



ORIGINAL ARTICLE

The importance of breathing techniques in preventing pulmonary complications after surgery

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ABSTRAKT

Respiratory physiotherapy is an important element in the prevention and treatment of postoperative respiratory complications, which frequently occur in patients after surgical procedures, particularly in the thoracic and abdominal areas. The aim of this study was to assess the impact of respiratory physiotherapy on reducing the risk of postoperative pulmonary complications and to determine the importance of early mobilization and patient education in the rehabilitation process. The study is based on a review of available scientific literature regarding the use of various respiratory physiotherapy methods in the postoperative period and their effectiveness in preventing pulmonary complications. The analysis of studies indicates that the use of respiratory techniques reduces the incidence of complications such as atelectasis and pneumonia, and the best therapeutic effects are achieved when breathing exercises are combined with early patient mobilization and appropriate preoperative education. The results of the review confirm that a comprehensive approach to respiratory physiotherapy increases its effectiveness in preventing postoperative complications. At the same time, the need for further research of high methodological quality is emphasized to standardize procedures and better determine the effectiveness of individual therapeutic methods.

KEYWORDS

postoperative pulmonary complications, breathing exercises, respiratory physiotherapy, incentive spirometry, postoperative rehabilitation, pulmonary prevention after surgery

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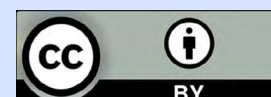
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1. Introduction

Postoperative pulmonary complications (PPCs) are one of the most common complications following surgical procedures. This term encompasses a variety of respiratory disorders occurring in the postoperative period, such as atelectasis, pneumonia, respiratory failure, bronchospasm, and exacerbation of existing lung diseases, such as chronic obstructive pulmonary disease (COPD). These complications can occur after both thoracic and non-thoracic surgeries, particularly abdominal procedures ^[1,2,3].

The incidence of postoperative pulmonary complications depends on the type of procedure, patient age, comorbidities, and perioperative treatment methods used. According to literature data, PPCs occur in approximately 5-20% of surgical patients, and in high-risk groups, this percentage may be significantly higher. Elderly patients, smokers, patients with chronic respiratory diseases, and patients undergoing extensive surgical procedures are particularly at risk ^[1,2,4].

The importance of postoperative pulmonary complications stems from their significant impact on treatment and patient prognosis. The occurrence of postoperative pulmonary complications is associated with an increased risk of mortality, prolonged hospitalization, and the need for additional diagnostic and therapeutic procedures. These complications also contribute to increased healthcare costs and a decreased quality of life for patients during recovery. Therefore, prevention of postoperative pulmonary complications is a key element of modern perioperative care ^[1,2,5].

In recent years, there has been a steady increase in the number of surgical procedures performed, which is related to the development of surgical medicine, an aging population, and the increased availability of modern surgical methods. Despite technological advances and improvements in anesthetic methods, postoperative pulmonary complications remain a significant clinical problem. Increasing attention is being paid to the importance of preventive measures undertaken both before and after surgery. Respiratory prophylaxis plays a particularly important role, aiming to maintain proper lung ventilation, prevent secretion retention in the airways, and reduce the risk of atelectasis and pulmonary infections. Properly implemented prophylaxis can reduce the number of complications and improve surgical outcomes ^[1,2,6].

A key element of preventive measures is respiratory physiotherapy, which encompasses a variety of techniques to support respiratory function. The most commonly used methods include deep breathing exercises, diaphragm training, effective coughing techniques, in-

centive spirometry exercises, and airway clearance methods. Given the growing importance of these interventions and the constantly evolving scientific knowledge, it is appropriate to analyze their effectiveness in preventing postoperative pulmonary complications ^[2,7].

2. Methodology

This study was conducted as a narrative literature review with elements of a systematic approach, aiming to critically evaluate the importance of breathing techniques in preventing pulmonary complications after surgery. Searches were performed in PubMed, Scopus, Web of Science, and Google Scholar for publications from 2018-2026 using terms including „postoperative pulmonary complications“, „breathing exercises“, „incentive spirometry“, „respiratory physiotherapy“ and „early mobilization“. Articles published in English and involving adult surgical patients were included.

3. Characteristics of Postoperative Pulmonary Complications

Postoperative pulmonary complications (PPCs) are among the most common complications following surgical procedures and constitute a significant clinical problem. Their occurrence is associated with increased morbidity and mortality, prolonged hospitalization, and increased treatment costs ^[1,2]. The risk of developing PPCs is particularly high after thoracic and abdominal surgery, but they can occur after any procedure requiring general anesthesia. The main mechanisms leading to the development of pulmonary complications include impaired ventilation, restricted diaphragmatic mobility, weakened cough reflex, airway secretion, and prolonged patient immobilization ^[4,8].

3.1. Definition and Classification of PPCs

Postoperative pulmonary complications are defined as respiratory disorders occurring in the postoperative period, negatively impacting the course of treatment and the patient's health. They may appear immediately after the procedure or develop within a few days after surgery. In clinical practice, PPC includes, among others, atelectasis, pneumonia, hypoxemia, respiratory failure, and bronchospasm ^[1,2,9].

Atelectasis is one of the most common postoperative pulmonary complications. It involves partial or complete collapse of the lung alveoli, leading to a re-

duced surface area for gas exchange. The development of atelectasis is primarily contributed to by shallow breathing caused by postoperative pain, the effects of anesthetics, and the accumulation of secretions obstructing the bronchial lumen [10,11].

Symptoms of atelectasis include shortness of breath, tachypnea, decreased oxygen saturation, and decreased alveolar murmurs over the affected lung area. Untreated atelectasis can lead to the development of pulmonary infections and a deterioration in the patient's respiratory function.

Postoperative pneumonia is a serious complication associated with infection of the lung parenchyma [1,9,11]. The development of the disease is facilitated by the accumulation of secretions in the airways, weakened body defense mechanisms, and limited physical activity after surgery. The most common symptoms include fever, cough, expectoration of sputum, shortness of breath, and deterioration in gas exchange parameters. Pneumonia can significantly prolong hospitalization, require antibiotic therapy, and increase the risk of respiratory failure. In severe cases, it poses a direct threat to the patient's life [1,2,8].

Hypoxemia refers to a decrease in the partial pressure of oxygen in arterial blood and is a common condition observed after surgical procedures. It can result from atelectasis, impaired ventilation, an abnormal ventilation-to-perfusion ratio, and the effects of drugs used during anesthesia [1,2]. Symptoms of hypoxemia include shortness of breath, increased heart rate, anxiety, weakness, and decreased oxygen saturation. In more severe cases, impaired consciousness and organ failure may occur. Early diagnosis and treatment of hypoxemia are crucial to preventing further complications.

Respiratory failure is one of the most serious postoperative pulmonary complications. It occurs when the respiratory system is unable to provide adequate gas exchange, leading to hypoxia and/or excessive carbon dioxide accumulation in the blood [1,9,12].

Causes of respiratory failure may include extensive atelectasis, severe pneumonia, exacerbation of existing lung disease, or complications related to anesthesia. Symptoms include increasing dyspnea, tachypnea, cyanosis, impaired consciousness, and significant deterioration of blood gas parameters. In many cases, oxygen therapy, noninvasive ventilation, or mechanical ventilation are necessary.

Bronchospasm is a narrowing of the airways due to contraction of bronchial smooth muscle. This complication is more common in patients with bronchial asthma, chronic obstructive pulmonary disease, or other respiratory conditions [1,2,9,12].

Factors that trigger postoperative bronchospasm include airway irritation during intubation, drug reactions, and secretion retention. Symptoms include wheezing, shortness of breath, chest tightness, and prolonged expiratory phase. Bronchospasm leads to increased airway resistance and impedes proper lung ventilation, requiring prompt diagnosis and appropriate treatment [13,14].

Postoperative pulmonary complications constitute a diverse group of disorders with a common mechanism leading to deterioration of respiratory function. Their prevention is based primarily on early implementation of rehabilitation activities, the use of breathing techniques, and patient activation within the first few days after surgery [2,6,15].

3.2. Risk Factors

The occurrence of postoperative pulmonary complications depends on many factors related to both the patient's health status and the characteristics of the surgical procedure. Identification of risk factors is crucial for planning preventive measures and implementing appropriate pulmonary rehabilitation methods. The most important factors increasing the likelihood of developing PPC include advanced patient age, comorbidities, the type and duration of surgery, the use of general anesthesia, and postoperative immobilization [1,12,13].

Advanced age is one of the most important risk factors for postoperative pulmonary complications. Aging is accompanied by a gradual deterioration of respiratory function, decreased lung tissue elasticity, and weakened respiratory muscle strength. Elderly individuals also experience decreased airway clearance and a reduced cough reflex [9,12,16].

Elderly patients are more likely to suffer from chronic diseases, which further increase the risk of postoperative complications. For this reason, older adults require special care and early implementation of preventive measures, including pulmonary rehabilitation and postoperative mobilization [1,9,12].

A significant factor increasing the risk of PPC is comorbidities affecting the respiratory and circulatory systems. Chronic obstructive pulmonary disease (COPD) is particularly important, as it leads to limited airflow, increased secretion production, and decreased respiratory function. Patients with COPD are at increased risk of developing atelectasis, pneumonia, and respiratory failure after surgical procedures [2].

Obesity is also a significant risk factor. Excess body weight limits the mobility of the diaphragm and chest, impeding proper lung ventilation. Obese patients are

more likely to experience hypoventilation, impaired gas exchange, and a higher incidence of postoperative atelectasis^[12,18].

Tobacco smoking is one of the best-documented risk factors for pulmonary complications. Tobacco smoke damages the respiratory epithelium, impairs the mucociliary mechanism, and increases the production of bronchial secretions. Smokers are more likely to experience respiratory infections, bronchospasm, and impaired tissue healing after surgery. It has been shown that quitting smoking even a few weeks before surgery can significantly reduce the risk of PPC^[19,20].

The risk of developing pulmonary complications also depends on the type of surgical procedure performed. The highest risk is observed after thoracic and upper abdominal surgeries, as these procedures directly affect respiratory mechanics and diaphragmatic function^[4,8].

The duration of surgery is also important. Long-term procedures are associated with prolonged immobilization, greater exposure to anesthetics, and a greater risk of impaired lung ventilation. The longer the surgery, the greater the likelihood of atelectasis, hypoxemia, and other respiratory disorders in the postoperative period^[4,8].

General anesthesia is one of the main factors contributing to the development of postoperative pulmonary complications. Anesthetics affect respiratory muscle function, reduce diaphragmatic tone, and limit tidal volume. Additionally, the cough reflex and airway clearance are impaired.

During anesthesia, some alveoli may collapse, which contributes to the development of atelectasis in the first few hours after surgery. After waking up, patients often breathe more shallowly due to postoperative pain, which further exacerbates ventilation disorders^[1,21].

Prolonged lying down after surgery is a significant factor contributing to the development of postoperative pulmonary complications. Physical inactivity leads to limited ventilation of the lower lungs, secretion retention, and respiratory muscle weakness. Consequently, the risk of atelectasis, pneumonia, and impaired gas exchange increases^[21].

Immobilization also adversely affects blood circulation and overall body function. For this reason, contemporary postoperative care standards emphasize the importance of early upright standing and activation of patients. Early mobilization, combined with breathing exercises, is one of the most effective ways to reduce the risk of postoperative pulmonary complications. Recognizing risk factors allows for the identification of patients requiring special care and the implementation of appropriate preventive measures. Comprehensive

treatment, including respiratory rehabilitation, patient education, and early mobilization play a key role in reducing the incidence of PPC and improving surgical outcomes^[5,6,15].

3.3. Mechanisms of Complications

Pulmonary complications following surgical procedures constitute a significant clinical problem, contributing to prolonged hospitalization, increased treatment costs, and poorer patient outcomes. The development of postoperative pulmonary complications is mainly associated with impaired ventilation, reduced lung volumes, respiratory muscle dysfunction and ineffective airway clearance.

General anesthesia and surgical trauma alter normal respiratory mechanics. Following surgery, patients frequently exhibit shallow breathing due to pain and discomfort, which reduces tidal volume and limits alveolar expansion. Consequently, lung volumes such as functional residual capacity (FRC), vital capacity (VC), and total lung capacity (TLC) decrease significantly. Restricted diaphragmatic movement and respiratory muscle weakness further impair ventilation and contribute substantially to PPC development. Weakness of the diaphragm, which is responsible for most of the work of breathing, reduces inspiratory efficiency and contributes to shallow breathing, limited effective ventilation, and impaired cough effectiveness. As a result, alveolar collapse may occur, particularly in dependent lung regions, increasing the risk of atelectasis and impaired gas exchange^[12,22,23,24].

Another important mechanism is ineffective airway clearance. Postoperative pain often suppresses deep breathing and effective coughing, while anesthesia may impair mucociliary transport through its effects on respiratory epithelial cilia. As a result, secretions accumulate within the airways, increasing the risk of small airway obstruction, atelectasis, and pulmonary infection. Retained secretions also create favorable conditions for bacterial growth and contribute to the development of postoperative pneumonia^[1,2,9].

Collectively, these physiological disturbances lead to ventilation-perfusion mismatch, impaired oxygenation, and increased susceptibility to pulmonary complications. In severe cases, they may progress to hypoxemia and respiratory failure. Understanding these mechanisms provides the physiological rationale for implementing respiratory physiotherapy and other preventive interventions during the postoperative period^[9,12,13].

4. Breathing Techniques Used After Sur-

gery

Postoperative breathing techniques are an important element in the prevention of pulmonary complications after surgical procedures. Their main goals are to improve lung ventilation, increase gas exchange efficiency, prevent secretion retention, and maintain normal respiratory muscle function. Regular respiratory physiotherapy helps reduce the risk of atelectasis, pneumonia, and respiratory failure, particularly in patients after abdominal and thoracic surgery. Both simple breathing exercises and more advanced techniques to support ventilation are used in clinical practice (Table 1) [2,5,6,25].

4.1. Deep Breathing Exercises

Deep breathing exercises are one of the basic methods of respiratory physiotherapy used in patients after surgical procedures. Their main goals are to improve lung ventilation, prevent secretion retention, and reduce the risk of postoperative pulmonary complications such as atelectasis, pneumonia, and respiratory failure. These techniques are particularly important after abdominal and thoracic surgery, where postoperative pain and limited diaphragmatic mobility lead to shallow breathing and reduced tidal volume (Table 1) [5,15,25].

4.1.1. Mechanism of Action

The mechanism of action of deep breathing exercises is based on increasing inspiratory volume and improving the function of the diaphragm and respiratory muscles. Taking slow, deep breaths increases transpulmonary pressure, allowing for more complete expansion of the alveoli. This improves ventilation in lung areas that may be insufficiently aerated after surgery due to patient immobilization, pain, or the effects of anesthetics [5,15].

Regular breathing exercises also support airway clearance by stimulating effective coughing and facilitating the removal of bronchial secretions. Furthermore, activation of the diaphragm has a beneficial effect on respiratory mechanics, reducing the work of accessory respiratory muscles and improving gas exchange [9,25]. Increasing thoracic mobility is also a key element, counteracting ventilatory limitations that develop in the postoperative period [5].

4.1.2. Impact on Lung Aeration

Deep breathing exercises play a significant role in improving lung aeration by increasing vital capacity and recruiting collapsed alveoli. Deep inhalations facilitate better airflow to the peripheral lung regions, which are particularly susceptible to atelectasis after surgery [5,15,25]. This improves the ventilation-to-perfusion ratio, resulting in more effective blood oxygenation [2,9].

Table 1. Characteristics of breathing techniques used in the prevention of postoperative pulmonary complications

Breathing technique	Main mechanism of action	Main clinical benefits	Limitations
Deep breathing exercises	Increase inspiratory volume and alveolar recruitment; improve diaphragmatic function	Improved lung aeration, increased vital capacity, reduced risk of atelectasis	Require patient cooperation and regular practice
Effective cough training	Facilitates airway clearance and secretion removal	Prevention of secretion retention, reduced risk of pneumonia, improved airway patency	Postoperative pain may limit effectiveness
Incentive spirometry	Visual feedback encourages sustained deep inspiration and alveolar expansion	Improved lung ventilation, increased inspiratory capacity, reduced atelectasis risk	Effectiveness depends on adherence and proper technique; limited benefit when used alone
Positive expiratory pressure (PEP) therapy	Maintains positive airway pressure during expiration, preventing airway collapse	Improved secretion mobilization, enhanced ventilation, reduced airway resistance	Requires specific equipment and patient training
Active Cycle of Breathing Techniques (ACBT)	Combines breathing control, thoracic expansion exercises, and forced expiration techniques	Effective airway clearance, improved ventilation, reduced secretion retention	Requires instruction and patient understanding

Research indicates that regular deep breathing exercises reduce the incidence of postoperative pulmonary complications and shorten hospitalization. Particularly beneficial effects are observed in patients who are mobilized early after surgery and regularly perform exercises under the supervision of medical personnel. In clinical practice, these exercises are often combined with other respiratory physiotherapy methods, such as effective cough training, patient mobilization, or incentive spirometry [6,26].

4.2. Effective Cough Training

Effective cough training is an essential element of respiratory physiotherapy used after surgical procedures. Its primary goal is to improve the clearance of retained secretions from the airways and prevent the development of pulmonary complications. After surgical procedures, especially those involving the thoracic and abdominal cavity, patients often avoid coughing due to postoperative pain, weakened respiratory muscles, and limited chest mobility. This leads to secretions becoming trapped in the airways and increases the risk of infection (Table 1) [2,9,27,28].

4.2.1. Airway Clearance

An effective cough enables the mechanical removal of secretions, microorganisms, and debris from the bronchi. A properly performed cough consists of a deep inhalation, a short air retention, and a forceful exhalation with the glottis partially closed. This mechanism increases airway pressure and creates a powerful airflow, which pushes secretions toward the upper airways, facilitating expectoration [29,30].

In the postoperative period, patients are instructed on how to cough safely and less painfully. A technique for stabilizing the surgical wound is often used, by supporting the surgical site with hands or a special pillow during coughing. This technique reduces pain and increases the effectiveness of bronchial tree clearance. Regular effective cough training improves airway patency and supports proper lung ventilation [2,23,27,31].

4.2.2. Preventing Secretion Retention

One of the most important goals of effective cough training is to prevent secretion retention in the airways. After surgery, the cough reflex is often weakened and the patient's motor activity is reduced, which promotes mucus accumulation in the bronchi. Retained secretions can lead to occlusion of the small bronchi, the development of atelectasis, and lower respiratory tract infections, including postoperative pneumonia [2,9,32].

Regular cough exercises support the removal of secretions and improve lung ventilation. Combined with deep breathing exercises and early patient mobilization, effective cough training significantly reduces the risk of respiratory complications. Patient education before surgery and in the early postoperative period is particularly important, as proper cough technique increases the effectiveness of therapy and accelerates recovery [2,5,6].

4.3. Incentive Spirometry

Incentive spirometry is a respiratory physiotherapy method used to prevent postoperative pulmonary complications. It involves the patient taking slow, deep breaths using a special device – an incentive spirometer. This technique aims to increase tidal volume, improve lung ventilation, and prevent atelectasis and secretion retention in the airways. Incentive spirometry is particularly common after abdominal and thoracic surgical procedures, where the risk of ventilation disturbances is the highest (Table 1) [2,5,7,9].

4.3.1. Principles of Use

Proper use of incentive spirometry requires appropriate patient instruction and regular exercise training. During therapy, the patient should assume a sitting or semi-sitting position and then take a slow, deep inhalation through the device's mouthpiece, trying to maintain the appropriate airflow. After reaching maximum inhalation, a brief air retention is recommended, which promotes better alveolar expansion. The patient then exhales calmly [2,5,33,34].

Exercises should be performed regularly, usually several times per hour in the postoperative period, as recommended by the medical staff. An important element of therapy is motivating the patient to systematically perform the exercises and monitoring their technique. Incentive spirometry is often combined with other respiratory physiotherapy methods, such as deep breathing exercises, effective cough training, and early patient mobilization [2,7,33,35].

4.3.2. Benefits and Limitations

The most important benefits of incentive spirometry include improved lung aeration, increased vital capacity, and a reduced risk of postoperative atelectasis. Regular exercise promotes alveolar recruitment, improves gas exchange, and facilitates the clearance of secretions from the airways. This method can also shorten hospitalization and improve breathing comfort in patients after surgical procedures [2,5,7,9,36].

Despite its numerous advantages, the effectiveness of incentive spirometry depends largely on patient compliance and proper exercise performance. Limitations of this method include postoperative pain, patient weakness, or a lack of motivation to exercise regularly. Some studies also indicate that incentive spirometry alone may be insufficient in preventing pulmonary complications if not used concurrently with other elements of pulmonary rehabilitation. Therefore, its use is recommended as part of a comprehensive postoperative treatment plan ^[2,5,9,33,35].

4.4. Positive Expiratory Pressure (PEP) Exercises

Positive expiratory pressure (PEP) exercises are one of the respiratory physiotherapy methods used in the prevention and treatment of postoperative pulmonary complications. This technique involves exhaling against the resistance generated by a special device, which creates positive airway pressure. PEP therapy is particularly useful in patients prone to secretion retention, atelectasis, and ventilation disorders following surgical procedures (Table 1) ^[1,2,37].

4.4.1. Mechanism of Action

The mechanism of action of PEP therapy is based on maintaining positive airway pressure during exhalation. The pressure generated prevents premature closure of small bronchi and alveoli, helping to maintain their patency and improving lung ventilation. This increases tidal volume and improves aeration in areas of the lungs at risk of collapse ^[2,38].

Positive expiratory pressure also supports the mobilization of retained secretions in the airways. Increased airflow during exhalation facilitates the movement of mucus from the peripheral bronchial tree to the larger bronchi, from where it can be effectively expectorated. PEP therapy may improve gas exchange and reduce respiratory resistance, which positively impacts the patient's breathing comfort in the postoperative period ^[2,37,39].

4.4.2. Clinical Applications

Positive expiratory pressure exercises are widely used in the care of post-surgical patients, especially after thoracic, cardiac, and abdominal surgery. This method is particularly recommended for patients at increased risk of pulmonary complications, such as the elderly, smokers, and patients with chronic respiratory conditions ^[41].

In clinical practice, PEP therapy can be performed using various devices, including traditional PEP masks

or mouthpieces, as well as oscillation systems that additionally generate vibrations that aid in the separation of secretions from the bronchial walls. Exercises are typically performed in series under the supervision of a physiotherapist or medical staff, and their effectiveness is enhanced by the simultaneous use of other respiratory rehabilitation methods, such as deep breathing exercises, effective cough training, and early patient mobilization ^[2,37,41].

Clinical studies suggest that PEP therapy may improve ventilation parameters and may contribute to reducing postoperative respiratory complications, particularly when used as part of multimodal respiratory rehabilitation. However, the effectiveness of this method depends on appropriate patient selection, correct exercise technique, and systematic therapy ^[3].

4.5. Active Cycle of Breathing Technique (ACBT)

Active Cycle of Breathing Techniques (ACBT) is a respiratory physiotherapy method used to improve lung ventilation and clear airways of retained secretions. This method is widely used in patients after surgery, especially when there is an increased risk of postoperative pulmonary complications. ACBT combines various breathing techniques into a structured cycle that allows for effective secretion removal while reducing excessive patient fatigue (Table 1) ^[5,41,42].

4.5.1. Technique Components

ACBT consists of three basic components: breathing control, exercises to increase tidal volume, and the forced expiration technique.

The first stage is breathing control, which involves calm, regular breathing using the diaphragm. The goal of this stage is to reduce respiratory muscle tension, reduce shortness of breath, and prepare the patient for subsequent exercise stages ^[2,41].

The second stage involves exercises to increase tidal volume, which involves taking several deep breaths with brief air retention. This technique promotes alveolar expansion, improves ventilation, and supports the movement of secretions from the peripheral lungs to the larger bronchi ^[43].

The third stage is the forced expiratory technique, also known as „huffing.” It involves performing a vigorous exhalation with an open glottis, which allows secretions to be moved toward the upper airways without excessive strain on the patient. If necessary, the cycle can be completed with an effective cough to clear the secretions ^[43].

The individual elements of ACBT are performed alternately, allowing for gradual clearing of the bronchial tree and improving the patient's respiratory capacity [2,41].

4.5.2. Indications for Use

Active cycle breathing techniques are primarily used in patients with retained secretions in the airways and ventilation disorders following surgical procedures [5,41,42]. They are particularly common after thoracic, cardiac, and abdominal procedures, where postoperative pain and limited chest mobility hinder effective breathing and coughing [5,42]. ACBT is also recommended for patients with chronic respiratory diseases, such as chronic obstructive pulmonary disease, cystic fibrosis, or bronchiectasis, who are at increased risk of secretion retention [41]. In the postoperative setting, this technique helps prevent atelectasis, pneumonia, and other complications related to mucus retention in the airways [5,42].

Advantages of ACBT include the ability for patients to independently perform exercises after prior instruction and the ability to tailor the intensity of therapy to the patient's condition [41,42]. The technique's effectiveness increases when combined with other respiratory rehabilitation methods, such as deep breathing exercises, effective cough training, or early postoperative mobilization [2,5].

4.6. Patient Mobilization and Respiratory Reeducation

Patient mobilization and respiratory reeducation are important elements of postoperative management aimed at preventing pulmonary complications [2,5,44]. Prolonged immobilization after surgery leads to impaired lung ventilation, weakened respiratory muscles, and an increased risk of secretion retention in the airways [2,35,44]. Early initiation of physical activity and learning the proper breathing pattern have a beneficial effect on respiratory function and accelerate the recovery process (Table 1) [2,15,44].

4.6.1. Early Verticalization

Early verticalization involves mobilizing the patient as quickly as possible after surgery, in accordance with their clinical condition and the recommendations of the therapeutic team [2,5,44]. This process involves a gradual transition from a lying to a sitting position, then verticalization, and initial attempts at walking [2,44]. Modern postoperative care standards emphasize the

importance of mobilizing the patient as early as possible, often as early as the first 24 hours after surgery [5].

Verticalization has a beneficial effect on respiratory mechanics by increasing diaphragmatic mobility and improving ventilation of the lower lungs. It also reduces the risk of atelectasis by enabling better expansion of the alveoli and improving the ventilation-to-perfusion ratio [2,44]. Early mobilization also supports the effective removal of secretions from the respiratory tract and reduces the risk of pulmonary infections [2,5].

An additional benefit of verticalization is improved blood circulation and the prevention of complications related to immobilization, such as venous thrombosis and muscle weakness [5,44]. In clinical practice, verticalization is often combined with breathing exercises and patient education on proper breathing [2,5,41].

4.6.2. The Importance of Physical Activity

Physical activity plays a significant role in preventing postoperative pulmonary complications. Regular exercise increases the frequency and depth of breathing, which promotes better lung aeration and improves gas exchange [2,41,44]. Physical activity also supports the function of respiratory muscles and facilitates the clearance of retained secretions from the airways [2,37,41].

Respiratory re-education involves learning the correct breathing pattern, primarily diaphragmatic breathing, which allows for more efficient use of lung capacity [2,41]. These exercises help reduce the shallow breathing pattern characteristic of the postoperative period, most often resulting from pain and sparing the surgical site [2,5,44]. Proper breathing technique reduces the use of accessory respiratory muscles and improves patient comfort [2,41].

Early mobilization and respiratory re-education are now considered fundamental elements of comprehensive postoperative rehabilitation [2,5,44]. Their regular use contributes to a reduction in the incidence of atelectasis, pneumonia, and other respiratory complications, and also contributes to a shorter hospital stay and a faster patient recovery [2,5].

5. Effectiveness of breathing techniques in light of scientific research

Assessing the effectiveness of breathing techniques used after surgical procedures is an important element of current research on the prevention of postoperative pulmonary complications [2,5,45]. Numerous scientific publications analyze the impact of respiratory phy-

siotherapy on improving lung ventilation, reducing the risk of atelectasis and pneumonia, and shortening hospital stays in patients after surgical procedures [2,5,44]. Methods such as deep breathing exercises, incentive spirometry, positive expiratory pressure (PEP) techniques, active cycle of breathing (ACBT), and early patient mobilization are particularly important [2,25,45]. However, despite the overall positive findings reported in the literature, the level of evidence supporting individual interventions varies significantly.

5.1. Analysis of Clinical Studies

The effectiveness of breathing techniques used after surgical procedures is the subject of numerous clinical trials and scientific analyses [2,5,44]. Current reports indicate that properly conducted respiratory physiotherapy can significantly reduce the risk of postoperative pulmonary complications, improve ventilation parameters, and accelerate patient recovery. The most frequently evaluated methods include deep breathing exercises, incentive spirometry, positive expiratory pressure (PEP) techniques, active cycle of breathing (ACBT), and early patient mobilization [2,5,15].

5.1.1. Results of randomized controlled trials

Randomized controlled trials indicate that regular use of breathing techniques after surgery has a beneficial effect on respiratory function and reduces the number of pulmonary complications [2,5,15]. Particularly good results were observed in patients after abdominal and thoracic surgery, who are at the highest risk of atelectasis and pneumonia [5,44].

Numerous studies have shown that deep breathing exercises and incentive spirometry improve lung vital capacity, increase oxygen saturation, and support alveolar recruitment [5,25,45]. Patients who practiced regular breathing exercises required less frequent prolonged oxygen therapy and had shorter hospital stays compared to control groups [2,5,15].

However, interpretation of these findings requires caution, as there is a lack of strong evidence supporting incentive spirometry as a standalone intervention. Although it is widely implemented in clinical practice, current literature suggests that its isolated use does not consistently provide superior outcomes compared with standard breathing exercises or general postoperative care. This indicates that incentive spirometry should be considered a supportive tool rather than an independent preventive strategy.

Studies on PEP therapy and ACBT techniques confirm their effectiveness in clearing the airways and preventing secretion retention [37,41]. A reduced incidence

of postoperative pneumonia and improved coughing efficiency have been observed in patients undergoing comprehensive pulmonary rehabilitation. Early patient mobilization is also considered crucial, as it improves lung ventilation and reduces the effects of prolonged immobilization [2,5,44]. Despite numerous positive results, some studies indicate that the effectiveness of individual techniques may depend on the type of surgery, the patient's age, comorbidities, and the patient's level of involvement in the rehabilitation process [2,5,45]. The importance of individually tailoring a breathing exercise program to the patient's needs is also emphasized [2,44].

Importantly, airway clearance techniques such as ACBT and PEP appear to be more effective in secretion removal than incentive spirometry alone, particularly in patients with increased mucus production or impaired cough function. Their direct influence on mucus mobilization and airway patency addresses one of the key mechanisms of postoperative complications more effectively than inspiratory training alone.

Despite numerous positive results, outcomes across studies remain inconsistent due to heterogeneity of rehabilitation protocols, including differences in exercise frequency, duration, supervision, and patient education. This variability reduces the reliability of direct comparisons between studies and contributes to divergent conclusions regarding the effectiveness of individual techniques. Moreover, patient-related factors such as age, comorbidities, type of surgery, and level of adherence further influence outcomes.

5.1.2. Meta-analyses and systematic reviews

Meta-analyses and systematic reviews constitute a significant source of knowledge regarding the effectiveness of breathing techniques in the prevention of postoperative pulmonary complications. The results of many studies confirm that comprehensive respiratory physiotherapy reduces the risk of developing atelectasis, pneumonia, and respiratory failure after surgical procedures [2,5,15,44].

Particularly beneficial effects are achieved when combining various therapeutic methods, such as deep breathing exercises, effective cough training, incentive spirometry, and early patient mobilization [2,5,41]. The authors of the reviews emphasize that multimodal rehabilitation strategies are more effective than single interventions, highlighting the importance of addressing multiple physiological mechanisms simultaneously [2,5,45].

However, some meta-analyses indicate limited effectiveness of incentive spirometry alone, when used without additional forms of rehabilitation [5,25,45]. Attention is drawn to the need for appropriate patient in-

struction and systematic exercise performance, as the lack of patient cooperation significantly reduces the effects of therapy [2,44,45].

Current clinical recommendations emphasize the importance of a multifaceted approach to the prevention of pulmonary complications after surgical procedures. Respiratory physicians, combined with early patient activation and appropriate pain management, is considered a fundamental element of effective postoperative care [2,5,44].

Although most studies report beneficial effects of respiratory physiotherapy, considerable heterogeneity exists regarding intervention protocols, outcome measures, and patient populations. Therefore, direct comparison between studies remains difficult and may partly explain inconsistencies in the reported effectiveness of individual techniques.

5.2. Comparison of the Effectiveness of Individual Methods

Current research indicates that the effectiveness of breathing techniques used after surgical procedures

may vary depending on the type of method used, the nature of the surgical procedure, and the patient's clinical condition [2,5,15]. In postoperative practice, the most common comparisons are the effectiveness of incentive spirometry, breathing exercises, and comprehensive respiratory physiotherapy encompassing several therapeutic methods simultaneously [2,5,45]. The aim of these analyses is to determine which procedure most effectively reduces the risk of postoperative pulmonary complications and improves patients' respiratory function (Table 2) [2,5,44].

5.2.1. Incentive Spirometry vs. Breathing Exercises

Incentive spirometry and traditional breathing exercises are among the most commonly used methods for the prevention of postoperative pulmonary complications. Both techniques aim to improve lung ventilation, increase tidal volume, and prevent atelectasis, but they differ in their method of execution and therapeutic impact [2,5].

Clinical studies indicate that deep breathing exercises effectively improve chest wall mobility and activate the diaphragm, which promotes better alveolar expansion.

Table 2. Hierarchical ranking of respiratory physiotherapy methods used in the prevention of postoperative pulmonary complications based on clinical effectiveness and strength of available evidence

Level of effectiveness	Method	Primary mechanism of action	Clinical effectiveness (summary)	Strength of evidence
1 (highest)	Multimodal physiotherapy + early mobilization	Combined effect: lung recruitment, secretion clearance, improved ventilation-perfusion, prevention of immobilization effects	Most effective strategy; reduces overall PPC risk; superior to single interventions	High (consistent evidence from reviews and guidelines)
2	Airway clearance techniques: Active Cycle of Breathing Technique (ACBT), Positive Expiratory Pressure therapy (PEP)	Mobilization and removal of airway secretions; prevention of airway collapse; improvement of mucus clearance	Highly effective in patients with secretion retention; reduces risk of atelectasis and pneumonia	Moderate to high (strong mechanistic and clinical support, but heterogeneous protocols)
3	Deep breathing exercises / respiratory re-education	Alveolar recruitment, increased tidal volume, improved diaphragmatic function	Effective in improving lung aeration and preventing atelectasis; limited effect on secretion clearance	Moderate (consistent but not superior alone vs multimodal care)
4 (lowest)	Incentive Spirometry	Visual feedback-guided deep inspiration and lung expansion	Limited and inconsistent evidence as a standalone intervention	Low to moderate (heterogeneous and inconclusive results)

sion ^[1,2]. This technique is simple, requires no specialized equipment, and can be performed by virtually any patient after appropriate instruction. Numerous studies have shown that regular practice of breathing exercises leads to improved ventilation parameters and a reduced risk of developing atelectasis and pneumonia ^[2,5].

Incentive spirometry, on the other hand, involves taking controlled deep breaths using a special device that allows for a visual assessment of the exercise's effectiveness. Proponents of this method emphasize its motivating nature and the ability to monitor the patient's progress. Some studies indicate that incentive spirometry improves vital lung capacity and promotes alveolar recruitment ^[2]. However, some scientific analyses have not demonstrated a significant advantage of this method over traditional breathing exercises performed without a device ^[5,25,45]. The literature emphasizes that the effectiveness of incentive spirometry depends primarily on the consistency of exercises and proper patient instruction. If patient compliance is insufficient, the effects of therapy may be limited. This is consistent with findings suggesting limited additional benefit of IS when used in isolation, reinforcing the need for multimodal rehabilitation strategies ^[2,5].

5.2.2. The Impact of Comprehensive Physiotherapy

A growing number of studies indicate that comprehensive respiratory physiotherapy, encompassing the simultaneous use of various therapeutic methods, achieves the greatest effectiveness in preventing postoperative pulmonary complications. Rehabilitation programs most often combine deep breathing exercises, effective cough training, incentive spirometry, PEP techniques, ACBT, and early patient mobilization ^[2,5].

Comprehensive treatment addresses multiple mechanisms responsible for the development of pulmonary complications ^[5]. Breathing exercises improve lung ventilation and increase breathing capacity, airway clearance techniques facilitate secretion removal, and early upright positioning supports diaphragm function and reduces the effects of immobilization ^[1,2]. Combining various methods can achieve better therapeutic results than using a single technique. Clinical studies show that patients receiving comprehensive respiratory physiotherapy are less likely to develop atelectasis and pneumonia and recover more quickly after surgery ^[2,5]. Shorter hospital stays and a reduced need for prolonged oxygen therapy have also been observed ^[5]. These beneficial effects are particularly evident in high-risk patients, such as the elderly, smokers, and patients with chronic respiratory diseases ^[2,5].

Current clinical recommendations emphasize that effective prevention of postoperative pulmonary complications should be based on an individually tailored and multifaceted rehabilitation program. Patient education, appropriate pain management, and close collaboration with the therapeutic team are also crucial. This can increase the effectiveness of therapy and improve patient safety in the postoperative period ^[2,5].

5.3. Limitations of Available Research

Despite numerous studies confirming the beneficial effects of breathing techniques on the prevention of postoperative pulmonary complications, the available scientific literature has many limitations that hinder a clear assessment of the effectiveness of individual methods. These problems primarily concern small study groups, significant heterogeneity in the therapeutic techniques used, and methodological differences between individual studies. These factors make it difficult to compare results and limit the ability to formulate universal clinical recommendations ^[2,5].

One of the most frequently highlighted limitations of respiratory physiotherapy studies is the small sample size. Many analyses involve relatively small numbers of patients, which reduces the statistical power of the obtained results and makes it difficult to demonstrate significant differences between the therapeutic methods studied.

Small patient groups also limit the ability to generalize the results to a broader population of postoperative patients. This is particularly true for patients with various comorbidities, the elderly, and patients undergoing different types of surgery. As a result, the effectiveness of specific breathing techniques may be difficult to clearly assess in different clinical groups. An additional problem is the frequent lack of long-term patient follow-up. Many studies focus solely on the early postoperative period, making it difficult to assess the lasting effects of pulmonary rehabilitation and its impact on subsequent respiratory function ^[1,2,5,46].

Another significant limitation of the studies is the significant heterogeneity of the therapeutic methods used. Individual studies differ in the type of breathing techniques used, the frequency of exercises, the duration of therapy, and the rehabilitation approach. Some analyses evaluate single methods, while others employ comprehensive rehabilitation programs encompassing several techniques simultaneously.

Differences also apply to the characteristics of the patient groups studied. The studies include patients who underwent various types of surgery, such as cardiac, thoracic, or abdominal surgery. Each of these gro-

ups is characterized by a different risk of pulmonary complications and a different response to pulmonary rehabilitation. This hinders direct comparison of results and assessment of the effectiveness of specific therapeutic methods.

Heterogeneity of studies also applies to the criteria for assessing the effects of therapy. Different publications analyze different parameters, such as the incidence of atelectasis, oxygen saturation levels, length of hospitalization, and spirometry test results. The lack of uniform assessment standards hinders accurate comparative analyses and the development of consistent clinical recommendations [2,5,15].

The scientific literature also highlights numerous methodological issues in studies on breathing techniques. One of these is the difficulty of conducting double-blind studies, which stems from the specific nature of respiratory physiotherapy. Patients and therapists typically know which method is being used, which can influence subjective assessments of therapy effectiveness.

A lack of standardization of treatment procedures is also a common problem. Differences in physiotherapists' experience, patient instruction, and patient engagement can influence the final study results. The effectiveness of breathing techniques depends largely on proper exercise performance and regularity of therapy.

Some studies are also limited by the lack of appropriate control groups or insufficient randomization of participants. This can lead to the risk of bias and hinder objective assessment of the effectiveness of the studied methods. Furthermore, some analyses are based on short follow-up periods, which prevents assessment of the long-term benefits of pulmonary rehabilitation.

Despite these limitations, most available studies indicate a beneficial effect of respiratory techniques in the prevention of postoperative pulmonary complications. However, further multi-center studies conducted according to uniform methodological standards are necessary to more precisely determine the effectiveness of individual methods and develop optimal postoperative rehabilitation models [2,5].

6. The Role of Medical Staff in the Prevention of PPC

Postoperative pulmonary complications (PPC) constitute a significant clinical problem, affecting the course of treatment, length of hospitalization, and prognosis for patients after surgical procedures [1,5]. Effective prevention of these complications requires the involvement of the entire therapeutic team, including

physicians, nurses, and physiotherapists [1,2]. Physiotherapists play a particularly important role in assessing the patient's respiratory function, planning rehabilitation, and teaching techniques to support proper lung ventilation [2,47]. Proper collaboration between medical staff and the patient reduces the risk of pulmonary complications and accelerates the recovery process [1,2,47].

6.1. Physiotherapist Responsibilities

Physiotherapists play a key role in the prevention of postoperative pulmonary complications, both preoperatively and postoperatively [5,47]. Their primary responsibilities include assessing the patient's functional status, identifying risk factors for pulmonary complications, and developing an individualized pulmonary rehabilitation program.

Physiotherapists also monitor therapy progress, modifying methods based on the patient's needs, and collaborating with other members of the therapeutic team [2,47].

The modern approach to postoperative rehabilitation assumes the patient's active participation in the treatment process. Therefore, a key element of a physiotherapist's work is not only providing exercises but also educating the patient and building their motivation to regularly perform the recommended preventive measures [2,47].

Patient education is one of the most important elements of PPC prevention [2,5]. It should begin preoperatively, when the patient has the opportunity to familiarize themselves with the principles of pulmonary rehabilitation and learn basic exercises [47]. Research indicates that individuals who are properly prepared for surgery cooperate better with medical staff and are more willing to participate in the postoperative rehabilitation process [2,47].

As part of the education, the physiotherapist provides information on the importance of breathing exercises, effective coughing techniques, and the need for early mobilization after surgery [2,5]. The patient is instructed on how to properly take deep breaths, use an incentive spirometer, and protect the postoperative wound when coughing. An important aspect of education also includes explaining the consequences of physical inactivity and failure to follow rehabilitation recommendations [2,47].

Appropriate education increases the patient's health awareness and improves their engagement in the treatment process. This allows for better therapeutic outcomes and reduces the risk of respiratory complications [2,47].

Another important task of the physiotherapist is selecting appropriate therapeutic techniques tailored to the patient's individual needs ^[2,47]. This process requires consideration of many factors, such as the type of surgery performed, the patient's age, respiratory function, postoperative pain level, and the presence of comorbidities ^[2,5].

For patients at risk of atelectasis, deep breathing exercises and incentive spirometry, which aim to improve lung aeration, may be particularly important ^[1,5]. For patients prone to secretion retention, a physiotherapist may use effective cough techniques, ACBT, or exercises using positive expiratory pressure (PEP) ^[2,7]. Early upright standing and gradual increase in the patient's physical activity are also important elements of therapy.

The selection of therapeutic methods should be regularly reviewed and modified depending on rehabilitation progress. Individualized treatment maximizes treatment effects and increases patient safety. Collaboration between physiotherapists, physicians, and nurses enables a comprehensive approach to PPC prevention and is a key element of modern postoperative care ^[2,5,47].

6.2. Collaboration within the Therapeutic Team

Effective prevention of postoperative pulmonary complications requires close cooperation among all members of the therapeutic team ^[2,5]. Comprehensive management includes the physician, nurse, and physiotherapist, who are jointly responsible for preparing the patient for surgery, monitoring their condition after surgery, and implementing appropriate preventive measures ^[2,47]. Interdisciplinary collaboration allows for the rapid identification of risk factors, proper treatment planning, and increased effectiveness of rehabilitation ^[1,47].

The physician is responsible for assessing the patient's overall health, qualifying them for surgery, and identifying factors that increase the risk of postoperative pulmonary complications. Based on the interview, physical examination, and diagnostic test results, the physician determines the level of surgical risk and makes decisions regarding perioperative management.

During the postoperative period, the physician monitors the patient's condition, monitors the course of treatment, and prescribes appropriate preventive and rehabilitation measures. Effective postoperative pain management also plays a significant role, as pain relief allows the patient to perform breathing exercises, cough effectively, and mobilize early ^[2,5].

The nurse plays an important role in the daily care of patients after surgery. Their responsibilities include monitoring vital signs, observing the patient's respiratory status, and early recognition of symptoms that may indicate developing pulmonary complications.

A crucial element of the nurse's work is supporting the patient in performing prescribed breathing exercises and encouraging physical activity. The nurse reminds the patient to perform exercises regularly, helps them adopt appropriate positions to facilitate breathing, and supports the process of standing upright. Through constant contact with the patient, they can also assess their level of commitment to rehabilitation and report any difficulties to other members of the treatment team ^[2,47].

A physiotherapist is responsible for planning, conducting, and monitoring pulmonary rehabilitation. Based on a functional assessment, they select appropriate therapeutic techniques, taking into account the patient's clinical condition and the type of surgical procedure performed.

The physiotherapist's main responsibilities include teaching breathing exercises, effective cough training, conducting therapy using incentive spirometry, PEP techniques, or ACBT, and implementing an early mobilization program. The physiotherapist monitors the effectiveness of the methods used, assesses the patient's progress, and modifies the treatment plan as needed. Their actions aim to improve lung ventilation, prevent secretion retention, and reduce the risk of postoperative pulmonary complications ^[2,5,47].

6.3. Patient Education

Proper preparation of the patient for the procedure and providing knowledge about pulmonary rehabilitation increase the effectiveness of preventive measures and improve patient cooperation with medical staff. Awareness of the purpose of the exercises and knowledge of postoperative management contribute to greater patient engagement in the treatment process ^[2,5,47].

Preoperative preparation includes providing the patient with information regarding the rehabilitation process and the importance of preventive measures after surgery ^[5]. During this period, the patient should be familiarized with the risk of pulmonary complications and the benefits of breathing exercises and early mobilization.

For patients in high-risk groups, it is recommended to begin breathing training before the procedure ^[48,49,50]. This allows for mastering proper exercise technique and increases the patient's willingness to actively participate

in postoperative rehabilitation. Preoperative education also reduces anxiety associated with the procedure and improves the patient's sense of security.

A key element of education is detailed instruction on performing breathing exercises. The patient should learn proper diaphragmatic breathing, deep inhalation, effective coughing, and the use of an incentive spirometer, if included in the treatment plan.

Instruction should include both theoretical and practical components [47]. Demonstration of exercises by a physiotherapist and the opportunity to perform them independently under specialist supervision allow for the correction of any errors and increase the effectiveness of subsequent therapy [2,48]. Patients should also receive information regarding the frequency of exercise and the importance of consistency in the rehabilitation process [47]. Properly conducted education and instruction increase the effectiveness of postoperative pulmonary complication prevention, improve patient cooperation with medical staff, and contribute to a faster return to full function after surgery [2,5,47].

7. Discussion

The literature review indicates that postoperative pulmonary complications remain one of the most significant clinical problems occurring after surgical procedures. Their presence is associated with increased patient morbidity and mortality, prolonged hospitalization, and increased treatment costs. The results of available research confirm that appropriate respiratory prophylaxis can significantly reduce the risk of these complications and contribute to improved surgical outcomes.

7.1. Interpretation of Research Results

The analysis of clinical trials, meta-analyses, and systematic reviews demonstrated that respiratory techniques are an effective tool for preventing postoperative pulmonary complications. Particularly beneficial effects were observed in reducing the incidence of atelectasis, improving ventilation parameters, and reducing the risk of postoperative pneumonia [2,6].

The study results indicate that deep breathing exercises effectively increase tidal volume and improve lung aeration [2,5]. Effective cough training is also considered important, as it supports airway clearance and reduces secretion retention [1,2]. Beneficial effects have also been demonstrated with techniques utilizing positive expiratory pressure (PEP) and active cycle breathing (ACBT),

particularly in patients at risk of bronchial secretion retention [51].

However, an analysis of the available literature indicates that the effectiveness of individual methods may vary. In the case of incentive spirometry, research results are inconsistent. Some authors emphasize its beneficial effect on improving lung ventilation, while other studies have not demonstrated a significant advantage of this method over traditional breathing exercises. This may be due to methodological differences between studies and the degree of patient engagement in the rehabilitation process [52].

7.2. The Importance of Respiratory Prophylaxis in Clinical Practice

Respiratory prophylaxis currently plays a significant role in modern perioperative care. Its importance stems primarily from its potential to reduce the incidence of postoperative pulmonary complications and improve the safety of patients undergoing surgical procedures [2,5].

Regular practice of breathing exercises contributes to improved lung ventilation, increased respiratory capacity, and the maintenance of normal respiratory muscle function [2,48]. Techniques that support airway clearance reduce the risk of secretion retention and infection, while early mobilization reduces the negative effects of postoperative immobilization [2,5].

The importance of respiratory prevention is particularly significant in patients belonging to high-risk groups, such as the elderly, patients with chronic obstructive pulmonary disease, obese patients, and smokers [5,47]. In these groups, properly conducted pulmonary rehabilitation can significantly reduce the number of complications and improve recovery [47,48].

Patient education is also a crucial element of effective prevention. Awareness of the importance of breathing exercises and the patient's active participation in the rehabilitation process increase the effectiveness of therapeutic interventions and contribute to improved treatment outcomes [2,47].

7.3. Possibilities of Implementing Postoperative Physiotherapy Standards

The results of the analyzed studies indicate the merits of implementing uniform respiratory physiotherapy standards in postoperative care [5,47]. Standardization of procedures could improve the quality of patient care and reduce variations in rehabilitation methods used between centers [5].

Implementation of these standards should include assessing the risk of postoperative pulmonary compli-

cations before surgery, patient education, early initiation of breathing exercises, and systematic mobilization of the patient after surgery ^[5,47]. It is also important to ensure collaboration between physicians, nurses, and physiotherapists, as only an interdisciplinary approach allows for optimal therapeutic outcomes.

In clinical practice, individualization of rehabilitation is particularly important. The physiotherapy program should be tailored to the type of surgery, the patient's age, respiratory function, and the presence of comorbidities ^[5,47]. This approach increases the effectiveness of therapy and allows for a better response to the needs of individual patients ^[47].

7.4. Directions for Further Research

Despite the growing number of publications on the prevention of postoperative pulmonary complications, further research is still needed. In particular, multi-center randomized trials involving larger patient groups are necessary to more clearly assess the effectiveness of individual breathing techniques ^[5,53].

Future research should focus on comparing comprehensive rehabilitation programs and determining the optimal frequency, duration, and intensity of breathing exercises ^[47,48]. Another important area of research is assessing the effectiveness of modern technologies supporting rehabilitation, such as mobile applications, telemedicine systems, and electronic devices monitoring exercise performance ^[54,55].

It is also worthwhile to conduct research on the effectiveness of individual methods in specific patient groups, including the elderly, patients with chronic respiratory diseases, and patients undergoing various types of surgical procedures ^[5,47]. This will allow for the development of more precise clinical recommendations and further improvement of postoperative rehabilitation standards ^[5].

In summary, an analysis of the current literature indicates that breathing techniques are an effective element in the prevention of postoperative pulmonary complications. The greatest benefits come from a comprehensive approach that includes breathing exercises, airway clearance techniques, and early patient mobilization ^[5,47]. Implementing these methods into daily clinical practice can improve surgical outcomes, shorten hospital stays, and increase patient safety ^[5,48].

The most effective strategy for preventing postoperative pulmonary complications is a multimodal approach combining early mobilization with respiratory physiotherapy techniques. Airway clearance methods such as ACBT and PEP appear more effective than incentive spirometry in patients with secretion retention,

whereas incentive spirometry alone shows limited and inconsistent evidence of clinical benefit.

8. Conclusions

Current evidence suggests that respiratory physiotherapy is an effective component of perioperative care and may reduce the incidence of postoperative pulmonary complications, particularly when delivered as part of a comprehensive rehabilitation program. The use of breathing techniques after surgical procedures improves lung ventilation, facilitates the removal of secretions from the respiratory tract, and reduces the risk of complications such as atelectasis and pneumonia.

Comprehensive rehabilitation programs combining breathing exercises with early patient mobilization are most effective. This approach promotes faster recovery of respiratory function, improves functional capacity, and may shorten hospitalization. Patient education before a planned surgical procedure is also a crucial element of effective therapy. Appropriate patient preparation increases patient engagement in the rehabilitation process and improves the effectiveness of exercises. The results of the analyzed studies confirm that respiratory physiotherapy should be an integral element of perioperative care, particularly in patients at increased risk of pulmonary complications. At the same time, it is important to emphasize the need for further research of high methodological quality, which will allow for the development of uniform standards of practice and a more precise determination of the effectiveness of individual respiratory physiotherapy methods in various patient groups.

References

1. Lusquinhos, J., Tavares, M., & Abelha, F. (2023). Postoperative Pulmonary Complications and Perioperative Strategies: A Systematic Review. *Cureus*, 15(5), e38786. <https://doi.org/10.7759/cureus.38786>
2. Dhillon, G., Buddhavarapu, V. S., Grewal, H., Munjal, R., Verma, R. K., Surani, S., & Kashyap, R. (2023). Evidence-based Practice Interventions for Reducing Postoperative Pulmonary Complications: A Narrative Review. *The open respiratory medicine journal*, 17, e18743064271499. <https://doi.org/10.2174/012210299X247199231128100613>
3. Huang, C., Zhao, X., Geng, S., Sun, S., Mousa, N. M., Xia, H., Xu, X., Deng, J., Lu, X., Xu, D., Zhao, B., Lim,

- M., Li, Y., Tang, W., Chen, X., Smith, F. G., Tang, C., & Feng, X. (2026). Non-drug perioperative interventions to reduce postoperative pulmonary complications after abdominal surgery: systematic review and meta-analysis. *BMJ (Clinical research ed.)*, 393, e089001. <https://doi.org/10.1136/bmj-2025-089001>
4. Chandler, D., Mosieri, C., Kallurkar, A., Pham, A. D., Okada, L. K., Kaye, R. J., Cornett, E. M., Fox, C. J., Urban, R. D., & Kaye, A. D. (2020). Perioperative strategies for the reduction of postoperative pulmonary complications. Best practice & research. *Clinical anaesthesiology*, 34(2), 153-166. <https://doi.org/10.1016/j.bpa.2020.04.011>
5. Odor, P. M., Bampoe, S., Gilhooly, D., Creagh-Brown, B., & Moonesinghe, S. R. (2020). Perioperative interventions for prevention of postoperative pulmonary complications: systematic review and meta-analysis. *BMJ (Clinical research ed.)*, 368, m540. <https://doi.org/10.1136/bmj.m540>
6. Boden, I., Reeve, J., Jernas, A., Denehy, L., & Fagevik Olsen, M. (2024). Preoperative physiotherapy prevents postoperative pulmonary complications after major abdominal surgery: a meta-analysis of individual patient data. *Journal of physiotherapy*, 70(3), 216-223. <https://doi.org/10.1016/j.jphys.2024.02.012>
7. Chang, P. C., Chen, P. H., Chang, T. H., Chen, K. H., Jhou, H. J., Chou, S. H., & Chang, T. W. (2023). Incentive spirometry is an effective strategy to improve the quality of postoperative care in patients. *Asian journal of surgery*, 46(9), 3397-3404. <https://doi.org/10.1016/j.asjsur.2022.11.030>
8. Piccioni, F., Spagnesi, L., Pelosi, P., Bignami, E., Guarnieri, M., Fumagalli, L., Polati, E., Schweiger, V., Comi, D., D'Andrea, R., Di Marco, P., Spadaro, S., Antonelli, S., Sollazzi, L., Mirabella, L., Schiavoni, M., Laici, C., Marelli, J. A., Fabiani, F., Ball, L., ... PPCs Investigators Group (2023). Postoperative pulmonary complications and mortality after major abdominal surgery. An observational multicenter prospective study. *Minerva anesthesiologica*, 89(11), 964-976. <https://doi.org/10.23736/S0375-9393.23.17382-2>
9. Junaidi, B., Hawrylak, A., & Kaw, R. (2024). Evaluation and Management of Perioperative Pulmonary Complications. *The Medical clinics of North America*, 108(6), 1087-1100. <https://doi.org/10.1016/j.mcna.2024.04.003>
10. Zeng, C., Lagier, D., Lee, J. W., & Vidal Melo, M. F. (2022). Perioperative Pulmonary Atelectasis: Part I. Biology and Mechanisms. *Anesthesiology*, 136(1), 181-205. <https://doi.org/10.1097/ALN.0000000000003943>
11. Lagier, D., Zeng, C., Fernandez-Bustamante, A., & Vidal Melo, M. F. (2022). Perioperative Pulmonary Atelectasis: Part II. Clinical Implications. *Anesthesiology*, 136(1), 206-236. <https://doi.org/10.1097/ALN.0000000000004009>
12. Tuna, M.E., Akgun, M. Preoperative pulmonary evaluation to prevent postoperative pulmonary complications. *APS* 1, 34 (2023). <https://doi.org/10.1007/s44254-023-00034-2>
13. Palermo, J., Tingey, S., Khanna, A. K., & Segal, S. (2024). Evaluation and Prevention of Perioperative Respiratory Failure. *Journal of clinical medicine*, 13(17), 5083. <https://doi.org/10.3390/jcm13175083>
14. Mazzotta, E., Soghomonyan, S., & Hu, L. Q. (2023). Postoperative sore throat: prophylaxis and treatment. *Frontiers in pharmacology*, 14, 1284071. <https://doi.org/10.3389/fphar.2023.1284071>
15. Wang, J., Li, H., Yan, W., Xue, N., Yin, J., Nawshehwan, & Yin, S. (2024). Prehabilitation Interventions for Cardiac Surgery to Prevent Postoperative Pulmonary Complications: Systematic Review and Meta-Analysis. *Iranian journal of public health*, 53(10), 2167-2179. <https://doi.org/10.18502/ijph.v53i10.16683>
16. Schneider, J. L., Rowe, J. H., Garcia-de-Alba, C., Kim, C. F., Sharpe, A. H., & Haigis, M. C. (2021). The aging lung: Physiology, disease, and immunity. *Cell*, 184(8), 1990-2019. <https://doi.org/10.1016/j.cell.2021.03.005>
17. Turan, A., Mascha, E. J., Roberman, D., Turner, P. L., You, J., Kurz, A., Sessler, D. I., & Saager, L. (2011). Smoking and perioperative outcomes. *Anesthesiology*, 114(4), 837-846. <https://doi.org/10.1097/ALN.0b013e318210f560>
18. Choi, J. Y., Al-Saedy, M. A., & Carlson, B. (2023). Positive end-expiratory pressure and postoperative complications in patients with obesity: a review and meta-analysis. *Obesity (Silver Spring, Md.)*, 31(4), 955-964. <https://doi.org/10.1002/oby.23675>
19. Harrogate, S., Barnes, J., Thomas, K., Isted, A., Kunst, G., Gupta, S., Rudd, S., Banerjee, T., Hinchliffe, R., & Mouton, R. (2023). Peri-operative tobacco cessation interventions: a systematic review and meta-analysis. *Anaesthesia*, 78(11), 1393-1408. <https://doi.org/10.1111/anae.16120>
20. Tang, E., Rodriguez, R. M., Srivastava, A., Malhan, R., Laksono, I., Yan, E., Englesakis, M., Wong, J., & Chung, F. (2025). Impact of short duration smoking cessation on post-operative complications: A systematic review and meta-analysis. *Journal of clinical anesthesia*, 106, 111967. <https://doi.org/10.1016/j.jcline.2025.111967>
21. Buonanno, P., Marra, A., Iacovazzo, C., Vargas, M., Coviello, A., Squillacioti, F., Nappi, S., de Siena, A. U., & Servillo, G. (2023). Impact of ventilation strategies on pulmonary and cardiovascular complications in pa-

- tients undergoing general anaesthesia for elective surgery: a systematic review and meta-analysis. *British journal of anaesthesia*, 131(6), 1093-1101. <https://doi.org/10.1016/j.bja.2023.09.011>
22. Hu, J., Guo, R., Li, H., Wen, H., & Wang, Y. (2024). Perioperative Diaphragm Dysfunction. *Journal of clinical medicine*, 13(2), 519. <https://doi.org/10.3390/jcm13020519>
 23. Norskov, J., Skaarup, S.H., Bendixen, M. et al. Diaphragmatic dysfunction is associated with postoperative pulmonary complications and phrenic nerve paresis in patients undergoing thoracic surgery. *J Anesth* 38, 386-397 (2024). <https://doi.org/10.1007/s00540-024-03325-5>
 24. Liu, H.M., Yu, H., Zuo, Y.D. et al. Postoperative pulmonary complications after sugammadex reversal of neuromuscular blockade: a systematic review and meta-analysis with trial sequential analysis. *BMC Anesthesiol* 23, 130 (2023). <https://doi.org/10.1186/s12871-023-02094-0>
 25. Ababneh, Q. M., Abdelrahman, H., & Abdelhameed, M. E. (2025). Effectiveness of Incentive Spirometry Versus Deep Breathing Exercises in Preventing Postoperative Pulmonary Complications After Abdominal Surgery: A Comprehensive Review. *Cureus*, 17(3), e80149. <https://doi.org/10.7759/cureus.80149>
 26. Liao, B., Liao, W., Yin, S., Liu, S., & Wu, X. (2024). Effect of ultrasound-guided lung recruitment to reduce pulmonary atelectasis after non-cardiac surgery under general anesthesia: a systematic review and meta-analysis of randomized controlled trials. *Perioperative medicine (London, England)*, 13(1), 23. <https://doi.org/10.1186/s13741-024-00379-7>
 27. Li, X., Li, X., Zhang, W., Liu, Q., Gao, Y., Chang, R., & Zhang, C. (2021). Factors and potential treatments of cough after pulmonary resection: A systematic review. *Asian journal of surgery*, 44(8), 1029-1036. <https://doi.org/10.1016/j.asjsur.2021.01.001>
 28. Wu, Y., Song, W., Zhu, D., Wang, Y., & Che, G. (2023). Risk factors for cough after pulmonary resection. *World journal of surgical oncology*, 21(1), 348. <https://doi.org/10.1186/s12957-023-03235-y>
 29. McGarvey, L., Rubin, B. K., Ebihara, S., Hegland, K., Rivet, A., Irwin, R. S., Bolser, D. C., Chang, A. B., Gibson, P. G., Mazzone, S. B., & CHEST Expert Cough Panel (2021). Global Physiology and Pathophysiology of Cough: Part 2. Demographic and Clinical Considerations: 14013-1423. <https://doi.org/10.1016/j.chest.2021.04.039>
 30. Hill, D. B., Button, B., Rubinstein, M., & Boucher, R. C. (2022). Physiology and pathophysiology of human airway mucus. *Physiological reviews*, 102(4), 1757-1836. <https://doi.org/10.1152/physrev.00004.2021>
 31. Singh, V., Agumbe Pai, S., & Hosmath, V. (2023). Clinical outcome of patients undergoing preoperative chest physiotherapy in elective upper abdominal surgeries. *Journal of perioperative practice*, 33(6), 182-189. <https://doi.org/10.1177/17504589211045225>
 32. Ko, E., Yoo, K. Y., Lim, C. H., Jun, S., Lee, K., & Kim, Y. H. (2023). Is atelectasis related to the development of postoperative pneumonia? a retrospective single center study. *BMC anesthesiology*, 23(1), 77. <https://doi.org/10.1186/s12871-023-02020-4>
 33. Franklin E, Anjum F. Incentive Spirometer and Inspiratory Muscle Training. [Updated 2023 Apr 27]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2026 Jan.- Available from: https://www.ncbi.nlm.nih.gov/sites/books/NBK572114/?utm_source=chatgpt.com
 34. Kotta, P. A., & Ali, J. M. (2021). Incentive Spirometry for Prevention of Postoperative Pulmonary Complications After Thoracic Surgery. *Respiratory care*, 66(2), 327-333. <https://doi.org/10.4187/respcare.07972>
 35. Silva, H. V. C., Lunardi, A. C., Pinto, A. C. P. N., Macedo, J. R. F. F., & Santos, E. D. C. D. (2024). Is Incentive Spirometry Superior to Standard Care in Postoperative Cardiac Surgery on Clinical Outcomes and Length of Hospital and Intensive Care Unit Stay? A Systematic Review with Meta-Analysis. *Brazilian journal of cardiovascular surgery*, 39(3), e20220319. <https://doi.org/10.21470/1678-9741-2022-0319>
 36. Zorrilla-Vaca, A., Grant, M. C., Urman, R. D., & Frendl, G. (2022). Individualised positive end-expiratory pressure in abdominal surgery: a systematic review and meta-analysis. *British journal of anaesthesia*, 129(5), 815-825. <https://doi.org/10.1016/j.bja.2022.07.009>
 37. Coppola, D.P., Schloss, J., Suggett, J.A. et al. Non-Pharmaceutical Techniques for Obstructive Airway Clearance Focusing on the Role of Oscillating Positive Expiratory Pressure (OPEP): A Narrative Review. *Pulm Ther* 8, 1-41 (2022). <https://doi.org/10.1007/s41030-021-00178-1>
 38. Xu, Z., Han, Z. & Ma, D. Efficacy and safety of long-term use of a positive expiratory pressure device in chronic obstructive pulmonary disease patients, a randomized controlled trial. *BMC Pulm Med* 23, 17 (2023). <https://doi.org/10.1186/s12890-023-02319-5>
 39. Rocamora-Pérez, P., Benzo-Iglesias, M. J., Valverde-Martínez, M. L. Á., García-Luengo, A. V., Aguilar-Parra, J. M., Trigueros, R., & López-Liria, R. (2022). Effectiveness of positive expiratory pressure on patients over 16 years of age with cystic fibrosis: systematic review and meta-analysis. *Therapeutic advances in respiratory disease*, 16, 17534666221089467. <https://doi.org/10.1177/17534666221089467>

40. You, J., Jiang, B., Dai, N., Lu, B., Zhao, C., & Zheng, Z. (2024). Effects of oscillatory positive expiratory pressure therapy in patients undergoing thoracic or upper abdominal surgery: A systematic review and meta-analysis. *Heliyon*, 10(18), e37798. <https://doi.org/10.1016/j.heliyon.2024.e37798>
41. Zisi, D., Chrysanthopoulos, C., Nanas, S., & Philipou, A. (2022). The effectiveness of the active cycle of breathing technique in patients with chronic respiratory diseases: A systematic review. *Heart & lung : the journal of critical care*, 53, 89-98. <https://doi.org/10.1016/j.hrtlng.2022.02.006>
42. Zhong, J., Zhang, S., Li, C., Hu, Y., Wei, W., Liu, L., Wang, M., Hong, Z., Long, H., Rong, T., Yang, H., & Su, X. (2022). Active cycle of breathing technique may reduce pulmonary complications after esophagectomy: A randomized clinical trial. *Thoracic cancer*, 13(1), 76-83. <https://doi.org/10.1111/1759-7714.14227>
43. Ning, G., Sihan, C., Daihong, J., Zhilong, Z., Aihua, Z., Liting, L., & Heling, G. (2025). Effect of position management combined with active cycle of breathing techniques on reducing postoperative pulmonary complications in lung cancer patients. *BMC cancer*, 25(1), 1780. <https://doi.org/10.1186/s12885-025-15029-4>
44. Kokotovic, D., Berkfors, A., Gögenur, I., Ekelöf, S., & Burcharth, J. (2021). The effect of postoperative respiratory and mobilization interventions on postoperative complications following abdominal surgery: a systematic review and meta-analysis. *European Journal of Trauma and Emergency Surgery*, 47, 975-990. <https://doi.org/10.1007/s00068-020-01522-x>
45. Sullivan, K. A., Churchill, I. F., Hylton, D. A., & Hanna, W. C. (2021). Use of Incentive Spirometry in Adults following Cardiac, Thoracic, and Upper Abdominal Surgery to Prevent Post-Operative Pulmonary Complications: A Systematic Review and Meta-Analysis. 1159/000517012
46. Xiang, Y., Zhao, Q., Luo, T., & Zeng, L. (2023). Inspiratory muscle training to reduce risk of pulmonary complications after coronary artery bypass grafting: a systematic review and meta-analysis. *Frontiers in cardiovascular medicine*, 10, 1223619. <https://doi.org/10.3389/fcvm.2023.1223619>
47. Bingül, E. S., Şentürk, N. M., & Kaynar, A. M. (2023). Prehabilitation: a narrative review focused on exercise therapy for the prevention of postoperative pulmonary complications following lung resection. *Frontiers in medicine*, 10, 1196981. <https://doi.org/10.3389/fmed.2023.1196981>
48. Assouline, B., Cools, E., Schorer, R., Kayser, B., Elia, N., & Licker, M. (2021). Preoperative Exercise Training to Prevent Postoperative Pulmonary Complications in Adults Undergoing Major Surgery. A Systematic Review and Meta-analysis with Trial Sequential Analysis. *Annals of the American Thoracic Society*, 18(4), 678-688. <https://doi.org/10.1513/AnnalsATS.202002-1830C>
49. Cook, A., Smith, L., Anderson, C., Ewing, N., Gammack, A., Pecover, M., Sime, N., & Galley, H. F. (2023). The effect of Preoperative threshold inspiratory muscle training in adults undergoing cardiac surgery on postoperative hospital stay: a systematic review. *Physiotherapy theory and practice*, 39(4), 690-703. <https://doi.org/10.1080/09593985.2022.2025548>
50. Huang, Y. T., Lin, Y. J., Hung, C. H., Cheng, H. C., Yang, H. L., Kuo, Y. L., Chu, P. M., Tsai, Y. F., & Tsai, K. L. (2022). The fully engaged inspiratory muscle training reduces postoperative pulmonary complications rate and increased respiratory muscle function in patients with upper abdominal surgery: a randomized controlled trial. *Annals of medicine*, 54(1), 2222-2232. <https://doi.org/10.1080/07853890.2022.2106511>
51. Dolic, D., & Salvitti, S. (2026). Efficacy of positive expiratory pressure in the prevention and treatment of postoperative pulmonary complications following thoracic and abdominal surgery. A systematic review and meta-analysis. *Monaldi archives for chest disease = Archivio Monaldi per le malattie del torace*, 96(2), 10.4081/monaldi.2026.3735. <https://doi.org/10.4081/monaldi.2026.3735>
52. Zhao, C. H., Sun, Y. H., & Mao, X. M. (2023). Volume Incentive Spirometry Reduces Pulmonary Complications in Patients After Open Abdominal Surgery: A Randomized Clinical
53. Xu, X., Cheung, D. S. T., Smith, R., Lai, A. Y. K., & Lin, C. C. (2022). The effectiveness of pre- and post-operative rehabilitation for lung cancer: A systematic review and meta-analysis on postoperative pulmonary complications and length of hospital stay. *Clinical rehabilitation*, 36(2), 172-189. <https://doi.org/10.1177/02692155211043267>
54. Reyhler, G., Piraux, E., Beaumont, M., Caty, G., & Liistro, G. (2022). Telerehabilitation as a Form of Pulmonary Rehabilitation in Chronic Lung Disease: A Systematic Review. *Healthcare (Basel, Switzerland)*, 10(9), 1795. <https://doi.org/10.3390/healthcare10091795>
55. Uzzaman, M. N., Agarwal, D., Chan, S. C., Patrick Engkasan, J., Habib, G. M. M., Hanafi, N. S., Jackson, T., Jebaraj, P., Khoo, E. M., Mirza, F. T., Pinnock, H., Shunmugam, R. H., & Rabinovich, R. A. (2022). Effectiveness of home-based pulmonary rehabilitation: systematic review and meta-analysis. *European*

respiratory review : an official journal of the European Respiratory Society, 31(165), 220076. <https://doi.org/10.1183/16000617.0076-2022>

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