the morphometric characteristics of lung capillaries in rabbits after standard left-sided pneumonectomy were studied. The results are presented in Table 3.

Table 3. Morphometric Characteristics of Lung Capillaries in Left-sided Pneumonectomy Using the Standard Method

Study Period	**Number of Capillaries per 0.1 mm of the Alveolar Septum, cap/mm**	**Average Capillary Diameter (d), µm**	**Capillary Cross-sectional Area (S) per 0.1 mm of the Alveolar Septum, µm²**
Control	12.33±0.41	4.60±0.06	16.61±0.06
1 hour	11.30±0.65	4.52±0.32	16.04±0.05
3 hours	8.50±0.36	4.62±0.75	17.31±0.07
6 hours	9.70±0.13	6.50±0.51*	24.75±0.02*
12 hours	13.57±0.23*	7.57±0.43*	44.98±0.05*
1 day	8.25±0.49	4.52±0.32	13.32±0.04
3 days	9.08±0.82	4.67±0.35	22.89±0.01*
7 days	10.36±0.05	5.30±0.61	25.32±0.07*
15 days	13.34±0.26*	5.68±0.22*	22.05±0.03*
30 days	12.30±0.71	5.06±0.10*	20.09±0.06

significant differences at p<0.05p < 0.05p<0.05

The results of the morphometric analysis of capillaries show significant changes in the average diameter and cross-sectional area of capillaries within the first 12 hours after surgery, indicating the capillary network's response to surgical intervention and adaptive processes in the lung tissue.

Morphometric Characteristics of Terminal Arterioles in Left-sided Pneumonectomy Using the Standard Method:

The changes in the morphometric characteristics of terminal arterioles in rabbits after standard left-sided pneumonectomy were studied. The results are presented in Table 4.

Table 4. Morphometric Characteristics of Terminal Arterioles in Left-sided Pneumonectomy Using the Standard Method

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Study Period	Outer Radius (RO), µm	Lumen Radius (Rnp), µm	Vessel Diameter (d), µm	Media Thickness (m), µm	Cross-sectional Area of the Muscle Layer (S), µm²	Kerogan Index (IK)
Control	40.3±0.85	31.55±0.76	41.82±0.32	32.10±0.97	396.50±1.25	0.056
1 hour	22.65±0.13	19.11±0.29	45.36±9.71	4.93±0.03*	534.78±2.21*	0.108
3 hours	29.11±0.71	25.68±0.12*	47.85±10.12	5.71±0.01*	667.10±5.04*	0.218
6 hours	50.87±0.21*	31.75±0.39	65.53±7.30	5.95±0.06*	1134.68±7.15*	0.098
12 hours	58.75±0.40*	38.38±0.01	76.77±5.90	5.20±0.07*	888.95±3.96*	0.090
1 day	69.37±0.84*	42.20±0.95	84.45±7.03	7.03±0.12*	2097.93±5.25*	0.083
3 days	64.54±0.49*	45.63±0.55*	99.37±3.41	6.65±0.32*	1366.30±5.41*	0.066
7 days	55.38±0.73*	39.67±0.62*	87.75±4.45	4.00±0.46	891.46±6.75*	0.045
15 days	52.75±0.76*	35.38±0.43*	61.55±3.22	5.03±0.39*	909.95±8.78*	0.081
30 days	52.75±0.76*	39.63±0.71*	79.25±7.15	5.25±0.03*	923.20±4.71*	0.066

significant differences at p<0.05p < 0.05p<0.05

Morphometric changes in terminal arterioles also demonstrate significant changes within the first day after surgery, indicating vascular remodeling and adaptation to conditions of reduced lung tissue volume.

Morphometric Characteristics of Precapillaries in Left-sided Pneumonectomy Using the Standard Method

The changes in the morphometric characteristics of lung precapillaries in rabbits after standard left-sided pneumonectomy were studied. The results are presented in Table 5.

Table 5. Morphometric Characteristics of Precapillaries in Left-sided Pneumonectomy Using the Standard Method

Study Period	Outer Radius (RO), µm	Lumen Radius (Rnp), µm	Vessel Diameter (d), µm	Cross-sectional Area (S), µm²
Control	21.31±0.61	17.48±0.42	34.96±1.02	101.71±1.07
1 hour	22.18±0.73	19.40±0.56*	38.81±0.83*	140.38±1.21*
3 hours	22.35±0.55	20.42±0.54*	40.85±1.15*	157.72±2.10*
6 hours	18.62±0.44	14.02±0.84	28.04±1.52	117.82±0.99
12 hours	28.82±0.19*	24.06±0.11*	48.15±0.97*	185.75±2.12*
1 day	25.61±0.46*	21.06±0.72*	42.31±1.15*	168.81±1.15*
3 days	22.30±0.67	18.27±0.71	36.53±1.74	130.48±1.25

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7 days	30.88±0.20*	25.78±0.23*	51.56±1.07*	224.65±4.41*
15 days	22.33±0.82	18.47±0.55	36.94±1.11	134.66±3.82
30 days	24.97±0.12*	21.99±0.11*	43.98±0.19*	177.00±1.01*

significant differences at $p<0.05$p

Morphometric analysis of precapillaries shows that the most significant changes occur within the first hours and days after surgery, with subsequent normalization or near-normal values by 30 days. This also indicates adaptive processes of lung tissue to new conditions.

Discussion

Morphometric Changes in Alveoli

Our study results show that significant morphometric changes occur in the alveoli of the remaining lung in rabbits after standard left-sided pneumonectomy. In the first hours after surgery, there is a significant increase in the true size of the alveolus and the specific area of the alveolus, which may indicate compensatory hyperinflation of the remaining lung tissue. This is explained by the body's need to compensate for the loss of lung tissue volume by increasing the volume of the remaining alveoli, leading to improved ventilation-perfusion characteristics.

Our results are consistent with other studies showing that the removal of part of the lung leads to compensatory hyperinflation and restructuring of the remaining tissue to maintain normal respiratory function. For example, studies by Hsia and Johnson (2015) and Brown et al. (2001) also demonstrated an increase in alveolar volume and improved ventilation of the remaining lung tissue after pneumonectomy.

The study by Chamoto et al. (2012) demonstrated that after pneumonectomy in rats, there is an increase in the number of alveolar macrophages, indicating an active role of inflammation in the adaptive processes of lung tissue. Similar results were obtained in studies by Ysasi et al. (2015), which showed that inflammation and remodeling of lung tissue are key mechanisms of compensation after partial pneumonectomy.

Morphometric Changes in Capillaries

Analysis of changes in the capillary network of the lung shows that after left-sided pneumonectomy, there is a significant increase in the average diameter of capillaries and their cross-sectional area. This may be related to compensatory vasodilation of the capillaries in the remaining lung to ensure adequate blood supply and gas exchange under conditions of reduced lung tissue volume. These changes are particularly noticeable in the first 12 hours after surgery, indicating an acute phase of adaptive reactions in the lung's vascular system.

Our study results confirm data obtained by other authors. In studies by Hsia et al. (2006) and Tsikis et al. (2023), an increase in capillary diameter and improved blood flow in the remaining lung tissue after partial pneumonectomy were also noted. These changes are related to the need to maintain adequate gas exchange and adapt the vascular network to new conditions.

Studies by Mammoto et al. (2019) and Sakurai et al. (2007) showed that increased capillary diameter and enhanced capillary blood flow are important mechanisms of compensation after pneumonectomy. These studies also demonstrated that adaptive changes in the capillary network are accompanied by endothelial cell activation and increased expression of vascular growth factors, such as VEGF (vascular endothelial growth factor).

By 30 days after surgery, the parameters of the capillary network also approximate control values, indicating the completion of adaptive processes and stabilization of hemodynamic conditions in the remaining lung.

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Morphometric Changes in Terminal Arterioles

Changes in the terminal arterioles of the lung also demonstrate significant adaptive reactions. The increase in the outer radius, lumen radius, and vessel diameter in the first day after surgery indicates an active phase of vasodilation aimed at improving perfusion of the remaining lung tissue. These changes are accompanied by an increase in media thickness and cross-sectional area of the muscle layer, which may be a response to increased mechanical load on the vessels of the remaining lung.

By 30 days after surgery, the parameters of arterioles also stabilize, indicating the completion of adaptive processes in the lung's vascular system under new conditions. Our results correlate with studies on other animal models, where similar changes in arterioles were observed after partial pneumonectomy.

The results of the study by Gibney et al. (2012) demonstrate that adaptive changes in arterioles after pneumonectomy include not only structural changes but also functional adjustments aimed at improving the response of vessels to mechanical and chemical stimuli. This is confirmed by the increase in media thickness and improved reactivity of arterioles to vasoactive substances.

Morphometric Changes in Precapillaries

Analysis of precapillaries shows that the most significant changes occur in the first hours and days after surgery. The increase in the outer radius, lumen radius, and vessel diameter indicates an active phase of adaptive processes aimed at improving microcirculation and gas exchange in the remaining lung tissue. These changes are particularly pronounced in the first 12 hours after surgery, confirming the acute phase of adaptive reactions.

By 30 days after surgery, the parameters of precapillaries stabilize, indicating the completion of adaptive processes and restoration of normal hemodynamic conditions in the remaining lung.

The study by West et al. (2013) showed that precapillaries play a key role in adapting microcirculation after pneumonectomy, ensuring adequate blood flow and gas exchange in the remaining lung tissue. This is confirmed by the increase in the diameter and cross-sectional area of precapillaries, which contributes to improved microcirculation.

Conclusion. The obtained results indicate significant morphometric changes in alveoli, capillaries, terminal arterioles, and precapillaries of the remaining lung in rabbits after left-sided pneumonectomy. These changes are related to compensatory and adaptive processes aimed at ensuring adequate ventilation and perfusion under conditions of reduced lung tissue volume. Stabilization of morphometric parameters by 30 days after surgery indicates the completion of adaptive processes and the restoration of functional activity in the remaining lung.

Conflict of interest

We declare no conflict of interest**.**

Authors' contribution

Development of the concept, processing of results, interpretation of the results, writing the article is equally done by all authors. We declare that this material has not been previously published and is not under consideration by other publishers.

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СОЛ ЖАҚТЫҚ ПНЕВМОНЭКТОМИЯДАН КЕЙІН ҚОЯН ӨКПЕ ТІНІНДЕГІ МОРФОМЕТРИЯЛЫҚ ӨЗГЕРІСТЕР МЕН БЕЙІМДЕЛУ ПРОЦЕСТЕРІ

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Түйіндеме

Кіріспе. Сол жақ пневмонэктомия - өкпенің ауыр ауруларын емдеуге арналған хирургиялық араласу, ол өкпе функциясын сақтау үшін ағзаның едәуір бейімделуін талап етеді. Өкпе тінін морфометриялық зерттеуге негізделген бейімделу процестерін түсіну, бұл операциядан өткен науқастардың нәтижелері мен өмір сүру сапасын жақсарту үшін жаңа емдеу және оңалту стратегияларын әзірлеуге көмектеседі.

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Мақсаты. Стандартты әдістерді қолдана отырып, кроликтердің өкпе тініндегі морфометриялық өзгерістерді талдау, сондай-ақ қалған өкпе тінінде жүретін компенсаторлық және бейімделу процестерін зерттеу.

Материалдар мен әдістер. Салмағы 2-ден 4 кг-ға дейінгі аралас тұқымды 30 ересек кролик екі эксперименттік серияға бөлінді. I сериясында 10 кроликке стандартты сол жақ пневмонэктомия жасалды, ал II сериясында 15 кроликке шағын қанайналым шеңберінің алдын ала артериовеноздық шунттауымен сол жақ пневмонэктомия жасалды. Салыстыру үшін 5 кроликке бақылау торакотомиясы жасалды. Альвеолалар, капиллярлар, терминалдық артериолалар мен прекапиллярларға морфометриялық талдау әртүрлі уақыт нүктелерінде: операциядан кейін 1, 3, 6, 12 сағат, сондай-ақ 1, 3, 7, 15 және 30 күн өткенде жүргізілді.

Нәтижелер. Альвеолаларда, капиллярларда, терминалдық артериолалар мен прекапиллярларда елеулі морфометриялық өзгерістер анықталды. Пневмонэктомиядан кейінгі алғашқы сағаттарда альвеолалардың нақты өлшемі мен белгілі альвеолярлық алаңының айтарлықтай ұлғаюы байқалды, бұл компенсаторлық гиперинфляцияны көрсетеді. Операциядан кейінгі алғашқы 12 сағат ішінде капиллярлардың диаметрі мен көлденең қимасы айтарлықтай ұлғайып, компенсаторлық вазодилатацияны көрсетеді. Терминалдық артериолалар сыртқы радиустың, люмен радиусының және тамыр диаметрінің ұлғаюын көрсетті, бұл белсенді вазодилатацияны және перфузияның жақсаруын көрсетеді. Прекапиллярлардағы өзгерістер алғашқы сағаттар мен күндерде ең маңызды болды, 30-шы күнге қарай тұрақтанды.

Қорытынды. Зерттеу көрсеткендей, кроликтерге сол жақ пневмонэктомия өкпе тініндегі айтарлықтай морфометриялық өзгерістерге әкеледі, бұл адекватты вентиляция мен перфузияны сақтау мақсатында компенсаторлық және бейімделу процестерімен байланысты. Бұл тұжырымдар өкпе тінінің бейімделу механизмдерін жақсырақ түсінуге ықпал етеді және пневмонэктомиядан өткен науқастарға арналған жаңа терапиялық және оңалту стратегияларын әзірлеуге негіз бола алады.

Түйінді сөздер: сол жақ пневмонэктомия, морфометриялық талдау, өкпе тінінің бейімделуі, компенсаторлық процестер, кроликтер, тамырларды қайта қалыптастыру.

МОРФОМЕТРИЧЕСКИЕ ИЗМЕНЕНИЯ И АДАПТАЦИОННЫЕ ПРОЦЕССЫ В ЛЕГОЧНОЙ ТКАНИ КРОЛИКА ПОСЛЕ ЛЕВОСТОРОННЕЙ ПНЕВМОНЭКТОМИИ

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Аннотация

Введение.

Левосторонняя пневмонэктомия – хирургическое вмешательство для лечения тяжелых заболеваний легких, требующее значительной адаптации организма для поддержания функции легких. Понимание адаптивных процессов, основанное на морфометрическом изучении ткани легких, может помочь разработать новые стратегии лечения и реабилитации для улучшения результатов и качества жизни пациентов, проходящих через эту операцию.

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Цель. Анализ морфометрических изменений в ткани легких у кроликов после левосторонней пневмонэктомии с использованием стандартных методов, а также в исследовании компенсаторных и адаптивных процессов, происходящих в оставшейся ткани легких.

Материалы и методы. Тридцать взрослых кроликов смешанных пород обоих полов, весом от 2 до 4 кг, были разделены на две экспериментальные серии. В серии I была проведена стандартная левосторонняя пневмонэктомия у 10 кроликов, в то время как в серии II была проведена левосторонняя пневмонэктомия с предварительным артериовенозным шунтированием малого круга кровообращения у 15 кроликов. Для сравнения была проведена контрольная торакотомия у 5 кроликов. Морфометрический анализ альвеол, капилляров, терминальных артериол и прекапилляров проводился в различные временные точки: 1, 3, 6, 12 часов, а также 1, 3, 7, 15 и 30 дней после операции.

Результаты. Значительные морфометрические изменения были обнаружены в альвеолах, капиллярах, терминальных артериолах и прекапиллярах оставшейся ткани легких. В первые часы после пневмонэктомии наблюдалось заметное увеличение истинного размера альвеол и специфической альвеолярной площади, что указывает на компенсаторную гиперинфляцию. Диаметр капилляров и их поперечное сечение значительно увеличивались в первые 12 часов после операции, что свидетельствует о компенсаторной вазодилатации. Терминальные артериолы демонстрировали увеличение внешнего радиуса, радиуса просвета и диаметра сосудов, что указывает на активную вазодилатацию и улучшение перфузии. Изменения в прекапиллярах были наиболее значительными в первые часы и дни, стабилизируясь к 30 дню после операции.

Заключение. Исследование показывает, что левосторонняя пневмонэктомия у кроликов приводит к значительным морфометрическим изменениям в оставшейся ткани легких, обусловленным компенсаторными и адаптивными процессами, направленными на поддержание адекватной вентиляции и перфузии. Эти выводы способствуют лучшему пониманию механизмов адаптации ткани легких и могут информировать разработку новых терапевтических и реабилитационных стратегий для пациентов, перенесших пневмонэктомию.

Ключевые слова: левосторонняя пневмонэктомия, морфометрический анализ, адаптация ткани легких, компенсаторные процессы, кролики, сосудистое ремоделирование.