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**Review**

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# Bronchial Lavage in the Treatment of Severe Bronchopulmonary Pathology in Adults. Approaches to Classification

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**INTRODUCTION** Currently, bronchial lavage (BL) is widely used in clinical practice for the treatment of severe bronchopulmonary lesion in adults. However, indications and contraindications for this procedure are not fully defined. In addition, it was not possible to find in the literature a classification of either BL in general or used for therapeutic purposes in particular, which significantly complicates the standardization of procedures for its use in various diseases.

**AIM OF STUDY** To determine possible classification characteristics, as well as indications, contraindications for therapeutic BL in adults and possible complications that may arise, based on the analysis of literature data.

**RESULTS** Therapeutic BL can be carried out both as planned and for health reasons. Indications for planned BL are purulent bronchitis, pneumonia, purulent-destructive infiltration, as well as chronic lung diseases: bronchiectasis, interstitial lesions. In turn, the indication for emergency therapeutic BL is progressive acute or chronic respiratory failure, developing due to bronchial obstruction. Such conditions may include massive pulmonary hemorrhage, acute obstruction of the bronchi with mucus and pus, postoperative atelectasis and hypoventilation of the lungs, aspiration of gastric contents, severe bronchial asthma, purulent destruction of the lungs, acute respiratory distress syndrome, thermochemical lesions of the respiratory tract.

Contraindications to therapeutic BL can be both absolute and relative. Absolute contraindications are intolerance to drugs used for local anesthesia; decompensated heart and (or) pulmonary failure; acute cerebrovascular accident; various types of arrhythmias; stenosis of the larynx and (or) trachea II–III degree; neuropsychiatric diseases; pain syndrome in the abdominal cavity; extremely serious condition of the patient, when clarification of the diagnosis can no longer affect treatment tactics. Relative contraindications include acute respiratory disease of the upper respiratory tract; coronary artery disease; severe diabetes mellitus; pregnancy (second half); chronic alcoholism; grade III enlargement of the thyroid gland. It should be noted that most of the absolute contraindications are conditional and are not taken into account when performing BL according to vital indications with appropriate medical and technical support.

Classification of BL used for medicinal purposes can be carried out according to the following criteria: method of sanitation; access used; level of sanitation; sanitized area; volume and composition of the lavage solution.

It is noteworthy that the methods of carrying out procedures for various conditions and diseases still remain unregulated. An exception is the final stage of the therapeutic BL procedure in the case of the use of surfactant preparations, which standardization is regulated by approved standard operating procedures.

It should also be noted that bronchial lavage for therapeutic purposes is justified from a pathoanatomical and pathophysiological point of view, but is accompanied by serious, albeit temporary, changes in the lungs, which can be partially avoided by improving the lavage technique.

**CONCLUSION** All of the above indicates that in order to solve existing problems, it is necessary to conduct systematic research in this direction with the involvement of all interested specialists.

**Keywords:** bronchial lavage, bronchoscopy, severe bronchopulmonary lesion

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ALV – artificial lung ventilation
ARDS – acute respiratory distress syndrome
BBL – bronchoscopic bronchial lavage
BL – bronchial lavage
FBS – fibrobronchoscopy
IV – intravenously
LF – lavage fluid
LS – lavage solution
NBBL – non-bronchoscopic bronchial lavage
RBS – rigid bronchoscopy

## INTRODUCTION

The first publication devoted to the use of bronchial lavage through a ureteral catheter with limited volumes of liquid (0.5–2 l) in the treatment of severe bronchopulmonary pathology in adults, called bronchial lavage (BL, hereinafter referred to as non-bronchoscopic bronchial lavage, NBBL), was published in light in 1929. In this work, *Vicente G.* presented the results of the successful use of NBBL in the treatment of bronchiectasis, lung gangrene and removal of foreign bodies from the respiratory tract [1].

The main works devoted to the use of lavage technologies for the treatment of severe bronchopulmonary pathology occurred in the 60s and 70s of the twentieth century. On the one hand, this was associated with the advent and active introduction into clinical practice of artificial lung ventilation devices (ALVs), and on the other hand, with the invention of the fiberglass endoscope (fiber bronchoscope) by *S. Ikeda* in 1968. The emergence of these developments has significantly expanded the possibilities of endoscopic examination not only by improving the quality of examination of the tracheobronchial tree, performing biopsies and administering drugs under visual control, but also its safety in terms of preventing such a formidable complication as hypoxia.

In the early 60s of the 20th century, *Simenstad J.O. et al.* published the results of the use of NBBL using large volumes of lavage solutions (LS) for postoperative atelectasis [2], aspiration of gastric contents [3, 4] and the presence of blood in the airways after chest trauma [5]. The implementation of NBBL through an endotracheal tube was first performed in 1960 *by Broom V.* in patients with status asthmaticus [6] and subsequently became standard for this procedure in various types of bronchopulmonary pathology [1, 7–9]. The main indications for NBBL were: status asthmaticus; Mendelssohn's syndrome; aspiration of foreign body; alveolar proteinosis. However, the method was not widely used primarily due to the fact that lavage was performed blindly, which significantly limited its effectiveness [1].

Subsequently, *Ramirez R.J. et al.* in 1965, they proposed the use of a double-lumen Carlens tube for NBBL in combination with general anesthesia in the treatment of severe bronchopulmonary pathology, and the use of large volumes (4.0–25.0 l) for this purpose was offered by *Kylstra J.A. et al.* in 1971 [10]. In Russia, this method of therapeutic lavage was first used in 1984 by V.A. Gerasin and employees of the All-Russian Research Institute of Pulmonology of the USSR Ministry of Health. Total lung lavage was performed under general anesthesia through one of the lumens of the Carlens endotracheal tube against the background of artificial ventilation of one lung [11].

Another direction in the development of lavage technologies for the treatment of severe bronchopulmonary pathology is associated with the advent and development of bronchoscopic technology. This procedure was first performed in 1964 *by Thompso N.T.* and *Pryor W.J.* in the treatment of a patient with treatment-resistant bronchial asthma (using a large amount of LS under anesthesia) [12]. In 1966, the authors published a method for performing bronchoscopic bronchial lavage (BBL) during rigid bronchoscopy (RBS), which became classic, as well as the results of treatment of 92 patients with severe forms of bronchial asthma, chronic bronchitis and emphysema. It should also be noted that, according to the authors, even the severe condition of patients with bronchial asthma is not a contraindication, since lavage turned out to be most effective in this category of patients [13]. Performing BBL was associated with the difficulty of mechanical ventilation (carried out using the Friedel-Lukomsky method) during RBS (using a rigid Friedel-type bronchoscope) in patients who were in status asthmaticus. It was expressed in deterioration of ventilation and the development of hypoxia when using large volumes of LS, which led to their reduction (the appearance of small portions of 20–30 ml) [1]. In turn, the problem of hypoxia in BBL during RBS in the treatment of severe bronchopulmonary pathology was resolved first with the help of injection ventilation, and later with high-frequency and jet ventilation [14].

After the advent of the flexible bronchoscope, the possibilities of therapeutic lavage during fibrobronchoscopy (FBS) for previously studied indications began to be actively explored. Much attention was paid to the issues of respiratory support for BBL during FBS. Initially, mechanical ventilation was used for this purpose through a conventional endotracheal tube or laryngeal mask. The next stage in the development of respiratory support for FBS and BL was the use of jet high-frequency mechanical ventilation, including transcatheter ventilation, which does not require cessation of spontaneous breathing, and also made it possible to use it in patients with severe somatic pathology [15, 16]. In addition, non-invasive mechanical ventilation using face or nasal masks is widely used for this purpose [17, 18], tracheal gas insufflation through a catheter, tracheal cannula or endotracheal tube [19–21], as well as non-invasive options for respiratory protection based on spontaneous breathing of oxygen. - an air mixture using nasal cannulas, simple face masks, and a Venturi-type mask [22–24].

Since the early 90s of the 20th century, publications began to systematically appear in the literature on the use of various variants of BL in the treatment of such severe bronchopulmonary pathology as acute respiratory distress syndrome (ARDS) [25–27].

Analysis of literature data showed that the main areas of research on the use of BL in severe bronchopulmonary pathology were the treatment of purulent bronchitis, pneumonia, lung abscesses, contamination of the respiratory tract with radioactive nuclides, as well as chronic lung diseases such as bronchiectasis, lipoid pneumonia, alveolar microlithiasis and cystic fibrosis.

A separate area includes BL methods used for emergency indications for: pulmonary hemorrhage, acute bronchial obstruction, including aspiration of gastric contents, bronchial asthma, purulent destruction of the lungs, thermal damage to the respiratory tract, as well as ARDS.

Currently, therapeutic BL is widely used in clinical practice in the treatment of severe bronchopulmonary pathology, but the indications and contraindications for this procedure are not fully defined. In addition, it was not possible to find in the literature a classification of either BL in general or used for therapeutic purposes in particular. All of the above allows us to formulate the purpose of this study.

**The aim** of the review, based on the analysis of literature data, is to determine possible classification criteria, as well as indications, contraindications for therapeutic BL in adults and their possible complications that may arise.

Russian and foreign scientific publications on indications, contraindications and methods of conducting therapeutic BL in adults were used as materials. A total of 70 literary sources on the research topic were analyzed.

## RESULTS

BL in adults is understood as a therapeutic and (or) diagnostic procedure, independent or carried out during bronchoscopy, during which the bronchopulmonary tree and (or) alveoli are washed with physiological or other solutions with possible subsequent aspiration of lavage fluid (LV), as well as its examination composition and (or) administration of drugs [28–30].

Currently, there are no clear indications and contraindications for therapeutic BL, as well as methods for its implementation. In this regard, specialists in their practical activities are forced to be guided to a greater extent by the indications and contraindications for bronchoscopy, rather than for BL.

As follows from the literature, therapeutic BL can be performed both during bronchoscopy and independently, both routinely and urgently for health reasons (emergency) [31–33]. In turn, depending on the zone of sanitation, it can be divided into tracheobronchial (sanitation) and bronchoalveolar [11, 34].

According to publications, the indications for carrying out planned therapeutic BL are:

1. Purulent bronchitis (if it is necessary to eliminate obstruction of the bronchi with mucus, pus and blood).
2. Pneumonia, including recurrent ones.
3. Lung abscesses (in the presence of pus in the intrapulmonary cavities).
4. Bronchopleural and bronchonodular fistulas.
5. Chronic lung diseases: bronchiectasis [35], interstitial lesions (lipoid pneumonia, alveolar microlithiasis and cystic fibrosis) [36–38].
6. Contamination of the respiratory tract with radioactive nuclides [39].

It should also be noted that despite the data obtained by Lukomsky G.I. et al. about the relatively low effectiveness of BL in the treatment of localized pulmonary suppuration (31.1%) due to the large number of unfavorable results and frequent complications caused by the development of resorptive syndrome and dissemination of infection in the respiratory tract [1], the use of the latter in some forms of such pathology cannot be considered unreasonable.

The indication for emergency therapeutic BL will be progressive acute or chronic respiratory failure developing due to bronchial obstruction. Such conditions may include:

1. Massive pulmonary hemorrhage.
2. Acute obstruction of the bronchi with mucus and pus, including in cystic fibrosis [1].
3. Postoperative atelectasis and pulmonary hypoventilation.
4. Aspiration of gastric contents.
5. Severe bronchial asthma, resistant to drug therapy, status asthmaticus caused by obstruction of the bronchi with viscous mucus [1].
6. Purulent destruction of the lungs [40].
7. ARDS [26, 27].
8. Thermochemical damage to the respiratory tract [41].

Moreover, in the case of BBL, it is carried out for both diagnostic and therapeutic purposes. In emergency conditions indicated in paragraph 1, RBS is performed under general anesthesia in the operating room, and in paragraphs 2–8, emergency FBS is performed through an endotracheal tube against the background of mechanical ventilation in the operating room or in the intensive care unit.

Contraindications to therapeutic BL can be both absolute and relative. Absolute contraindications are: intolerance to drugs used for local anesthesia; decompensated cardiac and pulmonary failure (myocardial infarction suffered less than 6 months ago, arterial hypertension with diastolic pressure more than 100 mm Hg, pulmonary and (or) cardiovascular failure of the third degree; bronchial asthma in the acute phase, if the interictal period is less than 3 weeks); acute cerebrovascular accident; different types of arrhythmias; stenosis of the larynx and (or) trachea II–III degree; neuropsychiatric diseases (epilepsy, schizophrenia, traumatic brain injury); pain in the abdominal cavity; an extremely serious condition of the patient, when clarification of the diagnosis can no longer affect treatment tactics.

Relative contraindications include: acute respiratory disease of the upper respiratory tract; coronary heart disease; severe diabetes mellitus; pregnancy (second half); chronic alcoholism; III degree enlargement of the thyroid gland.

It should be noted that most of the absolute contraindications are conditional and are not taken into

account when carrying out BL for health reasons with appropriate medication and technical support [28].

The classic method of performing BBL for FBS was proposed back in the mid-90s of the 20th century for diagnosing bronchopulmonary pathology. During the procedure, the bronchial tree and alveoli are washed with a sterile solution (most often physiological). The procedure allows not only to obtain bronchial secretions and cells from the deep parts of the lungs, but also to ensure the removal of cellular detritus from the bronchi and alveoli. BL involves the introduction into the bronchial cavity during bronchoscopy of LS in a volume of 100 to 300 ml, necessary to dilute the bronchial secretion and reduce its viscosity, followed by aspiration. The resulting bronchial secretion is sent to the laboratory to determine the presence of an infectious, inflammatory or tumor process, as well as to assess the severity of the disease [42].

BL during bronchoscopy can be performed using either a rigid or flexible bronchoscope. The second method is more preferable because it is less traumatic, it can be performed under local anesthesia, and patients tolerate it better. However, a flexible bronchoscope is not able to completely replace a rigid one, not only in diagnosing bronchopulmonary pathology, but also in its treatment. This is due to the fact that the aspiration channel of the fiberoptic bronchoscope is not wide enough to remove large clots of sputum and casts of thick bronchial contents. In addition, simultaneous rinsing and aspiration using significant volumes of liquid is impossible through it [1].

Carrying out BBL includes the following stages:

1. Anesthesia, which can be local, general or combined.

a) Local anesthesia. For local anesthesia, use a 2% solution of lidocaine or trimecaine. The type of anesthesia directly depends on the access used, which can be transnasal or transoral. With transnasal access, anesthesia of the lower nasal passage is carried out by aspiration or application.

b) General anesthesia. For premedication, 0.1% atropine 0.5-1.0 ml is used, intramuscularly 30 minutes or intravenously (iv) 5 minutes before the study, and for general anesthesia barbiturates are used. Then a short-acting muscle relaxant is administered. During induction of anesthesia, auxiliary ventilation is used, and after the administration of muscle relaxants, the patient is transferred to mechanical ventilation, against which the study is carried out.

2. Bronchoscopy and BL. The study is carried out in a sitting or lying position, depending on the method of anesthesia used. A fiberoptic bronchoscope is slowly inserted into the respiratory tract through the nasal or oral cavity and a visual examination of the mucous membranes of the respiratory tract is performed.

After examining the tracheobronchial tree, the fiber bronchoscope is inserted into the subsegmental or segmental bronchus, depending on the location of the segment being examined, and it is washed. In the classical version, before performing BL, the bronchus is jammed with a fiberoptic bronchoscope [42]. After that, a polyethylene catheter is inserted into the mouth of the bronchus through the biopsy canal, through which a sterile physiological or other solution heated to 36.0–37.0°C is supplied into the lumen of the segment in small portions (10.0–30.0 ml). Subsequently, the latter is completely aspirated when the vacuum is less than 100 mm Hg. [29]. The resulting liquid is a bronchial wash. Then the catheter is advanced 6.0–7.0 cm deep into the segmental bronchus, and portions of the solution are injected in fractions, which are completely aspirated each time. On average, the volume of a single administered solution is 30.0–60.0 ml with 2–3-fold administration, and the maximum volume of the total administered liquid should not exceed 300 ml.

All fluid aspirated from the lungs is lavage fluid and is collected in a sterile container for further examination. The swabs are stored at a temperature below 5.0°C for no more than 2 hours from the moment of collection. LF should not be stored in a glass container due to the possibility of macrophage adhesion, which can lead to distortion of the results of cytological examination.

Therapeutic bronchoscopy, as a rule, ends with the administration of a mucolytic and (or) antibiotic. Currently, 2.0 ml of a 5% solution of *N*-acetylcysteine is used as a mucolytic, which dilutes sputum, as a result of which it is easier and more abundant than before sanitation [35]. A new direction in BL is the use of perfluorocarbon compounds as LS. The latter have a number of unique physicochemical properties, such as high molecular weight compared to water, density (1,700–1,980 g/cm$^3$) and viscosity, as well as poor absorption and low biological activity, which can be used to remove sputum of any consistency from lower respiratory tract.

Recently, in order to increase the effectiveness of BBL, a number of authors have recommended combining it with vibrational drainage of sputum, which promotes more efficient removal of sputum in patients with severe pneumonia who are on mechanical ventilation. As studies have shown, such a combination not only improves respiratory function, reduces the intensity of the inflammatory process, but also reduces both the duration of mechanical ventilation and stay in the intensive care unit, and improves subsequent recovery [43].

3. After BL, the patient is insufflated with oxygen through a nasal catheter or endotracheal tube (in case of general anesthesia) for 10–15 minutes. 2–3 days after BL, it is recommended to perform a chest X-ray to exclude possible lung damage.

Complications during therapeutic FBS can be divided into those directly related to anesthesia, bronchoscopy, BL and the use of drugs (Table 1).

Methods with an average volume of LS used include the method of conducting BL, which consists of sequential washing of each segmental bronchus with 10.0–20.0 ml of LS with the simultaneous removal of bronchial contents. In this case, lavage is carried out first in the bronchial reservoirs of one lung, and then the other. Considering that the total number of segments is 19 (10 in the right and 9 in the left lung), the total number of LS can vary from 190.0 to 380.0 ml [29, 55, 56].

Methods with a large volume of LS may include the methods proposed by G.I. Lukomsky. et al. [1] and Thompson H.T., Prior W.J. [13]. The method proposed by Lukomsky G.I. et al., are carried out under general anesthesia and jet mechanical ventilation. Through a constantly open bronchoscope using a Friedel guide, sequential catheterization of all zonal bronchi of both lungs (lobar and B6) is performed. A catheter with a diameter of 2–2.5 mm is advanced into one of the segmental bronchi until it stops. A metal aspirator is placed next to the guide, bringing its end to the mouth of the lobar bronchus. Using a syringe, 100–150 ml of LS, warmed to body temperature, is slowly injected into the bronchus, while simultaneously tightening the catheter until the LF begins to flow through the suction. After this, while continuing to introduce LS, the catheter is again advanced deep into the bronchus, to the optimal position, which is determined by the free flow of the LF into the suction. After BL of one lobe, the catheter is moved to another lobar bronchus, and all manipulations are repeated. In total, from 500 ml to 1.5 liters of liquid are spent on washing, and 1/3–1/2 of the injected volume can be aspirated. In turn, Thompson's method involves performing BL during rigid bronchoscopy against the background of general anesthesia and mechanical ventilation, which involves the simultaneous administration of 1,500–2,000 ml of LS to liquefy bronchial secretions, followed by a single aspiration.

A similar method has been proposed for the treatment of pneumoconiosis. Sequential lavage with large volumes of saline solution of one lung is carried out against the background of oxygen ventilation of the second lung. The volume of solution for each wash is from 1000 to 2000 ml per lung [13].

*Table 1*

**Complications and adverse reactions during therapeutic bronchoscopy and bronchial lavage in adults [44–46]**

| No. | Complications/adverse reactions | | Cause |
|---|---|---|---|
| 1. | Anesthesia | Dizziness, nausea, hypotension, tachycardia, fainting, psychomotor agitation, laryngo- and bronchospasm, anaphylactic shock | Toxic-allergic reactions to drugs used for local and general anesthesia |
| 2. | Bronchoscopy | Nosebleeds, acute laryngitis | Mechanical trauma to the mucous membrane; coagulopathies |
| | | Cyanosis, hypercapnia, low $SpO_2$ and (or) tachycardia with transition to bradycardia and asystole | Hypoventilation leading to hypoxia |
| 3. | Bronchial lavage | Severe cough during manipulation | Low or high temperature lavage solution |
| | | Transient bradycardia | Reaction to catheter insertion |
| | | Fever and transient pulmonary infiltrates | The reason is not clear |
| | | Overhydration, damage to the pulmonary parenchyma (bleeding, pneumothorax), hypoxia, encephalopathy of varying severity | Excessive volume of lavage solution administered |
| 4. | Instillation of drugs | Bronchospasm, hyperthermia above 38.0°C | Allergic reactions to injected drugs |

*Table 2*

**Classification of bronchial lavage procedures used for medicinal purposes**

| No. | Classification feature | |
|---|---|---|
| 1. | According to the sanitation method | 1.1. Non-bronchoscopic<br>1.2. During bronchoscopy<br>1.2.1. Rigid<br>1.2.2. Flexible |
| 2. | By access used | 2.1. Without intubation<br>2.2. Through the laryngeal mask [26]<br>2.3. Through an endotracheal or tracheostomy tube |
| 3. | According to the level of sanitation | 3.1. Tracheobronchial<br>3.2. Bronchoalveolar<br>3.3. Combined |
| 4. | According to the sanitized area | 4.1. Segmental<br>4.2. Lobar<br>4.3. One lung<br>4.4. Two lungs |
| 5. | By volume of lavage solution used | 5.1. Small up to 100.0 ml [47–49]<br>5.2. Medium, 100.0–400.0 ml<br>5.3. Large, 400.0–4,000.0 ml<br>5.4. Very large, 4,000.0–8,000.0 |
| 6. | According to the basic lavage solution | 6.1. Physiological 0.9% NaCl solution;<br>6.2. 0.05–0.08% sodium hypochloride solution [50, 54];<br>6.3. 0.05–1% solution of dioxidine (quinoxoline derivative) [40]<br>6.4. 0.1–0.2% dioxidine solution in 2% sodium bicarbonate solution<br>6.5. 0.1–1.0% solution of potassium furagin (a nitrofuran drug) in 0.9% NaCl [1]<br>6.6. Specially prepared buffer-saline solution [51] |
| 7. | For additional medications added to the lavage solution or upon completion of bronchial lavage* | 7.1. Mucolytics<br>7.2. Antibiotics<br>7.3. Proteolytic enzymes<br>7.4. Bronchodilators<br>7.5. Immunomodulators (activated human protein *C* [48])<br>7.6. Surfactants and similar substances (Surfactant- *BL* [49], perfluorocarbon liquids [52, 53]) |

Note: * — for each of these agents, a method and regimen of administration is specified

In turn, methods with a very large volume of LS include the method presented in the patent by V.V. Agadzhanyan, et al. [51], according to which, after preliminary ventilation of two lungs with maximum inspiratory volume parameters for 15 minutes, they switch to ventilation of one lung with isolation of the second and, upon reaching normal gas exchange parameters, begin lavage of the non-ventilated lung with liquid. In this case, the volume of the first fill is 2,100–3,000 ml, the subsequent ones are 400–800 ml, and the number of lavage cycles per lung is 5–7. After the end of each cycle, the irrigated lung is ventilated using a manual ventilation device (10 breaths). To prevent overhydration and the development of pulmonary edema, diuresis is stimulated. For the same purpose, the volume of intravenous infusion is reduced to 400 ml of a 5% glucose solution. A solution consisting of: NaCl— 2.88 g, KCl— 0.08 g, $CaCl_2$— 0.04 g, $MgSO_4$— 0.024 g, $NaHCO_3$— 0.86 g, $NaH_3PO_4$— 0.024 g, $Na_2HPO_4$— 0.028 g, distilled water up to 400 ml.

It should be noted that methods of performing BL with small and medium volumes of LS are preferable, since the main disadvantage of methods with large and very large volumes is a significant amount of non-evacuated (remaining in the lungs) fluid, which can reach 600 ml or more, which can lead to complications , including those incompatible with life. Such complications may include resorptive syndrome and gas exchange disorders of varying severity [45, 46].

The development of resorptive syndrome and gas exchange disorders is due to two main reasons. The first is that, due to the physiological characteristics of the tracheobronchial tree, it is possible to maximally aspirate no more than 70–75% of the administered LS. Accordingly, the more secretion in the bronchial tree and (or) the higher its viscosity, the greater the volume of LS used. Which in turn can lead to a decrease in the respiratory surface, disruption of gas exchange in the lungs and, as a result, the development of hypoxia.

The second is associated with increased absorption as a result of BL of the contents of the tracheobronchial tree, which is due to the fact that bronchial secretions cannot be completely removed from the bronchi. The remaining secretion, mixing with the non-removable part of the LS, becomes less viscous, as a result of which its rheological properties are significantly improved, and as a result of this, its resorption in the tracheobronchial tree increases. Together with the secretion, various biologically active substances enter the bloodstream (decomposition products of pathogenic microorganisms, cells of desquamated bronchial epithelium, segmented leukocytes).

Resorptive syndrome can have varying degrees of severity, from a moderate temperature reaction to severe encephalopathy (up to loss of consciousness). Moreover, the volume of solution administered during lavage is approximately proportional to the severity of the resorptive syndrome.

In addition, the degree of destruction and (or) leaching of surfactant from the alveoli directly depends on the volume of LS used, as well as the completeness of its aspiration. This is manifested by both a temporary decrease in compliance (compliance) and an increase in the resistance of the lungs during mechanical ventilation immediately after BL, which 24–48 hours later undergo complete spontaneous involution [57]. The above disorders develop against the background of changes in the architecture of the lungs, such as capillary dilatation, alteration of alveolar cells, as well as interstitial and intracellular edema. However, *Finley T.N. et al.* (1967), based on a study of the condition of the lung tissue and the composition of the aspirate, came to the conclusion that the use of LS in a volume not exceeding 300 ml per injection followed by careful aspiration is safe for the lung parenchyma [58]. In addition, according to a number of authors, the destruction and (or) leaching of surfactant from the alveoli directly depends not only on the volume of LS used and the completeness of aspiration, but also on its physicochemical properties [59, 60].

It should also be noted that data on the effect of BL on the course of severe bronchopulmonary pathology are ambiguous [61]. Thus, if in the works of some authors [62, 63] it was shown that BBL effectively improves pulmonary mechanics and function, as well as indicators of blood gases and inflammation in patients with severe pulmonary infection on mechanical ventilation, then in the studies of others [27, 64 ] at first glance, the opposite result was obtained. However, upon detailed analysis, it is noteworthy that negative results were obtained immediately after BL at the so-called surrogate points, which does not allow a final conclusion to be made.

*Franchineau G. et al.* are of interest, according to which the negative effect of BL on regional ventilation was recorded and persisted for at least 6 hours only in patients with normal pulmonary function or mild ARDS, while with In moderate and severe cases, positive dynamics of regional ventilation, recruitment, respiratory mechanics and gas exchange in the lungs were observed [65].

All of the above indicates the need for further research aimed at identifying specific indications and contraindications for BL in specific nosological forms of severe bronchopulmonary pathology, as well as standardization and unification of methods for its implementation. It should be noted that currently only methods for administering exogenous surfactant used are standardized. for a replacement purpose in the treatment of ARDS, which in essence is the final stage of BL.

## CONCLUSION

In this study, based on an analysis of available literature data, an attempt was made to:

— systematize indications and contraindications for therapeutic bronchial lavage;

— identify and systematize the manifestations and causes of complications and adverse reactions that arise during therapeutic bronchial lavage;

— highlight the classification characteristics of therapeutic bronchial lavage in order to unify the design of standard operating procedures within a single conceptual field;

— to identify promising directions for further research in this area.

In the process of the analysis, it was found that, despite the large number of available scientific publications, as well as the widespread use of bronchial lavage for therapeutic purposes in clinical practice in adults, a number of issues such as indications, contraindications, as well as procedures for performing procedures for various conditions and diseases still remain unregulated. An exception is the final stages of therapeutic bronchial lavage procedures in the case of the use of surfactant preparations, the standardization of which is

regulated by approved standard operating procedures.

It should also be noted that bronchial lavage for therapeutic purposes is justified from a pathoanatomical and pathophysiological point of view, but is accompanied by serious, albeit temporary, changes in the lungs, which can be partially avoided by improving the lavage technique.

All of the above indicates that in order to solve existing problems, it is necessary to conduct systematic research in this direction with the involvement of all interested specialists.

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