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Intraoperative use of a polymer mesh implant in common destructive pulmonary tuberculosis complicated by empyema with bronchopleural fistula

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Abstract

The article observes a clinical case – intraoperative use of anterior mediastinal plastic surgery with a mesh implant for transsternal occlusion of the main bronchus in a patient with widespread destructive pulmonary tuberculosis complicated by pleuralempyema with bronchopleural fistula.

A control examination after 1.5 years showed a clinical cure of tuberculosis of a single lung. When comparing functional indicators, there was a slight increase in vital capacity (VC) and forced expiratory volume in the first second (FEV_1). There were no changes in the indicators of pO_2, pCO_2. Also, unchanged left ventricular ejection fraction and a substantial decrease in pulmonary artery pressure positively affected the patient's general condition.

Keywords: staged surgical treatment, fibrous-cavernous tuberculosis, mediastinal pulmonary hernia, transsternal occlusion of the main bronchus, plasty of the anterior mediastinum with a mesh implant.

Conflict of interest: nothing to disclose.

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Compliance with ethical standards
The method described in the work was considered by the Local Ethics Committee for Monitoring the Testing of New Medicines and Conducting Clinical Trials at the FSBI "CTRI". Protocol No.7/4 dated October 28, 2020. The authors received the patient's voluntary consent in writing for the publication of medical data.

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Интраоперационное применение полимерного сетчатого импланта при распространенном деструктивном туберкулезе легких, осложненном эмпиемой с бронхоплевральным свищом

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Аннотация

Приводится наблюдение из практики – интраоперационное применение пластики переднего средостения сетчатым имплантом при трансстернальной окклюзии главного бронха у пациентки с распространенным деструктивным туберкулезом легких, осложненным эмпиемой плевры с бронхоплевральным свищом.

Контрольное обследование через 1,5 года показало клиническое излечение туберкулеза единственного легкого. При сравнении функциональных показателей отмечалось незначительное повышение ЖЕЛ и $ОФВ_1$. Также отмечено отсутствие изменений в показателях pO_2, pCO_2. Изменений в показателе фракции выброса левого желудочка не было, а также присутствовало выраженное снижение давления в легочной артерии, что положительно сказалось на общем состоянии пациентки.

Ключевые слова: этапное хирургическое лечение; фиброзно-кавернозный туберкулез; медиастинальная легочная грыжа; трансстернальная окклюзия главного бронха; пластика переднего средостения сетчатым имплантом.

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Соответствие нормам этики
Метод, описанный в работе, рассмотрен «Локальным этическим комитетом по контролю за испытанием новых лекарственных препаратов и проведением клинических исследований» в ФГБНУ «ЦНИИТ». Протокол заседания №7/4 от 28.10.2020 г. Авторы в письменной форме получили добровольное согласие пациента на публикацию медицинских данных.

Список сокращений
МЛГ – медиастинальная легочная грыжа; ФВД – функция внешнего дыхания; ПЭ – пневмонэктомия; МЛУ – множественная лекарственная устойчивость; ШЛУ – широкая лекарственная устойчивость; МБТ – микобактерия туберкулеза; КУМ – кислотоустойчивая микобактерия; ППСПСИ – пластика переднего средостения полимерным сетчатым имплантом; ТОГБ – трансстернальная окклюзия главного бронха; ВИЧ – вирус иммунодефицита человека; ЧСС – частота сердечных сокращений; ЧДД – частота дыхательных движений; АД – артериальное давление; ПЦР – полимеразная цепная реакция; РГ – рентгенография; КТ ОГК – компьютерная томография органов грудной клетки; ЖЕЛ – жизненная емкость легких; $ОФВ_1$ – объем форсированного выдоха за 1 секунду; ФБС – фибробронхоскопия; УЗИ – ультразвуковое исследование; ИВЛ – искусственная вентиляция легких; ЭхоКГ – эхокардиография.

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RATIONALE

As of 2018, there are more than 1500 pneumonectomies performed in the Russian Federation per year [1]. The surgery has a high risk of complications especially when performed in conditions of an infected pleural cavity due to pleural empyema or pyopneumothorax, and septic intoxication [2–4] in patients with expressed functional disorders of the respiratory and cardiovascular systems.

In cases of empyema with fistulas of large bronchi, in the infected cavity such surgical methods are used as re-resections of the stump, fistula packing with muscle flap or omentum. According to some authors, their efficacy may reach up to 90% [5–7].

The operation "trans-sternal occlusion of main bronchus (TOMB) in tuberculous empyemas with bronchial fistulae", in which the stump of the bronchus is treated outside of the infected cavity, was developed in 1964 by L.K. Bogush [2]. The operation is a modification of the method originally developed by P. Abruzzini in 1961 [3].

After the pulmonectomy, the mediastinal organs shift towards the operated hemithorax, which results in the lung overexpansion and formation of the mediastinal lung hernia (MLH). The incidence of MLH causing the progress of tuberculosis in the loci of the over-expanded single lung may reach 80% [8].

The doctors of the Federal State Funded Research Institution "Central Research Institute of Tuberculosis" (CRITUB) designed a method to correct this complication: reconstruction of the anterior mediastinum with polymer mesh implant (RAMPMI) sometimes used intraoperationally in trans-sternal occlusion. To prevent the shift of the mediastinum, especially in debilitated patients, the occluded lung was left in the atelectasis. The justification of such tactic was the work of L.K. Bogush et al. [9], which focused on the morphological manifestations of the activity of tuberculous inflammation in the lung shut down in various periods after the TOMB. The work showed that after the occlusion of the main bronchus and the pulmonary artery the activity of the tuberculous inflammation was gradually reducing, the disconnected lung was gradually fibrosing and performing the function of the biological seal. This kind of surgery is tolerated well by the patients. However, for some patients with low functions due to a marked shift of the mediastinum and lung hernia and indications for the performance of TOMB and RAMPMI, the keeping of the lung as a biological seal after the first stage of treatment is not possible due to an intractable empyema of the pleura even with drain lavage.

AIM

Demonstrate the surgical tactics and after-history of treatment of a patient with widespread destructive pulmonary tuberculosis complicated by pleural empyema with bronchopleural fistula, shift of the mediastinum with mediastinal lung hernia (MLH) and low values of respiratory function.

The article focuses on the clinical case of a successful surgical treatment of the patient: stage one – simultaneous use of two methods – trans-sternal occlusion of the main bronchus and the reconstruction of the lung hernia with mesh implant; stage two – pleuropneumoectomy.

CASE HISTORY

Patient M., female, 38 years old, HIV-negative, was admitted in April 2021 with complaints of shortness of breath under minimal physical activity (mMRC 3), dry cough at night, strong expectoration in the morning. Past history: pulmonary tuberculosis for 9 years (from 2012). The initial form of the disease is not known. In July 2020, she was diagnosed with "fibrocavernous tuberculosis of the left lung in the phase of infiltration and seeding. Mycobacterium tuberculosis (MBT) +. Multiple drug resistant (MDR) MBT." The patient was not on treatment regularly and interrupted treatment more than once; the MBT developed a pre-extensive drug resistance. In 2021, the patient came to the CRITUB and was admitted to determine possibility of surgical treatment.

The patient was moderately severe upon admission (25.03.2021). Auscultation: harsh breathing, on the left, audible to the anterior axillary line, on the right, in all sections. Respiratory rate (RR): 22 per minute. Dyspnea rate on the mMRC scale: 3 points. Regular heart tones. Heart rate (HR): 80 per minute. Arterial blood pressure (BP): 120/80 mmHg. Luminescent microscopy of the sputum did not find acid-fact

Figure 1. *X-Ray (A) and CT of the chest organs (B) at admission, where A – displacement of the mediastinal organs (trachea, heart) to the left; B – large upper anterior pulmonary hernia, large focus in S2 of the right lung, destroyed left lung.*

Рисунок 1. *Рг (А) и КТ-исследования органов грудной клетки (В) при поступлении: А – выраженное смещение органов средостения (трахея, сердце) влево; В – разрушенное левое легкое, больших размеров верхне-передняя легочная грыжа, крупное образование в S2 правого легкого.*

mycobacteria; the sputum study by polymerase chain reaction (PCR) found the DNA of Mycobacterium tuberculosis (MBT). Using the SINTOL method, the causating microorganism resistance was determined to isoniazid, rifampicin, and fluoroquinolones. Using the BACTEC method on the sputum, MBT growth was established and resistance of MBT to levofloxacin, kanamycin, moxifloxacin, para-aminosalycilic acid, rifampicin, ethambutol, and isoniazid.

Upon admission (25.03.2021), X-ray and CT of the chest organs were performed (**Fig. 1**).

The study of the X-ray and CT of the chest organs on admission revealed the following: the left lung is considerably smaller in volume, airless parenchyma, visualized lumen of the bronchi. The multilocular air cavity of the pleural empyema is located in the posterior costal section on the level of fourth to eleventh ribs, with low level of fluid and multiple small bronchopleural fistulas. On the left at the level of the second intercostal space, an encysted air cavity (size: 1.8x1.4x2.4 cm) with fluid. The mediastinum organs are shifted to the left and rotated. In the right lung, overexpanded for compensation, there are scattered multiple tuberculomae and dense partially calcific loci of various sizes. Probable presence of a small destructive air cavity in the shallow tuberculema located in the S5 under the pleura along the left parasternal line. Pulmonary mediastinal hernias are visualized: anterior superior up to the left anterior axillary line, left posterior in the section between the left paravertebral and scapular line. The volume (V3) of the hernia of the anterior mediastinum of the right lung is 740.65 cm3, and of the hernia of the posteroinferior mediastinum, 379.97 cm3. Conclusion: CT signs of pleural empyema on the left with bronchopleural fistulas, multiple tuberculomae of the right lung. Mediastinal pulmonary hernias of the right lung (Fig. 1).

In the assessment of the respiratory function (RF) the following was observed (12.05.2021): expiratory vital capacity (VC) is 42.8% of due value (DV), forced expiratory volume in the first second (FEV1) is 19.6% of DV. VC/FEV1 is 48.3%. Conclusion: drastic decrease of ventilator capacity of the lungs of mixed type: VC is considerably decreased, obstruction is pronounced.

Analysis of blood gas (24.05.2021): oxygen partial pressure (pO2) 73 mmHg, carbon dioxide partial pressure (pCO2) 42.0 mmHg, pH 7.421 – moderate hypoxaemia.

Fiber-optic bronchoscopy (26.05.2021): Conclusion: throughout bilateral bronchitis of 1 degree. Compression of the bronchi of the left lung. No data on tuberculous lesions in the bronchi.

Diagnosis: fibrocavernous tuberculosis of the left lung in the phase of infiltration and seeding complicated with empyema with bronchopleural fistulas. MBT (+), pre-extensive drug resistance MBT (isoniazid, rifampicin, streptomycin, ethambutol, pyrazinamide, ofloxacin, moxifloxacin, levofloxacin, protionamide).

The patient was provided treatment considering body mass and data on MBT drug susceptibility as follows: pyrazinamide, amikacin, cyclesorine, linezolid, bedaquiline.

The patient's case was discussed on the surgical council. Considering the pleural empyema with bronchopleural fistulas, pronounced overexpansion of the right lung and respiratory failure, it was decided to perform the trans-sternal occlusion of the left major bronchus with simultaneous reconstruction of the anterior mediastinum with polymer mesh implant. Considering the severity of the patient's condition, the atelectatic lung was planned to be kept as biological seal to prevent shift of the mediastinum, provided that the operated hemithorax be fully sanated.

Surgery was performed on 02.06.2021: trans-sternal occlusion of the left major bronchus with simultaneous reconstruction of the anterior mediastinum with polymer mesh implant. The stages of the surgery are shown in Figures 2–6.

Process of the surgery. After the longitudinal sternotomy, a large size pulmonary hernia of the right lung was visualized (**Fig. 2**).

The release of the right lung from the adhesions was performed carefully considering the pronounced bullous changes in the superior lobe (Fig. 3), the bullas were treated with electro cauterization. The lung is mobilized and the hernia gate are identified (**Fig. 4**).

In the aorto-caval space, the left main bronchus is identified (**Fig. 5**) and traversed, the trachebronchial defect is reconstructed with single interrupted sutures.

Figure 2. *Mediastinal pulmonary hernia of the anterior mediastinum of the right lung.*

Рисунок 2. *Медиастинальная легочная грыжа переднего средостения правого легкого из трансстернального доступа.*

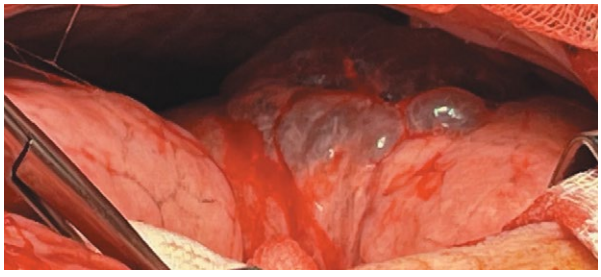

Figure 3. *Bullous changes in the right lung.*
Рисунок 3. *Буллезные изменения правого легкого.*

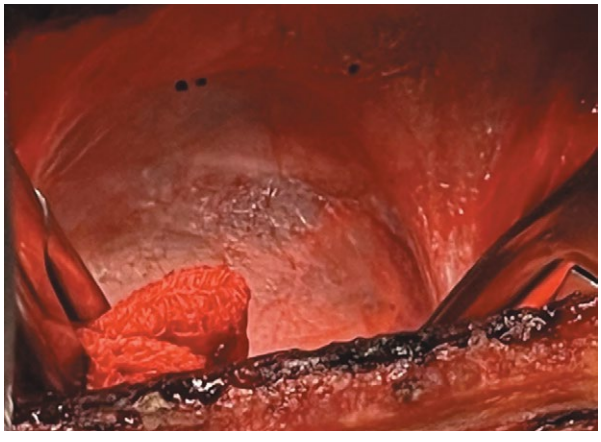

Figure 4. *Hernia gate.*
Рисунок 4. *Грыжевые ворота.*

The tissue of the right lung is placed in its 'proper' hemithorax, and the mesh implant is placed above the hernia gate and attached with single interrupted sutures (**Fig. 6**).

The duration of the surgery was 180 minutes, the blood loss was 250 ml. Drainage from the para-stump area was removed on the third day; from the parasternal zone, on the fifth day; from the right pleural area, on the forty-fifth day. The stitches were removed on the twenty-first day.

The post-surgery period was complicated with progressing respiratory failure, and the patient had to be connected to the artificial lung ventilation (ALV) for 19 days. On the third day (4.06.2021) due to the necessity of lengthy endotracheal ventilation, a tracheostomy was performed. Endoscopic sanation of the bronchial tree was performed daily, and anti-bacterial treatment was provided; the patient received cardinal and systemic medication, parenteral support, and anti-tuberculosis treatment continued. The patient's condition having improved, the tracheostomy tube was removed.

On 12.07.2021 (one month later), an X-Ray of the chest organs was performed: the left pleural cavity is intensively homogenously darkened, the lung is not differentiated. The mediastinal organs are in the left half of the chest cavity and rotated. In the right lung, no additional focal and infiltrational changes were found.

The ultrasonic (US) study of the left pleural cavity was performed on 06.07.2021: in the projection of the posterior and lateral sinuses, an encapsulated cavity was found, volume

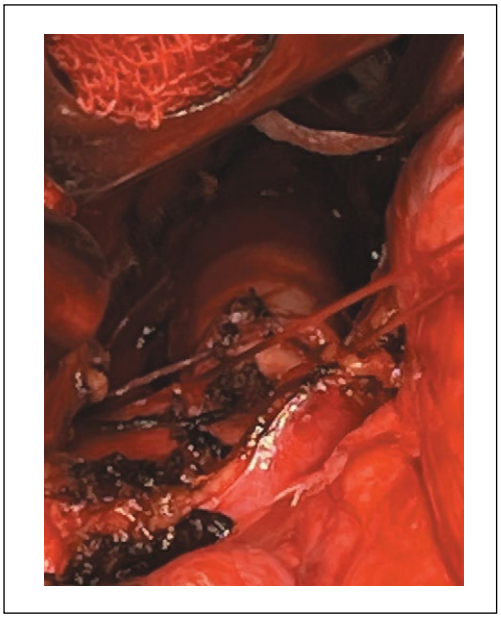

Figure 5. *Aorto-caval space, the left main bronchus is highlighted.*
Рисунок 5. *Аортокавальный промежуток, выделен левый главный бронх.*

up to 150–200 ml, filled with inhomogenous fluid. In order to ensure sanation of the left pleural cavity, the fluid was drained on 19.07.2023 under US control.

Using luminescent microscopy, the contents of the pleural cavity was studied. Acid-fast bacteria were found: 3 per 100 F.V.; PCR test identified the DNA of MBT. The SINTOL method identified resistance to isoniazid, rifampicin, fluoroquinolones. The BACTEC method did not identify growth of MBT.

The CT of the chest organs was performed 3 months later (7.10.2021): the left pleural cavity is intensively darkened by fluid contents, the lung is not differentiated. The dynamics of volume of the pulmonary mediastinal hernias was as follows: the volume of the hernia of the anterior mediastinum of the right lung was 466.23 cm3, the volume of the posterioinferior mediastinum was 636.33 cm3. In the single lung, the tuberculomae and the multiple partially calcific loci of various sizes remained in the previous quantity and sizes.

The respiratory function was tested after three months (10.08.2021): VC 53.7% DV, FEV1 21.0% DV, IT 41.3% – rapid decline of ventilator capacity of the lungs, mixed

Figure 6. *Installation of a mesh implant on the right intrapleurally on the right: stitching with dacron threads to the sternum when access is closed.*
Рисунок 6. *Установка сетчатого импланта справа интраплеврально справа: подшивание лавсановыми нитями к грудине при закрытии доступа.*

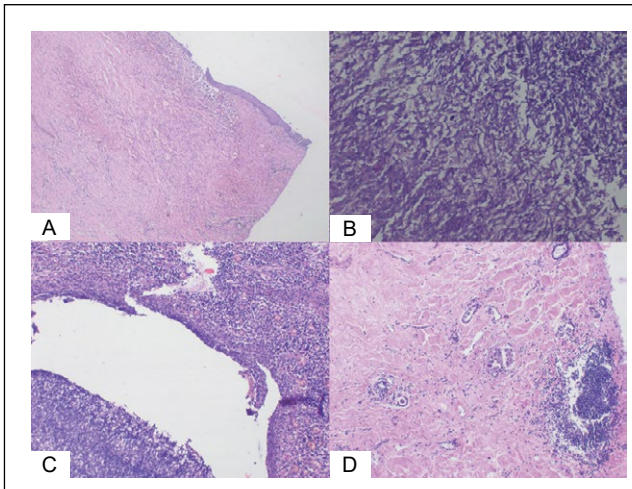

Figure 7. *Histological picture of the surgical material: 7A – the wall of the chronic cavity, staining with hematoxylin and eosin, x 40.; 7B – multiple hyphae of the fungus Aspergillus in necrotic masses in the lumen of the cavity, staining with hematoxylin and eosin, x 200.; 7C – multiple hyphae of the fungus Aspergillus in necrotic masses in the lumen of the cavity, staining with hematoxylin and eosin, x 100.; 7D – a focus of fibrosis in the lung tissue, staining with hematoxylin and eosin, x 100.*

Рисунок 7. *Гистологическая картина операционного материала: 7А – стенка хронической каверны. Окраска гематоксилином и эозином, х40.; 7В – множественные гифы гриба Aspergillus в некротических массах в просвете каверны. Окраска гематоксилином и эозином, х200.; 7С – множественные гифы гриба Aspergillus в некротических массах в просвете каверны. Окраска гематоксилином и эозином, х100.; 7D – очаг фиброза в легочной ткани. Окраска гематоксилином и эозином, х100.*

type. The obstruction is clearly pronounced, early expiratory collapse, VC is considerably reduced.

The patient's case was brought before the council: considering the persistence of the pleural empyema on the left after the trans-sternal occlusion of the left main bronchus, despite the daily sanations, the keeping of the disconnected lung as a biological seal was not possible in this case. A decision was made to perform pleuropneumoectomy, which was more traumatic for the patient but necessary due to vital and epidemiological indications.

Four months after Stage 1 (27.10.2021), the operation of left side pleuropneumoectomy was performed.

During the operation, in the presence of pronounced pleural connections, multiple cavities filled with large quantities of purulent matter were found. The duration of the operation was 235 minutes, the intraoperative loss of blood was 400 ml. Drainage removed on the 28th day; the stitches removed on the 14th day.

In the post-surgery period, on 29.10.2021, similar to the case after the first surgery, the patient developed progressive respiratory failure and had to be connected to the ALV, and a tracheostomy was performed. The patient stayed on the ALV for three days.

Using luminescent microscopy, Acid-fast bacteria were found in the surgical specimen: 4 per 100 F.V.; PCR test identified the DNA of MBT. The SINTOL method identified persisting resistance to isoniazid, rifampicin, fluoroquinolones.

Histological findings in the surgical specimen of the removed lung: the specimen contains pulmonary tissue with focal sclerotic changes (**Fig. 7A**), loci of dystelectasis and atelectasis, inhomogeneous lymphohystiocytic infiltration

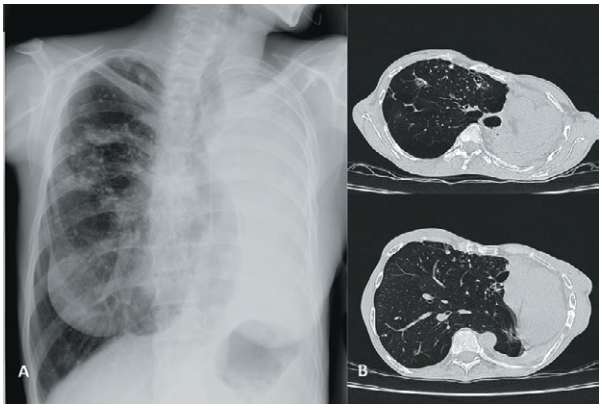

Figure 8. *X-Ray (A) and CT of the chest (B) 1.5 years after surgical treatment.*

Рисунок 8. *Рг (А) и КТ-исследования органов грудной клетки (В) через 1,5 года после хирургического лечения.*

of some of the interalveolar septa, in the perivascular and peribronchial areas, formation was seen of lymphohystiocytic sheaths with individual eosinocytes. In the lumen of a part of alveoli, there are old hemorrhages and accumulations of hemosiderophagi. There are sections of caseosis with signs of organization in the regular three-layer capsule, presence of multinucleated cells of Pirogov-Langhans and traces of leukocytes. Presence of perifocal granulomae of various age (**Fig. 7D**) with multinucleated cells of Pirogov-Langhans, no caseification. In the large focus of caseosis there is a large number of fungi druses (**Fig. 7B, 7C**), the capsule is represented with developing granulation tissue with moderate levels of macrophages and leukocytes and some eosinocytes. The pleura is with pronounced fibrosis and multi-phase granulomatous reaction of the epithelioid type with some leukocytes. The stump of the main bronchus is of normal structure without granulomatous reaction. Conclusion: picture of tuberculous inflammation in the pulmonary tissue with signs of development, formation of a mycetoma in one of the foci.

In two months (07.12.2021), the patient was discharged from the clinical department to continue treatment at the local antituberculosis dispensary; she completed a course of antituberculosis therapy and returned to her regular life.

Follow-up after 1.5 years: minor shortness of breath under marked physical activity (mMRC 2). X-Ray and CT examination: the left hemithorax is intensively homogeneously darkened. Air bubbles are not identified. Pulmonary mediastinal hernias: the volume (V3) of the anterior mediastinum of the right lung was 371.59 cm3, the volume of the posterioinferior mediastinum was 456.52 cm3. In the single lung, there were tuberculomas and multiple dense foci of varying sizes (**Fig. 8**).

The anterior lung hernia reduced in volume from 740.65 cm3 to 371.59 cm3, or by 49.82%, and the posterior lung hernia increased from 379.97 cm3 to 456.52 cm3, or by 22.85%. The total volume of the lung hernia (anterior + posterior mediastinum) reduced from 1120.62 cm3 to 828.11 cm3, or by 26%.

The respiratory function data, studies of blood gases and echocardiography parameters across the stages of treatment of Patient M. follow below **in Table 1**.

Functional values	Before Stage I	After Stage I 3 months later	After Stage II 3 years later
VC (% DV)	42,8	53,7	53
FEV1 (% DV)	19,6	22,4	25
FEV1/VC, %	48,3	43,8	47,1
$PaCO_2$, mmHg	42,4	39,6	40,2
PaO_2, mmHg	73	64	71
EF, %	62	62	63
Avg. Systolic pressure in the lung artery, mmHg	50	45	35

Table 1. *Dynamics of respiratory function, blood gases and echocardiography parameters*

Таблица 1. *Динамика показателей ФВД, газов крови и показателей ЭхоКГ*

As seen from Table 1, in comparison with pre-surgery values, there can be seen a minor increase in the VC from 42.8% to 53%, increase in the FEV1 from 19.6% to 25%, which is accounted for by the elimination of pathological bypass due to pneumonectomy. There is also a plateau in the values of pO2, pCO2, proving absence of influence from the damaged lung in the gas exchange function. No change in the left ventricle ejection fraction and pronounced decrease of pressure in the lung artery from 50 to 35 mmHg are noteworthy. They contributed positively to the patient's overall condition.

DISCUSSION

Treatment of patients with widespread destructive pulmonary tuberculosis complicated by pleural empyema with bronchopleural fistula is the most complicated task in phthisiology. According to the literature data, fibrous changes in the failed lung bring about the shift of mediastinum organs in its direction, and after pneumonectomy, the shift of the single lung will increase resulting in the formation of the lung hernia [4]. There appear bullous changes in the overexpanded lung [10], which has an adverse effect on the patient's functional capabilities [11].

The first mention of severe respiratory obstruction after pneumonectomy dates back to [12]. The very term 'post-pneumonectomy syndrome' was introduced in 1979 by K. Wasserman [13]. The part of the lung that forms the lung hernia may find itself in the conditions similar to strangulation causing disorder of ventilation and blood flow in the area, and the share of contribution to total ventilation and blood flow in the area may be not more than 10% [14].

The difficulty of this complication is supported by the variety of methods of treatment and prevention of development of the post-pneumonectomy syndrome (PPS) described in the literature: attachment of the pericardium to the posterior surface of the sternum, surgical and chemical treatment of the phrenic nerve to induce relaxation of the diaphragm and, respectively, reduction of hemithorax on the surgical side [14]. Methods of filling the hemithorax volume with various materials are used in most cases to treat the PPS.

K. Wasserman et al. (1979) [13], C. Gebitekin (2006) [15] suggested using silicone implants for mammoplasty to adjust the hemithorax volume and to return the mediastinum to 'its proper place'. N. Muthialu et al. (2015) [16] used a modified version of tissue expander for the same purpose. J.J. Jung et al. (2016) suggested an original method of staged treatment of PPS: after inflation and repositioning of the mediastinum, the mesh implant was put in place and tied to the "ribs, costal cartilage in the front and the vertebral column in the back" [17]. X. Li et al. (2014) devised a no less intriguing strategy of preventing the PPS by printing the lung on a 3D printer and its subsequent implantation in the hollow pleural cavity (the experiment was performed on dogs) [18]. Literature has detailed descriptions of cases of using endobronchial stents for successful treatment of patients with post-pneumonectomy syndrome; it was recommended that stents be used in the event surgery was impossible [19].

According to [20], the refusal from using the reconstruction of the anterior mediastinum with mesh implant in performing the TOMB would result in the increase of the anterior lung hernia, and the increase could have reached 15%. This is confirmed by the study of M.N. Vasyukov et al. (2021), which states that the volume of the right remaining lung would increase on average by 11.4% one year after the surgery [21].

The follow-up of treatment of our patient 1.5 year after the operation showed the decrease of the total volume of the lung hernia by 26% proving the high efficacy of the method.

Staged surgical treatment comprising, on the first stage, trans-sternal occlusion of the main bronchus and the lung artery of the failed lung with simultaneous reconstruction of the anterior mediastinum with mesh implant and, one the second stage, removal of the disconnected lung, is a most justified tactic for patients with low respiratory values and pleural empyema.

CONCLUSION

The use of reconstruction of the anterior mediastinum with mesh implant to eliminate or prevent formation of the lung hernia with simultaneous trans-sternal occlusion allows not only the clinical healing of the patient but to improve respiratory function, which is confirmed by follow-up in the long term after the surgical treatment. According to authors [11], in case of severe and debilitated patients the atelectatic lung was not removed but was kept as a biological seal. In this case, however, this solution was not justified due to the pleural empyema, an active tuberculous process, resulting in the necessity of pneumonectomy. Individual approach to the patient and the correctly chosen tactic ensured clinical healing and a chance for the patient to go back to normal life.

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Contribution of individual authors.

R.V. Tarasov – developed the study concept, has been responsible for scientific data collection, its systematization and analysis, wrote the first draft of the manuscript; E.V. Krasnikova – text editing; S.S. Sadovnikova – text editing; A.S. Khozikov – collection and processing of morphological material; M.A. Bagirov – managed the development of the study concept, supervised the study.

All authors gave their final approval of the manuscript for submission, and agreed to be accountable for all aspects of the work, implying proper study and resolution of issues related to the accuracy or integrity of any part of the work.

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