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ОРИГИНАЛЬНОЕ ИССЛЕДОВАНИЕ
ORIGINAL RESEARCH

Respiratory therapy with positive expiratory pressure in patients after left ventricle geometric reconstruction

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Abstract. *Relevance*. The respiratory system of patients with post-infarction left ventricle aneurysm and chronic heart failure is often characterized by decreased external respiratory function and the development of respiratory complications in the early postoperative period. Positive expiratory pressure therapy (PEP-therapy) is considered an effective method of respiratory rehabilitation after cardiac surgery. However, there is currently no data on the application of this technique in patients after LVGR (left ventricle geometric reconstruction). *The aim*: to study the functional state of the respiratory system in patients after LVGR in the early postoperative period using PEP-therapy. *Materials and Methods*. 57 patients after LVGR surgery were examined. Two groups of patients were identified: group I — patients undergoing PEP-therapy (n = 27), and group II — patients undergoing standard respiratory gymnastics (n = 30, control group). The study included 3 stages: I Stage — before surgery; II Stage — 2–3 days after surgery; III Stage — 10–12 days after surgery. *Results and Discussion*. At the preoperative stage, cardiorespiratory system disorders were found in groups I and II (FVC: 89.2% and 87.3%; EDV: 174.2 ml and 179.9 ml, respectively), as well as the risk of developing sleep-disordered breathing (Oxygen desaturation index [ODI]: 7.1 and 6.7, respectively). On the second day after surgery, a significant decrease in all spirometry indicators was observed in both groups, with the ODI in groups I and II increasing by 2.9 ($p < 0.001$) and 3.1 ($p < 0.001$) times, respectively. Chest CT revealed atelectasis in various parts of the lungs in 100% of the examined patients. Upon discharge from the hospital, group I after PEP-therapy showed better recovery of respiratory parameters compared to the control group (FEV_1: 22.1% vs 9.4%; PEF: 58.1% vs 19.5%, respectively). The ODI in group I returned to baseline values, and the number of patients with atelectasis decreased by 1.6 times. In group II, the ODI remained increased by 57.2%, and CT results remained unchanged. *Conclusions*: The use of PEP-therapy in the early period after LVGR surgery allows not only to reduce the number and volume of atelectasis but also to more effectively restore respiratory parameters and pulmonary gas exchange compared to the course of standard respiratory gymnastics.

Keywords: the left ventricle geometric reconstruction, PEP-therapy, spirometry, atelectasis, postoperative pulmonary complications.

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Introduction

The functional state of the respiratory system in patients with coronary heart disease accompanied by chronic heart failure (CHF) is often characterized by impaired physiological mechanisms of the upper respiratory tract, manifesting as deterioration of the lungs' eliminative function, reduced external respiratory function indicators, and decreased gas exchange [1]. The severity of these dysfunctions may increase with the progression of heart failure, especially after cardiac surgical interventions [2]. It is necessary to emphasize the importance of patients' preoperative condition (degree of obesity, presence of harmful habits, comorbidities), as it significantly affects the state of the respiratory system and the speed of its recovery after cardiac surgery.

It should be noted that the number of comorbid patients with cardiovascular and respiratory pathologies [3], such as COPD [4], is growing each year, as well as the association with sleep apnea syndrome of both central and obstructive nature [5].

The decrease in physiological indicators of pulmonary ventilation in patients with CHF significantly increases the risks of postoperative complications in the early period, prolongs their hospital stay, which is a predictor of high mortality in this category of patients [6, 7].

One of the most common bronchopulmonary complications after cardiac surgery is atelectasis. The average frequency of this complication is more than 50% [8, 9]respiratory complications remain a leading cause of postcardiac surgical morbidity and can prolong hospital stays and increase costs. The high incidence of pulmonary complications is in part due to the disruption of normal ventilatory function that is inherent to surgery in the thoracic region. Furthermore, patients undergoing such surgery often have underlying illnesses such as intrinsic lung disease (e.g., chronic obstructive pulmonary disease. Among the main causes of atelectasis are the use of mechanical ventilation combined with prolonged cardiopulmonary bypass during cardiac surgical interventions, which can lead not only to the development of interstitial and alveolar edema but also to the appearance of atelectasis zones [10], due to the development of systemic inflammation, damage to surfactants and disruption of their production [11].

The development of atelectasis reduces the ventilation-perfusion ratio, worsens lung tissue elasticity [12], and often provokes the development of infectious processes in various parts of the lungs. This situation is especially relevant for patients after LVGR due to the complexity and duration of the surgical intervention [13].

There are various methods of respiratory rehabilitation for patients after cardiac surgery, aimed at restoring chest excursion after sternotomy, improving gas exchange, restoring mucociliary clearance, and expanding collapsed alveolar areas. Typically, to improve ventilation of various lung regions and facilitate sputum expectoration after cardiac surgery, conventional respiratory gymnastics consisting of static and dynamic exercises is used.

Among the most promising and effective methods of respiratory training in this group of patients, especially those with bronchopulmonary pathology, positive expiratory pressure therapy (PEP-therapy) can be highlighted [14, 15].

By creating moderate positive pressure in the airways, «air traps» are eliminated and collateral bronchial ventilation is improved, which allows effective recruitment of atelectatic alveoli and restoration of gas exchange. Moreover, some devices for PEP-therapy, such as EzPAP, allow maintaining positive inspiratory pressure in the airways, which prevents their collapse during inhalation [16, 17] and increases the effectiveness of respiratory training. The device is equipped with a high-flow oxygen connection and can be used for patients with gas exchange disorders who require constant oxygen therapy. The special design of the apparatus accelerates inspiratory flows, resulting in the patient taking a deeper breath, which improves lung tissue elasticity and restores lung vital capacity.

Currently, there is very little research in domestic and foreign literature concerning the analysis of the effectiveness of various respiratory rehabilitation methods in patients after the left ventricle geometric reconstruction (LVGR). There is also a lack of data on the application of PEP-therapy methods and their impact on the functional state of the respiratory system in this group of patients.

In this regard, the aim of this study is to investigate the effect of respiratory training with positive expiratory pressure on the functional state of the respiratory system in patients after LVGR.

Materials and methods

A prospective study was conducted at the A.N. Bakulev National Medical Research Center for Cardiovascular Surgery and approved by the local ethics committee (protocol No. 5 dated 07.10.2023). The study involved 57 patients who underwent planned the left ventricle geometric reconstruction surgery. The average age of patients was 60 ± 8 years (50 men and 7 women). All patients signed informed consent to participate in the study.

Inclusion criteria for patients in the study were: 1) left ventricle geometric reconstruction surgery; 2) absence of chronic respiratory diseases in the medical history; 3) age not younger than 18 years; 4) patient's willingness to follow the study protocol.

Exclusion criteria were: 1) pneumothorax in the early postoperative period; 2) postoperative acute heart failure; 3) acute cerebrovascular accident; 4) severe cognitive impairment.

Two methods of respiratory rehabilitation were used to restore respiratory function in patients in the early postoperative period: 1) PEP-therapy using the EzPAP device (Smiths Medical (Portex) UK) and 2) conventional (standard) respiratory gymnastics.

Depending on the rehabilitation method, two groups of patients were identified: group I — patients undergoing PEP-therapy (n = 27), and group II — patients undergoing standard respiratory gymnastics (n = 30, control group). Patients in the first group received PEP-therapy using the EzPAP device 5 times a day for 7—10 minutes in a sitting position, 30 minutes before or 1 hour after meals. The ratio of inhalation to exhalation was 1:2 or 1:3. The expiratory pressure was controlled using a manometer and should not exceed 10–20 cm H_2O.

Patients in the second group trained in the same regimen throughout the day. Static and dynamic breathing exercises were applied.

The study consisted of three stages: I Stage — before surgery; II Stage — 2–3 days after surgery; III Stage — 10–12 days after surgery (discharge from the hospital).

The indicators of the following research methods were studied: 1) spirometry; 2) echocardiography; 3) computed tomography and radiography; 4) tissue and pulmonary gas exchange indicators were calculated (PaO_2/FiO_2, CaO_2, Qs/Qt, DO_2, VO_2, REO_2 and $P(A\text{-}a)O_2$); 5) 24-hour pulse oximetry; 6) integral rheography (IRG).

Spirometry was conducted according to the methodological recommendations of the Russian Respiratory Society [18] using the SMP-21/01-»R-D» device (Russia). The following indicators were studied: FVC, FEV_1, FEV_1/FVC, FEV_3, FEV_6, MVV, FEF_{25}, FEF_{50}, FEF_{75}, FEF_{25-75} and PEF. Measurement results were expressed as percentages of calculated expected values.

Echocardiographic examination was performed in accordance with the recommendations of the American Society of Echocardiography [19] using a Philips HD15 device (Philips, Netherlands). The main indicators of LV function were studied: EF, EDV, ESV, EDD, ESD, SV and the presence of LV hypokinesis zones.

24-hour pulse oximetry was performed using the MD300W device (ChoiceMMed, China) and evaluated minimum SpO_2, maximum SpO_2, average SpO_2 and oxygen desaturation index (ODI).

Using integral rheography («Diamant-R» (Diamant, Russia)), the volume of total (TBW) and extracellular fluid (ECW) was determined.

The surgery was performed under general anesthesia with cardiopulmonary bypass and mechanical ventilation. Body temperature was maintained at normal or moderately hypothermic levels. Cardioplegic solution was used for myocardial protection.

Statistical analysis was performed using Stattech 4.1.2 and SPSS 26.0 software. The Shapiro-Wilk test was used to assess the normality of distribution. For normally distributed data, mean values (M), standard deviations (SD), and 95% confidence interval (95% CI) were calculated. For non-normally distributed data, median values (Me), upper and lower quartiles (Q1–Q3) were calculated. When comparing two groups on a quantitative indicator with normal distribution, Student's t-test was used, and in the absence of normal distribution, the Mann-Whitney U-test was used. McNemar's test was used to compare binary indicators of two related samples. One-way repeated measures ANOVA was used to analyze quantitative data of three or more related sets. The significance of changes was assessed using Pillai's trace. Differences were considered statistically significant at $p < 0.05$.

Results and discussion

A comparative analysis of clinical and demographic characteristics between the two groups did not reveal any statistically significant differences ($p > 0.05$) (Table 1).

Table 1

Clinical and demographic characteristics of patients

Indicators	Group I(n = 27)	Group II(n = 30)	P
Demographic indicators			
Age, full years	58 ± 9	62 ± 8	0.082
Height, cm	174 ± 5	172 ± 7	0.270
Body weight, kg	87 ± 12	83 ± 15	0.303
Body mass index, kg/m^2	29 ± 4	28 ± 4	0.966
Female, abs. (%)	3 (11.1)	4 (13.3)	1.000
Male, abs. (%)	24 (88.9)	25 (83.3)	
Smoking, abs. (%)	12 (44.4)	18 (60.0)	0.240
Concomitant diseases			
COVID-19, abs. (%)	15 (55.6)	14 (46.7)	0.503
Diabetes mellitus	6 (22.2)	6 (20.0)	1.000
Hypertension	18 (66.7)	20 (66.7)	1.000
Acute cerebrovascular accident	0 (0.0)	2 (6.7)	0.492
Surgical characteristics of patients			
Duration of operation, hour	6 ± 1	6 ± 2	0.285
Duration of cardiopulmonary bypass, min	116 ± 45	126 ± 57	0.503

End of the table 1

Indicators	Group I(n = 27)	Group II(n = 30)	P
Aortic compression time, min	73 ± 33	63 ± 29	0.235
Number of shunts applied	2 ± 1	2 ± 1	0.820
Duration of stay in the ICU, hour	35 ± 10	39 ± 25	0.554
Duration of ventilation in the ICU, hour	20 ± 5	24 ± 20	0.321

Analysis of preoperative computed tomography (CT) results showed the presence of post-inflammatory phenomena (pneumofibrosis) in 18 patients in groups I and II (66.7% and 60% respectively). Additionally, in group II, two patients were found to have post-COVID changes in lung parenchyma of the «ground glass» type. However, these differences between groups were not statistically significant ($p > 0.05$).

Analysis of spirometry data conducted before surgery revealed a decrease in both volume and flow respiratory parameters of the lungs in both groups. No statistically significant intergroup differences were found ($p > 0.05$). The spirometry data are presented in Table 2.

Table 2

Spirometry results at the preoperative stage in groups I and II

Indicators	Group I	Group II	P
FVC,%	89.2 ± 8.4 [85.9—92.6]	87.3 ± 7.3 [84.6—90.1]	0.367
FEV_1,%	90.6 ± 10.3 [86.5—94.7]	88.0 ± 13.8 [82.8—93.2]	0.429
FEV_1/FVC	101.7 ± 5.3 [99.5—103.8]	98.9 ± 8.9 [95.5—102.2]	0.164
FEV_3,%	88.5 ± 9.4 [84.8—92.3]	88.1 ± 12.0 [83.6—92.6]	0.883
FEV_6,%	89.9 ± 11.5 [85.3—94.4]	89.4 ± 15.1 [83.7—95.0]	0.897
PEF,%	90.7 ± 8.5 [87.3—94.0]	88.8 ± 21.1 [80.9—96.7]	0.667
FEF_{25},%	83.4 ± 13.1 [78.2—88.6]	80.8 ± 20.4 [73.2—88.4]	0.578
FEF_{50},%	80.7 ± 13.2 [75.5—86.0]	78.9 ± 13.4 [73.8—83.9]	0.604
FEF_{75},%	75.5 ± 18.2 [68.3—82.7]	71.4 ± 19.7 [64.0—78.8]	0.419
$FEF_{25–75}$,%	81.7 ± 14.9 [75.8—87.7]	77.2 ± 20.9 [69.3—85.0]	0.349
ELA,%	107.1 ± 19.5 [99.3—114.8]	110.8 ± 20.7 [103.0—118.5]	0.492
MVV,%	85.9 ± 11.4 [81.4—90.5]	85.3 ± 13.8 [80.1—90.4]	0.849
FEV_1/FEV_6,%	99.5 ± 7.5 [96.5—102.5]	96.8 ± 9.7 [93.0—100.6]	0.259

Preoperative echocardiography showed an increase in the left ventricle (LV) volume parameters and a decrease in myocardial contractility in both groups. The LV ejection fraction was 42.8 ± 6.4% in group I and 44.9 ± 4.7% in group II, without statistically significant differences between the groups ($p = 0.170$). At the same time, the EDV and ESV indicators were noticeably higher than normal values and were as follows: for EDV: 174.2 ± 19.1 ml — group I and 179.9 ± 35.0 ml — group II; for ESV: 102.1 ± 16.4 ml and 103.0 ± 28.1 ml, respectively. The p-values for intergroup differences in these indicators did not reach statistical significance ($p = 0.459$ and $p = 0.892$, respectively).

Analysis of 24-hour pulse oximetry data before surgery revealed a decrease in the average level of arterial blood oxygenation in both groups relative to normal values. In group I, the mean oxygenation value was 91.2 ± 2.1%, and in group II — 92.5 ± 3.4%. The oxygen desaturation index (ODI) value in group I was 7.1 ± 0.6, and in group II — 6.7 ± 0.9. Intergroup differences were not statistically significant ($p > 0.05$).

On the second day after surgery, both groups showed a statistically significant decrease in both flow and volume spirometry parameters. In group I, FVC, FEV_1, and MVV decreased by 26.6% ($p < 0.001$), 33.2% ($p < 0.001$), and 36% ($p < 0.001$) respectively. The decrease in group II was comparable and amounted to 31.4% ($p < 0.001$), 35.2% ($p < 0.001$), and 37.7% ($p < 0.001$) respectively (Figure 1). The dynamics of FEV_3 and FEV_6 indicators corresponded to this trend, their decrease also amounted to more than 30% from baseline values ($p < 0.05$).

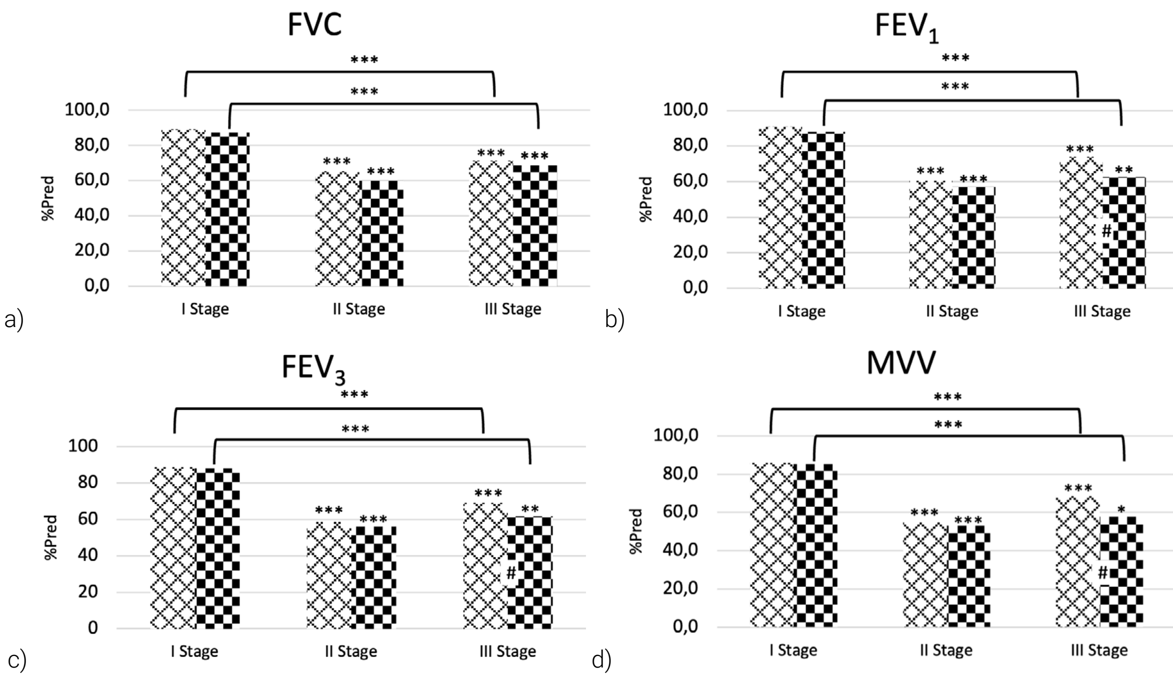

Fig. 1 (a—d). Dynamics of volume spirometry indicators in patients of groups I and II at all stages of the study

Note: ⊠ — group I; ▩ — group II. * — presence of interstage differences (* — $p < 0.05$; ** — $p < 0.01$; *** — $p < 0.001$); # — presence of intergroup differences.

Peak expiratory flow (PEF), as well as flow indicators reflecting the conductance of various parts of the airways (FEF_{25}, FEF_{50}, FEF_{75}, and $FEF_{25—75}$) decreased by more than 30% from baseline values ($p < 0.05$), with PEF, in group I, decreasing by 44.6% from the preoperative level ($p = 0.001$) (Figure 2).

As the change in spirometric indicators on the second day after surgery was symmetrical in both groups, no statistically significant intergroup differences were found ($p > 0.05$).

Echocardiography data obtained by the Simpson method at the second stage of the study were characterized by a significant decrease in LV volume parameters. EDV in groups I and II decreased by 26.2% ($p < 0.001$) and 27.7% ($p < 0.001$) respectively; ESV decreased by 28.7% ($p < 0.001$) and 27.6% ($p < 0.001$), and stroke volume by 23.9% and 30% ($p < 0.001$) respectively. Data by Teichholz method indicate a decrease in EDD in groups I and II by 9.7% ($p < 0.001$) and 7.7% ($p < 0.001$), and ESD by 10.2% ($p < 0.001$) and 6.8% ($p < 0.001$) respectively. No statistically significant intergroup differences were found ($p > 0.05$).

Analysis of 24-hour pulse oximetry results on the second day after surgery revealed an increase in sleep-disordered breathing (SDB) in patients of both groups. In groups I and II, ODI increased by 2.9 ($p < 0.001$) and 3.1 ($p < 0.001$) times respectively. The mean oxygenation value in groups I and II was 86 ± 4.5% and 87 ± 2.8% respectively. No intergroup differences were found (p>0.05).

Analysis of pulmonary and tissue gas exchange data in patients of both groups on the second day after surgery revealed a significant deviation of the main integral indicators relative to reference values. The normal value of the PaO_2/FiO_2 oxygenation index is about 500 while the mean values in groups I and II were lower by 28.6% and 35.2% respectively (Table 3).

Table 3

Gas exchange rates in patients of groups I and II on the second day after surgery

Indicators	Group I	Group II	P
Index PaO_2/FiO_2	357 ± 91[321—394]	324 ± 66[299—349]	0.115
CaO_2, ml/l	148 ± 16[141—154]	149 ± 19[142—156]	0.841
$P(A-a)O_2$, mmHg	147 ± 59[124—170]	159 ± 36[145—172]	0.378
Qs/Qt,%	16 ± 7[13—18]	15 ± 3[14—16]	0.574
Index DO_2, ml/kg/m^2	403 ± 129[352—454]	427 ± 148[372—482]	0.530
VO_2 index, ml/kg/m^2	97 ± 40[81—113]	108 ± 37[94—122]	0.307
REO_2,%	23 ± 8[20—27]	26 ± 6[24—29]	0.142

When assessing the volumes of total body water (TBW) and extracellular water (ECW) at the second stage of the study, an increase in both indicators was found in the first and second groups by 25.3% and 26.7% ($p = 0.011$; $p = 0.002$), and by 35.1% and 34.3% ($p < 0.001$; $p < 0.001$) respectively.

At the second stage of the study, all patients underwent chest X-ray. Additionally, 14 patients from group I and 15 from group II (29 patients in total) underwent additional chest CT. CT data of patients from both groups indicate the appearance of inflammatory and congestive changes, such as «ground glass» opacities, hydrothorax, mosaic perfusion, hypoventilation, etc. Computed tomography revealed bilateral and unilateral atelectasis of various parts of the lungs in 100% of the examined patients. According to X-ray data, atelectasis was detected in only 3 out of 29 examined patients. CT data of patients are presented in Table 4.

Analysis of spirometry data conducted before discharge from the hospital on the 10—12th day (Stage III) showed statistically significant positive dynamics of most respiratory indicators in both groups. However, the restoration of respiratory function was more pronounced in patients who underwent PEP-therapy (group I) than in the control group (group II). Statistically significant intergroup differences were found in the dynamics of not only volume parameters (FEV_1: 22.1% vs 9.4% [$p = 0.001$]; FEV_3: 17.6% vs 9.7% [$p = 0.015$]; MVV: 24.9% vs 8.4% [$p = 0.003$] respectively) (Figure 1), but also flow parameters of spirometry (PEF: 58.1% vs 19.5% [$p = 0.019$]; FEF_{25}: 30.9% vs 20.4% [$p = 0.002$]; FEF_{50}: 36.5% vs 4.1% [p = 0.001]; FEF_{75}: 25.8% vs 19.9% [p = 0.016]; $FEF_{25—75}$: 39.9% vs 7.5% [p = 0.001] respectively) (Figure 2).

Moreover, in the control group, there was practically no recovery dynamics of FEF_{50} and $FEF_{25—75}$ indicators by Stage III of the study ($p = 0.335$ and $p = 0.165$ respectively). For FVC, positive dynamics in groups I and II were characterized as statistically significant (9.1% [$p < 0.001$] and 14.6% [$p < 0.001$]), however, no differences between groups were observed (p = 0.333).

Analysis of echocardiography data at discharge from the hospital (Stage III of the study) did not reveal statistically significant changes in all studied parameters since the operation, except for the LV ejection fraction. In group I, the improvement in LVEF was 12.7% ($p < 0.001$), and in group II only 4% ($p = 0.008$). However, no intergroup differences were found ($p = 0.505$).

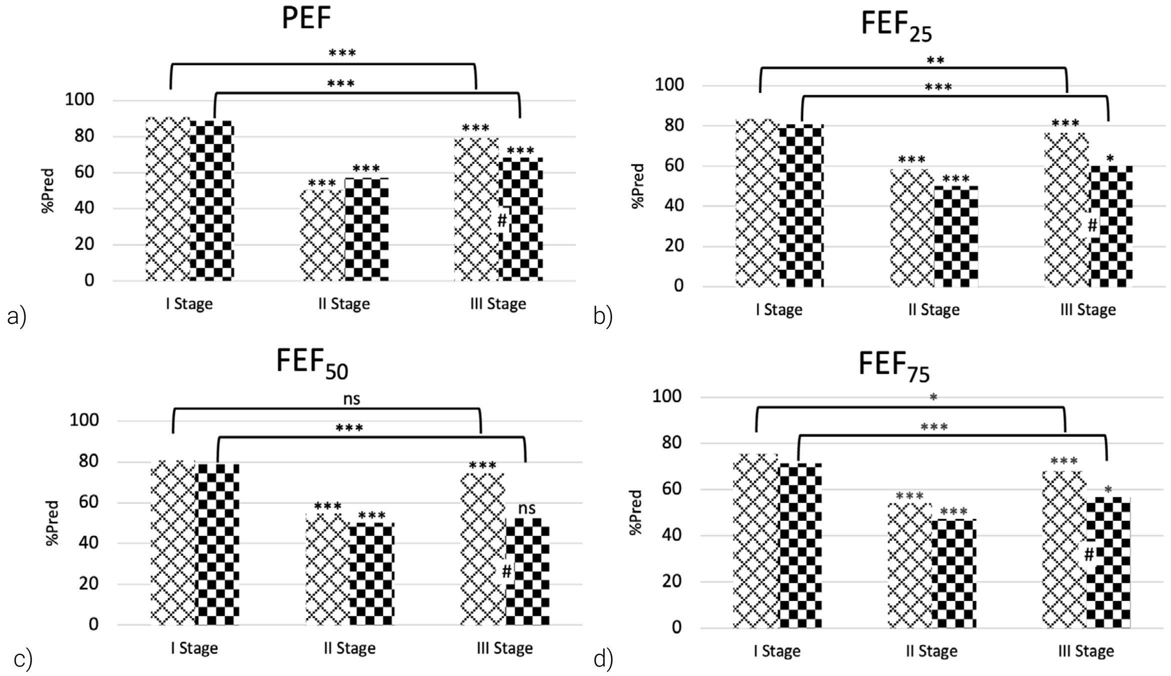

Fig. 2 (a-d). Dynamics of spirometry flow parameters in patients of groups I and II at all stages of the study

Note: ☒ — group I; ▩ — group II. * — presence of interstage differences (* — p < 0.05; ** — p < 0.01; *** — p < 0.001); # — presence of intergroup differences; ns — absence of statistically significant differences.

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At the third stage of the study, patients in both groups showed positive dynamics in ODI and mean SpO_2 value, with statistically significant differences ($p = 0.003$). In group I, the mean SpO_2 value increased to 91.7 ± 3.7%, and the ODI index decreased by 63.6% to 7.5 ± 0.6 ($p < 0.001$) (Figure 3). Thus, both indicators in group I returned to baseline values.

In group II, the ODI index was also significantly lower compared to the same indicator at the second stage of the study (49.3%, $p < 0.001$), but at the same time, it remained elevated by 57.2% (10.5 ± 0.8 [$p < 0.001$]) compared to the initial value. At discharge, the mean SpO_2 value in these patients remains 10.2% ($p = 0.011$) lower than before the operation.

The results of computed tomography obtained during Stage III of the study showed that inflammatory and congestive changes persist in patients of both groups up to discharge from the hospital. The number of patients with unilateral or bilateral hydrothorax (residual) in both groups did not change significantly by the time of discharge ($p > 0.05$). At the same time, in group I, a statistically significant decrease (by 42.9%, $p = 0.014$) in the number of patients with atelectasis was revealed. Moreover, the number of patients with atelectasis in group I became 1.6 times less than in the control group ($p = 0.035$). CT data are presented in Table 4.

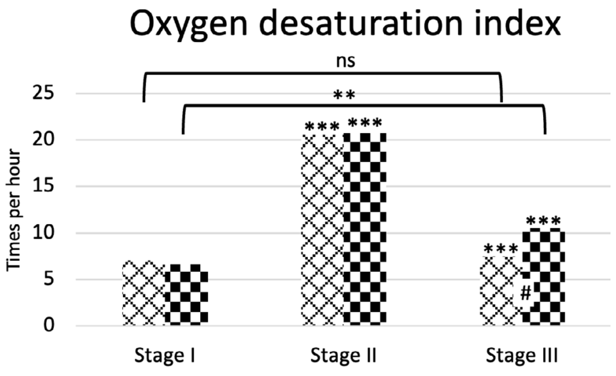

Fig. 3. Indicators of the oxygenation index in patients of groups I and II at all stages of treatment

Note: ⊠ — group I; ▩ — group II. * — presence of interstage differences (* — p < 0.05; ** — p < 0.01; *** — p < 0.001). # — presence of intergroup differences; ns — absence of statistically significant differences.

Table 4

Computed tomography data in patients of group I and II at the second and third stages of the study

Indicators	Stage	Group I	Group II	P
Pneumofibrosis	Stage II	14 (100)	15 (100)	1.000
	Stage III	14 (100)	15 (100)	1.000
«Ground glass»	Stage II	7 (50.0)	4 (26.7)	0.264
	Stage III	4 (28.6)	4 (26.7)	1.000
Areas of consolidation (atelectasis)	Stage II	14 (100)	15 (100)	1.000
	Stage III	8 (57.1)	14 (93.3)	0.035*
Hydrothorax	Stage II	13 (92.9)	9 (60.0)	0.080
	Stage III	11 (78.6)	7 (46.7)	0.128
Paresis of the dome of the diaphragm	Stage II	5 (35.7)	7 (46.7)	0.710
	Stage III	5 (35.7)	7 (46.7)	0.710

According to IRG data, TBW and ECW indicators did not recover by the end of the third stage of the study and exceeded the initial values in group I by 11.1% and 21.4% ($p = 0.029$; $p = 0.017$), and in group II by 10.2% and 23.1% ($p = 0.016$; $p = 0.009$) respectively, without significant differences between groups ($p > 0.05$).

In this study, a comparative assessment was conducted on the effect of positive expiratory pressure therapy versus conventional respiratory gymnastics on the respiratory system of patients after the left ventricle geometric reconstruction in the early postoperative period.

Analysis of the study results revealed impairments in external respiratory function in both groups during the preoperative period. The decrease in respiratory function in patients with post-infarction left ventricle aneurysm is likely due to systemic hemodynamic disturbances and the development of chronic heart failure, leading to congestion in the pulmonary circulation and an increase in interstitial edema, causing restrictive disorders of external respiratory function [20, 21]. Additionally, patients with CHF may experience increased mucus production and impaired mucociliary clearance [22], due to respiratory epithelial dysfunction [23], which can provoke obstructive respiratory disorders.

Spirometry data on the 2nd day after surgery in patients of both groups show a significant decrease (by 30–40%) in almost all spirometry indicators. According to literature data, these disorders may be caused by a decrease in lung tissue compliance due to an increase in extracellular fluid [24], which is also confirmed by the results of our study. Furthermore, the decrease in external respiratory function indicators after surgery may also be caused by disruption of chest integrity, pain syndrome, mucus hyperproduction, and impaired mucociliary clearance [10, 25].

By the time of hospital discharge (10–12 days post-intervention), patients in the first group, who underwent PEP-therapy, demonstrated statistically significant improvements of pulmonary function, especially in the flow characteristics of spirometry (PEF, FEF_{25}, FEF_{50}, etc.), compared to patients who received a standard course of respiratory gymnastics. The obtained results indicate the effectiveness of therapy with the EzPAP device, which maintains constant positive pressure in the airways, preventing their collapse during inhalation, allowing for more effective restoration of mucociliary clearance and patency of all bronchial sections. Moreover, moderate expiratory resistance in the safe range of 10–20 cm H_2O [26, 27] contributes to more effective restoration of respiratory muscle tone [28–30], allowing patients to perform breathing maneuvers qualitatively during spirometry examination.

Comparative analysis of radiography and CT data showed that conventional radiography performed in the early postoperative period does not fully determine the presence and extent of atelectasis affecting various parts of the lungs, compared to diagnostic methods such as lung ultrasound and CT [31, 32]bedside chest radiography, and lung ultrasonography with that of thoracic computed tomography. Three pathologic entities were evaluated in 384 lung regions (12 per patient. In our study, chest CT on the 2nd day after surgery revealed the formation of atelectasis in 100% of examined patients in both groups, which is comparable with the results obtained by Hedenstierna et al. [33].

It is known that the main factors in the development of X-ray negative microatelectasis are prolonged cardiopulmonary bypass [34], surfactant damage and disruption of its production, as well as a decrease in alveolar pressure [35], leading to alveolar collapse and impaired alveolar gas exchange. Pulmonary and tissue gas exchange data obtained on the 2nd day after surgery and the results presented in Table 3 confirm significant impairments in lung oxygenation function in patients of both groups.

The use of PEP-therapy allows for a statistically significant reduction in the number of patients with atelectasis in group I by the time of hospital discharge, as well as a reduction in the volume of remaining atelectasis. At the same time, group II showed almost no decrease in the number and volume of atelectasis. This is likely due to the fact that positive expiratory pressure allows for the recruitment of collapsed alveoli by increasing transpulmonary pressure [36], and maintaining positive pressure during inhalation prevents their derecruitment [37]. Meanwhile, classical breathing exercises do not have a desorption effect. Furthermore, it should be noted that with traditional respiratory gymnastics, it is impossible to dose and control the level of positive expiratory pressure, resulting in insufficient increase in transpulmonary pressure, which significantly reduces the effectiveness of this respiratory rehabilitation method [38].

During 24-hour pulse oximetry at the preoperative stage, respiratory function disorders during sleep were detected in patients of both groups. A decrease in blood oxygenation indicators was observed, with the mean desaturation index being above normal values in both groups (ODI>5), which increased the risk of sleep apnea episodes in this category of patients. It is known that patients with cardiovascular pathology are at risk for SDB. In patients with coronary heart disease complicated by heart failure, the prevalence of sleep apnea exceeds 70% [39]. Moreover, not only can the presence of sleep apnea affect the occurrence of cardiovascular diseases and the development of CHF, but in turn, the presence of CHF can provoke the occurrence of sleep apnea syndrome and potentiate an increase in the frequency of apnea/hypopnea episodes of both central and obstructive types [40].

In our study, a significant increase in the ODI was observed in the early postoperative period in patients of both groups. These disorders may be due to the influence of a combination of intraoperative factors, such as intubation causing damage and edema of the vocal cords and larynx, as well as the use of general anesthesia and muscle relaxants during surgery. These risk factors, against the background of the forced supine position of the patient, can provoke obstructive breathing disorders during sleep, as well as exacerbate the course of moderate to severe OSAS [41]. The influence of postoperative heart failure on sleep apnea/hypopnea should be emphasized, which leads to worsening of congestion in the pulmonary circulation, especially in the horizontal supine position during sleep, leading to interstitial edema and increased ODI [42–44].

Patients in group I receiving PEP-therapy showed restoration of ODI and average oxygenation to preoperative values at Stage III of the study, while in group II they remained reduced. Apparently, the effect of PEP-therapy is largely provided by maintaining constant positive pressure in the airways during sessions on the EzPAP device with connected main oxygen. Improvement in the oxygenating function of the lungs against the background of oxygen therapy positively affects the recovery of respiratory disorders [45]. In addition, constant positive pressure likely contributes to the restoration of airway stability and a reduction in the number of desaturation episodes. This is supported by studies that have proven the effectiveness of the assisted ventilation technique with constant positive pressure during sleep — CPAP, which prevents the collapse of airways and eliminates episodes of apnea/hypopnea [46].

Thus, regular use of PEP-therapy in the early postoperative period contributes to the stabilization of airways, improvement of blood oxygenation, and reduction in the frequency of SAS episodes of both obstructive and central nature.

Conclusion

The use of PEP-therapy using the EzPAP device in patients after LVGR in the early postoperative period allows not only to reduce the number and volume of atelectasis but also to more effectively restore spirometry indicators compared to patients receiving a standard course of respiratory gymnastics.

In the early postoperative period after LVGR, patients experience impaired gas exchange and a significant increase in the number of desaturation episodes during sleep. PEP-therapy contributes to the restoration of blood oxygenation indicators and desaturation index to baseline values by the time of discharge, while in patients receiving a standard course of respiratory gymnastics, these indicators remain reduced.

The use of PEP-therapy in the early period after LVGR surgery can be successfully applied in conjunction with conservative methods of respiratory rehabilitation, as it is safe and well-tolerated by patients.

References / Список литературы

1. Horodinschi RN, Bratu OG, Dediu GN, Pantea Stoian A, Motofei I, Diaconu CC. Heart failure and chronic obstructive pulmonary disease: a review. *Acta Cardiol*. 2020;75(2):97—104. doi: 10.1080/00015385.2018.1559485

2. Ramalho SHR, Shah AM. Lung function and cardiovascular disease: A link. *Trends Cardiovasc Med*. 2021;31(2):93—98. doi: 10.1016/j.tcm.2019.12.009

3. Nikitina TG, Pelekh DM, Filipkina TYu, Golukhova EZ. Impact of comorbidity on immediate results of surgical correction of valvular heart defects. *Clinical Physiology of Circulation*. 2022;19(3):238—246. (In Russian). doi: 10.24022/1814-6910-2022-19-3-238-246. [*Никитина Т.Г., Пелех Д.М., Филипкина Т.Ю., Голухова Е.З.* Влияние коморбидности на непосредственные результаты хирургической коррекции клапанных пороков сердца // Клиническая физиология кровообращения. 2022. Т. 19. № 3. С. 238—246. doi: 10.24022/1814-6910-2022-19-3-238-246].

4. Axson EL, Sundaram V, Bloom CI, Bottle A, Cowie MR, Quint JK. Temporal Trends in the Incidence of Heart Failure among Patients with Chronic Obstructive Pulmonary Disease and Its Association with Mortality. *Ann Am Thorac Soc*. 2020;17(8):939—948. doi: 10.1513/AnnalsATS.201911-820OC

5. Yeghiazarians Y, Jneid H, Tietjens JR, Redline S, Brown DL, El-Sherif N, Mehra R, Bozkurt B, Ndumele CE, Somers VK. Obstructive Sleep Apnea and Cardiovascular Disease: A Scientific Statement from the American Heart Association. *Circulation*. 2021;144(3): E56-E67. doi: 10.1161/CIR.0000000000000988

6. Heidorn MW, Steck S, Müller F, Tröbs SO, Buch G, Schulz A, Schwuchow TS, Schuch A, Strauch K, Schmidtmann I, Lackner KJ, Gori T, Münzel T, Wild PS, Prochaska JH. FEV_1 Predicts Cardiac Status

and Outcome in Chronic Heart Failure. *Chest*. 2022;161(1):179—189. doi: 10.1016/j.chest.2021.07.2176

7. Babeshko SS, Barbukhatti KO, Shumkov DI, Kaleda VI, Porhanov VA. Predictors of adverse outcomes in early and long-term periods after aortic valve replacement in patients with severe left ventricular systolic dysfunction. *Russian Journal of Thoracic and Cardiovascular Surgery*. 2024;66(2):166—177. (In Russian). doi: 10.24022/0236-2791-2024-66-2-166-177. [*Бабешко С.С., Барбухатти К.О., Шумков Д.И., Каледа В.И., Порханов В.А.* Предикторы неблагоприятных исходов в ранние и отдаленные сроки после протезирования аортального клапана у больных с тяжелой систолической дисфункцией левого желудочка // Грудная и сердечно-сосудистая хирургия. 2024. Т. 66. № 2. С. 166—177. doi: 10.24022/0236-2791-2024-66-2-166-177].

8. Weissman C. Pulmonary complications after cardiac surgery. *Semin Cardiothorac Vasc Anesth*. 2004;8(3):185—211. doi: 10.1177/108925320400800303

9. Rubinowitz AN, Siegel MD, Tocino I. Thoracic Imaging in the ICU. *Crit Care Clin*. 2007;23(3):539—573. doi: 10.1016/j.ccc.2007.06.001

10. Girgin Z, Ciğerci Y, Yaman F. The Effect of Pulmonary Rehabilitation on Respiratory Functions, and the Quality of Life, following Coronary Artery Bypass Grafting: A Randomised Controlled Study. *Biomed Res Int*. 2021;2021:1—11. doi: 10.1155/2021/6811373

11. Albert RK. Constant V_T Ventilation and Surfactant Dysfunction An Overlooked Cause of Ventilator-induced Lung Injury. *Am J Respir Crit Care Med*. 2022;205(2):152—160. doi: 10.1164/rccm.202107-1690CP

12. Serin SO, Işıklar A, Karaören G, El-Khatib MF, Caldeira V, Esquinas A. Atelectasis in bariatric surgery: Review analysis and key practical recommendations. *Turkish J Anaesthesiol Reanim*. 2019;47(6):431—438. doi: 10.5152/TJAR.2019.66564

13. Merzlyakov VYu, Skopin AI, Mamedova SK, Baychurin RK, Khaziev RA. Successful repeated myocardial revascularization with reconstruction of the left ventricular cavity, performed under conditions of parallel perfusion and normothermia on the beating heart. *Russian Journal of Thoracic and Cardiovascular Surgery*. 2023;65(3):335—340. (In Russian). doi: 10.24022/0236-2791-2023-65-3-335-340. [*Мерзляков В.Ю., Скопин А.И., Мамедова С.К., Байчурин Р.К., Хазиев Р.А.* Успешная повторная реваскуляризация миокарда с реконструкцией полости левого желудочка, выполненная в условиях параллельной перфузии и нормотермии на сокращающемся сердце // Грудная и сердечно-сосудистая хирургия. 2023. Т. 65. № 3. С. 335—340. doi: 10.24022/0236-2791-2023-65-3-335-340].

14. Pieczkoski SM, de Oliveira AL, Haeffner MP, Azambuja A de CM, Sbruzzi G. Positive expiratory pressure in postoperative cardiac patients in intensive care: A randomized controlled trial. *Clin Rehabil*. 2021;35(5):681—691. doi: 10.1177/0269215520972701

15. Saliba KA, Blackstock F, McCarren B, Tang CY. Effect of Positive Expiratory Pressure Therapy on Lung Volumes and Health Outcomes in Adults with Chest Trauma: A Systematic Review and Meta-Analysis. *Phys Ther*. 2022;102(1):1—11. doi: 10.1093/ptj/pzab254

16. Nadi F, Azizi-Fini I, Izadi-Avanji FS. Impact of Continuous Positive Airway Pressure (CPAP) Masks on Arterial Blood Gas Parameters and Pulmonary Side Effects after Open-heart Surgery. *J Vessel Circ*. 2020;1(1):1—7. doi: 10.29252/jvesselcirc.1.1.1

17. Nieman GF, Gatto LA, Andrews P, Satalin J, Camporota L, Daxon B, Blair SJ, Al-khalisy H, Madden M, Kollisch-Singule M, Aiash H, Habashi NM. Prevention and treatment of acute lung injury with time-controlled adaptive ventilation: physiologically informed modification of airway pressure release ventilation. *Ann Intensive Care*. 2020;10(1):3. doi: 10.1186/s13613-019-0619-3

18. Russian respiratory society. Spirometry: a methodological guide. Ministry of health of the Russian Federation. 2021. 56 p. [Accessed 2024 May 08] Available from: https://spulmo.ru/upload/spirometriya_18_02_2022_ extEd.pdf?t=1. (In Russian). [Российское респираторное общество. Спирометрия: методическое руководство. Министерство здравоохранения Российской Федерации. 2021. 56 с. Дата обращения: 08.05.2024. Доступ по ссылке: https://spulmo.ru/upload/spirometriya_18_02_2022_extEd.pdf?t=1].

19. Mitchell C, Rahko PS, Blauwet LA, Canaday B, Finstuen JA, Foster MC, Horton K, Ogunyankin KO, Palma RA, Velazquez EJ. Guidelines for Performing a Comprehensive Transthoracic Echocardiographic Examination in Adults: Recommendations from the American Society of Echocardiography. *J Am Soc Echocardiogr*. 2019;32(1):1—64. doi: 10.1016/j.echo.2018.06.004

20. Iversen KK, Kjaergaard J, Akkan D, Kober L, Torp-Pedersen C, Hassager C, Vestbo J, Kjoller E. The prognostic importance of lung function in patients admitted with heart failure. *Eur J Heart Fail*. 2010;12(7):685—691. doi: 10.1093/eurjhf/hfq050

21. Lobacheva GV, Alshibaya MM, Mamalyga ML, Zatenko MA, Danilov SA, Arzumanyan MA. Respiratory system functional state in patients after the left ventricle geometric reconstruction followed by conventional respiratory rehabilitation. *RUDN Journal of Medicine*. 2023;27(2):182—94. (In Russian). doi: 10.22363/2313-0245-2023-27-2-182-194. [*Лобачева Г.В., Алшибая М.М., Мамалыга М.Л., Затенко М.А., Данилов С.А., Арзуманян М.А.* Функциональное состояние респираторной системы у пациентов после геометрической реконструкции левого желудочка с последующей конвенциональной респираторной реабилитацией // Вестник Российского университета дружбы народов. Серия: Медицина. 2023. Т. 27. № 2. С. 182—194. doi: 10.22363/2313-0245-2023-27-2-182-194]

22. Bazdyrev ED, Polikutina OM, Kalichenko NA, Slepynina YS, Barbarash OL. Disorders of respiratory function of lungs in patients with ischemic heart disease before planning coronary bypass grafting. *Siberian Medical Review*. 2017;(2 (104)):77—84. (In Russian). doi: 10.20333/2500136-2017-2-77-84. [*Баздырев Е.Д., Поликутина О.М., Каличенко Н.А., Слепынина Ю.С., Барбараш О.Л.* Нарушение респираторной функции легких у пациентов с ишемической болезнью сердца перед плановым проведением коронарного

шунтирования // Сибирское медицинское обозрение. 2017. № 2 (104). С. 77—84. doi: 10.20333/2500136-2017-2-77-84].

23. Feigin GA, Toktobolot KCh, Feigin AM. Features of the course and treatment of acute respiratory diseases in patients with pulmonary heart failure. *Vestnik of the Kyrgyz-Russian Slavic university*. 2018;18(9):73—77. (In Russian). [*Фейгин Г.А., Токтоболот К.Ч., Фейгин А.М.* Особенности течения и лечения острых респираторных заболеваний у больных с легочно-сердечной недостаточностью // Вестник Кыргызско-Российского Славянского университета. 2018. Т. 18. № 9. С. 73—77].

24. Magnussen H, Canepa M, Zambito PE, Brusasco V, Meinertz T, Rosenkranz S. What can we learn from pulmonary function testing in heart failure? *Eur J Heart Fail*. 2017;19(10):1222—1229. doi: 10.1002/ejhf.946

25. Dergachev AV, Lapteva IM, Sprindzhuk MV. Broncho-pulmonary complications after cardiac surgery. *Russian Journal of Cardiology*. 2007;(5):92—96. (In Russian). [*Дергачев А.В., Лаптева И.М., Спринджук М.В.* Бронхолегочные осложнения после операции на сердце // Российский кардиологический журнал. 2007. № 5. С. 92—96].

26. Brooks D, Newbold E, Kozar LF, Rivera M. The Flutter device and expiratory pressures. *J Cardiopulm Rehabil*. 2002 Jan;22(1):53—57. doi: 10.1097/00008483-200201000-00008.

27. O'Sullivan KJ, Dunne CP, Linnane B, McGrath D, O'Sullivan L. Design and initial testing of a novel disposable oscillating positive expiratory pressure device. *Ir J Med Sci*. 2023;192(5):2291—2299. doi: 10.1007/s11845-022-03225-1

28. Habib MH, Serry MZ, A. Hussein S, Nagy EN, Ghallab AM. Impact of combined Russian current and threshold PEP on dyspnoea and functional capacity in patients with COPD: a randomised controlled trial. *Physiother Q*. 2024;32(1):50—6. doi: 10.5114/pq.2024.135422

29. Dsouza FV, Amaravadi SK, Samuel SR, Raghavan H, Ravishankar N. Effectiveness of Inspiratory Muscle Training on Respiratory Muscle Strength in Patients Undergoing Cardiac Surgeries: A Systematic Review With Meta-Analysis. *Ann Rehabil Med*. 2021;45(4):264—73. doi: 10.5535/arm.21027

30. Sahar W, Ajaz N, Haider Z, Jalal A. Effectiveness of Pre-operative Respiratory Muscle Training versus Conventional Treatment for Improving Post operative Pulmonary Health after Coronary Artery Bypass Grafting. *Pakistan J Med Sci*. 2020;36(6):1216—1219. doi: 10.12669/pjms.36.6.2899

31. Lichtenstein D, Goldstein I, Mourgeon E, Cluzel P, Grenier P, Rouby JJ. Comparative Diagnostic Performances of Auscultation, Chest Radiography, and Lung Ultrasonography in Acute Respiratory Distress Syndrome. *Anesthesiology*. 2004;100(1):9—15. doi: 10.1097/00000542-200401000-00006

32. Touw HR, Parlevliet KL, Beerepoot M, Schober P, Vonk A, Twisk JW, Elbers PW, Boer C, Tuinman PR. Lung ultrasound compared with chest X-ray in diagnosing postoperative pulmonary complications following cardiothoracic surgery: a prospective observational study. *Anaesthesia*. 2018;73(8):946—954. doi: 10.1111/anae.14243

33. Hedenstierna G, Edmark L. Mechanisms of atelectasis in the perioperative period. *Best Pract Res Clin Anaesthesiol*. 2010;24(2):157—169. doi: 10.1016/j.bpa.2009.12.002

34. Kirillov AY, Yavorovskiy AG, Vyzhigina MA, Komarov RN, Nogtev PV, Bagdasarov PS, Khalikova EYu, Yavorovskaya DA, No II. Respiratory tactics during cardiopulmonary bypass in cardiac surgery. *Messenger Anesthesiol Resusc*. 2021;18(2):40—47. (In Russian). doi: 10.21292/2078-5658-2021-18-2-40-47 [*Кириллов А.Ю., Яворовский А.Г., Выжигина М.А., Комаров Р.Н., Ногтев П.В., Багдасаров П.С., Халикова Е.Ю., Яворовская Д.А., Но И.И.* Респираторная тактика во время искусственного кровообращения при кардиохирургических операциях // Вестник анестезиологии и реаниматологии. 2021. Т. 18. № 2. С. 40—47. doi: 10.21292/2078-5658-2021-18-2-40-47].

35. Zeng C, Lagier D, Lee JW, Vidal Melo MF. Perioperative Pulmonary Atelectasis: Part I. Biology and Mechanisms. *Anesthesiology*. 2022;136(1):181—205. doi: 10.1097/ALN.0000000000003943

36. Hu MC, Yang YL, Chen TT, Lee CI, Tam KW. Recruitment maneuvers to reduce pulmonary atelectasis after cardiac surgery: A meta-analysis of randomized trials. *J Thorac Cardiovasc Surg*. 2022;164(1):171—181.e4. doi: 10.1016/j.jtcvs.2020.10.142

37. Bautin AE. *Profilaktika i intensivnaya terapiya ostrogo respiratornogo distress-sindroma posle operacij na serdce i aorte* [PhD Thesis]. Saint Petersburg; 2015. [*Баутин А.Е.* Профилактика и интенсивная терапия острого респираторного дистресс-синдрома после операций на сердце и аорте: дис. … док. мед. наук. Санкт-Петербург, 2015].

38. Alshibaya MM, Mamalyga ML, Lobacheva GV. The effectiveness of respiratory methods of PEP-therapy and vibrational PEP-therapy after coronary artery bypass grafting. *Thoracic and cardiovascular surgery*. 2018;60(6):477—482. (In Russian). doi: 10.24022/0236-2791-201860-6-477-82. [*Алшибая М.М., Мамалыга М.Л., Лобачева Г.В.* Эффективность респираторных методов PEP-терапии и вибрационной PEP-терапии после аортокоронарного шунтирования // Грудная и сердечно-сосудистая хирургия. 2018. Т. 60. № 6. С. 477—482. doi: 10.24022/0236-2791-201860-6-477-82].

39. Legeyda IV, Buzunov RV, Sidorenko BA, Likov VF, Alekhin MN, Telnova OD, Antsereva AO. The use of computer pulse oximetry monitoring for screening of sleep apnea in patients of a hospital cardiology department. *Kardiologiya*. 2012;52(2):70—73. (In Russian). [*Легейда И.В., Бузунов Р.В., Сидоренко Б.А., Алехин М.Н., Ликов В.Ф., Тельнова О.Д., Анцерева А.О.* Применение мониторинговой компьютерной пульсоксиметрии для скрининга апноэ сна у пациентов кардиологического отделения стационара // Кардиология. 2012. Т. 52. № . 2. С. 70—73].

40. Gordeev IG, Shaydyuk OYu, Taratukhin EO. Sleep apnoea syndrome and cardiovascular disease: a modern view. *Russ J Cardiol*. 2012;(6):5—12. (In Russ.). [*Гордеев ИГ, Шайдюк ОЮ, Таратухин ЕО.* Синдром апноэ во сне и кардиологическая патология: современный взгляд // Российский кардиологический журнал. 2012. № 6. С. 5—12].

41. Buzunov RV. Long-term CPAP-therapy of obstructive sleep apnea syndrome. What the cardiologist should know? *Medical alphabet*. 2013;2(21):35—39. (In Russian). [*Бузунов Р.В.* Долгосрочная СИПАП-терапия синдрома обструктивного апноэ сна. Что нужно знать кардиологу? // Медицинский алфавит. 2013. Т. 2. № 21. С. 35—39].

42. Yumino D, Redolfi S, Ruttanaumpawan P, Su MC, Smith S, Newton GE, Mak S, Bradley TD. Nocturnal rostral fluid shift: A unifying concept for the pathogenesis of obstructive and central sleep apnea in men with heart failure. *Circulation*. 2010 Apr 13;121(14):1598—1605. doi: 10.1161/CIRCULATIONAHA.109.902452

43. Bradley TD, Floras JS. Sleep apnea and heart failure: Part I: Obstructive sleep apnea. *Circulation*. 2003;107(12):1671—1678. doi: 10.1161/01.CIR.0000061757.12581.15

44. Bradley TD, Floras JS. Sleep apnea and heart failure: Part II: Central sleep apnea. *Circulation*. 2003;107(13):1822—1826. doi: 10.1161/01.CIR.0000061758.05044.64

45. Wellman A, Malhotra A, Jordan AS, Stevenson KE, Gautam S, White DP. Effect of oxygen in obstructive sleep apnea: Role of loop gain. Respir *Physiol Neurobiol*. 2008;162(2):144—151. doi: 10.1016/j.resp.2008.05.019

46. Tarasik ES, Bulgak AG, Zatoloka NV, Koush EV. The obstructive sleep apnea and cardiovascular diseases. *Meditsinskie novosti*. 2016;(6):18—24. (In Russian). [*Тарасик Е.С.*, *Булгак А.Г.*, *Затолока Н.В.*, *Ковш Е.В.* Синдром обструктивного апноэ сна и сердечно-сосудистые заболевания // Медицинские новости. 2016. № 6. С. 18—24].

Респираторная терапия с положительным давлением на выдохе у пациентов после геометрической реконструкции левого желудочка

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Аннотация. *Актуальность.* Дыхательная система пациентов с постинфарктной аневризмой левого желудочка на фоне ХСН часто характеризуется снижением функции внешнего дыхания и развитием респираторных осложнений в раннем послеоперационном периоде. Терапия с положительным экспираторным давлением (PEP-терапия) считается эффективным методом респираторной реабилитации после кардиохирургических операций. Однако в настоящее время отсутствуют данные применения этой методики у пациентов после ГРЛЖ (геометрической реконструкции левого желудочка). *Цель исследования:* изучить функциональное состояние дыхательной системы пациентов после ГРЛЖ в раннем послеоперационном периоде на фоне PEP-терапии. *Материалы и методы.* Обследовано 57 пациентов после операции ГРЛЖ. Выделено две группы пациентов: группа I — пациенты, проходящие курс PEP-терапии ($n = 27$), и группа II — пациенты, проходящие курс стандартной дыхательной гимнастики ($n = 30$, контрольная группа). Исследование включало 3 этапа: I этап — до операции; II этап — через 2–3 дня после операции; III этап — через 10–12 дней после операции. *Результаты и обсуждение.* На предоперационном этапе в I и II группах обнаружены нарушения кардиореспираторной системы (ФЖЕЛ: 89,2% и 87,3%; КДО: 174,2 мл и 179,9 мл соответственно), а также риск развития дыхательных расстройств сна (индекс десатурации [ИД]: 7,1 и 6,7 соответственно). На вторые сутки после операции в обеих группах наблюдалось значительное снижение всех показателей спирометрии, при этом ИД в I и II группах вырос в 2,9 ($p < 0,001$) и 3,1 ($p < 0,001$) раза соответственно. КТ грудной клетки выявила ателектазы различных отделов легких у 100% обследованных пациентов. При выписке из стационара в I группе после курса PEP-терапии наблюдалось лучшее восстановление респираторных показателей по сравнению с контрольной группой ($ОФВ_1$: 22,1% и 9,4%; ПОС: 58,1% и 19,5% соответственно). ИД в I группе вернулся к исходным значениям, а количество пациентов с ателектазами сократилось в 1,6 раза. Во второй группе ИД оставался увеличенным на 57,2%, а результаты КТ сохранялись без изменений. *Выводы.* Применение PEP-терапии в раннем периоде после операции ГРЛЖ позволяет уменьшить не только количество и объемы ателектазов, но и более эффективно восстанавливать респираторные показатели и легочный газообмен по сравнению с курсом стандартной дыхательной гимнастики.

Ключевые слова: геометрическая реконструкция левого желудочка, PEP-терапия, спирометрия, ателектаз, послеоперационные легочные осложнения

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