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Review Article

Pulmonary Rehabilitation: A Cornerstone in Post-Lung Cancer Surgery Care

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Abstract

Lung cancer remains a leading cause of cancer-related mortality globally, and surgical resection is a primary treatment for early-stage disease. Postoperative pulmonary complications (PPCs) significantly impact patient outcomes and recovery. Pulmonary rehabilitation (PR) has emerged as a critical intervention to mitigate the adverse effects of lung resection and enhance overall well-being. This review synthesizes current evidence on PR for post-lung cancer surgery patients, encompassing its benefits, implementation challenges, and future research directions. While existing studies demonstrate the efficacy of PR in improving pulmonary function, exercise capacity, and quality of life, the optimal program design and long-term outcomes require further investigation. Large-scale randomized controlled trials, standardized PR protocols, and patient-centered research are essential to advance the field and optimize PR delivery for post-lung cancer patients.

Key words: pulmonary rehabilitation; lung cancer; postoperative complications; exercise; quality of life

1.Introduction

Lung cancer, a malignant neoplasm originating from the bronchial mucosa or glands, poses a significant global health burden [1]. As reported by the World Health Organization (WHO), it remains the leading cause of cancer-related mortality in 87 countries, with a staggering 1.79 million deaths attributed to the disease in 2020 alone [2]. This underscores the urgent need for comprehensive strategies to prevent, detect, and manage lung cancer.

Despite advancements in diagnostic and therapeutic modalities, surgical resection remains the cornerstone of curative treatment for early-stage non-small cell lung cancer (NSCLC) [3]. However, pulmonary resection is associated with substantial morbidity, including a heightened risk of postoperative pulmonary complications (PPCs) such as pneumonia, respiratory failure, and atelectasis [4, 5]. These complications significantly impact patient outcomes, prolong hospital stays, increase healthcare costs, and diminish quality of life [6].

To mitigate the adverse sequelae of lung resection and optimize patient recovery, pulmonary rehabilitation (PR) has emerged as a critical component of postoperative care. A growing body of evidence supports the efficacy of PR in improving pulmonary function, exercise tolerance, and overall well-being in patients with lung cancer [7, 8]. By addressing physical, psychological, and educational needs, PR aims to reduce the incidence and severity of PPCs, facilitate a faster return to independence, and enhance long-term survival [9]. This review comprehensively examines the current state of knowledge regarding PR for post-lung cancer surgery patients, highlighting its benefits, challenges, and future directions.

2.Problems After Lung Cancer Surgery

Surgical resection of lung tissue, while curative in early-stage NSCLC, inevitably results in physiological alterations that compromise pulmonary function. This functional impairment manifests as dyspnea, reduced exercise capacity, and diminished quality of life [10]. Moreover, the invasive nature of lung surgery predisposes patients to a range of postoperative complications, including pneumonia, respiratory failure, and pulmonary embolism, which can significantly prolong hospital stays, increase healthcare costs, and elevate mortality rates [11, 12].

A retrospective analysis revealed that the incidence of postoperative complications within 30 days of lung resection can be as high as 58%, with a mortality rate of 3.6% during the same period [13]. These findings

underscore the substantial burden of postoperative morbidity and mortality associated with lung cancer surgery and highlight the imperative for effective interventions, such as pulmonary rehabilitation, to optimize patient outcomes.

3. Concepts and Training Methods Related to Pulmonary Rehabilitation

3.1 Concepts Related to Pulmonary Rehabilitation

Pulmonary rehabilitation (PR) is a multidisciplinary, evidence-based intervention designed to improve the physical and psychological well-being of individuals with chronic respiratory conditions [11, 12]. The concept of PR emerged in the mid-20th century, with the American College of Chest Physicians introducing the term in 1974 [11]. Since then, the field has evolved significantly, with a growing body of evidence supporting its efficacy.

A seminal consensus statement by the American Thoracic Society (ATS) and the European Respiratory Society (ERS) in 2013 defined PR as a comprehensive program that includes but is not limited to exercise training, education, and behavior modification [12]. This program is tailored to the individual patient based on a thorough assessment of their respiratory condition, functional status, and psychosocial needs. The overarching goal of PR is to optimize functional status, reduce symptoms, and enhance the overall quality of life for individuals with chronic respiratory diseases.

Beyond its physical benefits, PR plays a crucial role in addressing the psychological and social impact of chronic respiratory conditions. By providing education and support, PR empowers patients to manage their disease, adhere to treatment plans, and participate actively in their healthcare. Importantly, PR is applicable across the spectrum of respiratory diseases, including various stages of lung cancer, demonstrating its versatility and potential to improve outcomes for a wide range of patients.

The National Institute for Health and Clinical Excellence (NICE) guidelines have further underscored the importance of PR in reducing mortality and pulmonary complications, while improving lung function in patients with chronic respiratory diseases [13, 14]. These guidelines highlight the cost-effectiveness of PR and emphasize its role as a cornerstone of comprehensive care for individuals with respiratory conditions.

3.2. Pulmonary rehabilitation training methods and evaluation indicators

3.2.1. Training methods

At present, the methods of postoperative pulmonary rehabilitation training adopted in clinical practice vary. Because pulmonary rehabilitation training contains a lot of content, many researchers develop personalized training methods based on the specific conditions of patients and research purposes. Pulmonary rehabilitation training mainly includes exercise training, health education, nutritional support and psychological education. Its core is exercise training. According to the different parts of the exercise, exercise training can be divided into upper limb training and lower limb training. Upper limb training methods include finger wall climbing exercises, elbow flexion and extension exercises, upper limb weight lifting, etc.; lower limb training methods include walking, climbing stairs, jogging and cycling, etc.

According to the purpose of training, exercise training can be divided into: endurance training, interval training, resistance training, respiratory muscle exercise and balance training [15]. Endurance training is recommended to be performed at least 3 times a week for 8 weeks. The most common endurance training mode is walking (ground walking and stationary cycling); interval training consists of high-intensity exercise (20 s to 30 min) and rest or lower-intensity training (30 s to 30 min), including cycling and walking [16]. Interval training during cycling or walking avoids the need for long rest periods, thereby minimizing interruptions to the exercise process and can be completed with less dyspnea and leg fatigue [16-18]. Resistance training refers to the activation of local muscle groups in relatively high-load repetitive weightlifting exercises [15]. Resistance training is recommended to be performed 1 to 3 sets of 8 to 12 repetitions per set 2 or 3 days a week [19], including resistance training of the upper and lower limbs. Common respiratory muscle exercises include pursed lip/abdominal breathing, yoga gymnastics, balloon blowing, etc. [20]. There is no consensus on the optimal duration of respiratory muscle training, but most studies provide a total exercise duration of 30 to 60 minutes per day, usually 2 to 3 times, and an average of 3 to 7 days per week [21]. Balance training is becoming an adjunct to traditional PR training programs [15]. Balance training includes circuit training such as standing exercises and gait transitions.

3.2.2. Evaluation indicators

1) Functional exercise capacity: The 6-minute walk test (6 MWT) is used to assess functional and motor capacity. The test is performed according to published guidelines and the better of 16 and 2 attempts is recorded [22]. A 30-meter corridor is used and the patient is instructed to walk as far as possible in 6 minutes. Standardized encouragement is given at the end of each minute. Oxygen saturation and pulse rate are continuously monitored throughout the test, and the modified Borg volume is used immediately after the test to quantify the degree of dyspnea and leg fatigue.

2) Skeletal muscle strength: Handgrip strength (HF) and quadriceps strength (QF) were measured as indicators of skeletal muscle strength. 1 HF was assessed using a dynamometer. The patient was required to squeeze the dynamometer with maximal force for at least 5 seconds. After 1 exercise attempt, HF was tested twice with at least 60 seconds of rest between each attempt. The highest value of the 2 attempts for both hands was recorded (kg). Cardiac strength was measured for both limbs to consider the potential impact of postoperative pain on the operated side. During the test, the patient stood upright with his feet hip-width apart, elbows fully extended, holding the dynamometer, wrist in neutral position, and index finger flexed 90˚. 2 Quadriceps strength was assessed as the peak force generated by the leading leg during a seated maximal isometric knee extension exercise using a handheld dynamometer with a strap, and the highest value of at least 2 maneuvers was recorded and expressed in kilograms feet (kgf).

3) Respiratory function: The respiratory function of patients was tested by spirometry, including forced vital capacity (FVC), forced expiratory volume in 1 second (FEV1), percentage of forced expiratory volume in 1 second to predicted value (FEV1%), and ratio of forced expiratory volume in 1 second to forced vital capacity (FEV1/FVC) [23].

4) Quality of life: The core quality of life scale (EORTC QLQ-C30) was used to assess the quality of life of patients. The scale has 5 dimensions (physical, emotional, role, cognitive, and social) and 30 items. Each item is scored on a scale. The higher the overall score, the higher the quality of life of the patient.

4. Current status of pulmonary rehabilitation (PR) after lung cancer surgery

Pulmonary rehabilitation (PR) is a minimally invasive treatment intervention that provides patients with a variety of tools to improve

respiratory symptoms and quality of life [24,25]. Studies have shown that exercise training can improve the exercise capacity and quality of life of lung cancer patients undergoing surgery [26]. Xu Haijiang et al. [27] believed that the combination of osimertinib and pulmonary rehabilitation training can improve the lung function of patients with non-small cell lung cancer (NSCLC) who underwent radical resection of lung cancer, reduce their postoperative morbidity, and thus improve their quality of life, which is conducive to reducing the medical burden on patients and society. A meta-analysis [28] included 8 randomized controlled trials to explore the effects of aerobic exercise and resistance training on patients after lung cancer surgery. The study showed that exercise training can improve the exercise capacity and quadriceps strength of patients after lung resection of non-small cell lung cancer. In a randomized controlled trial by Scott et al. [29], lung cancer survivors with poor cardiopulmonary fitness (CFR) were included in 48 three-week continuous supervised courses, which included aerobic training (AT), combined training (CT) and resistance training (RT). The study showed that AT and CT significantly improved the peak maximum oxygen uptake (Vo2) of lung cancer survivors. At the same time, multiple studies have shown that pulmonary rehabilitation can also improve quality of life, forced expiratory volume in 1 second and forced vital capacity, and reduce lung cancer complications and mortality [30-33]. In addition, most lung cancer patients have nutritional problems to varying degrees. PR provides an opportunity to educate patients to maintain a proper diet [24]. The combination of increased calorie intake, exercise, and in some cases the use of anabolic steroids may lead to significant weight gain. Due to calorie intake, more high-protein foods need to be eaten. Protein is broken down into amino acids by the human body. These amino acids are absorbed by the body and can be synthesized into muscle through proper exercise, thereby increasing weight. In addition, since lung cancer patients have a large nutritional demand after surgery, standardized nutritional intervention can reduce the degree of protein breakdown in the patient's body, avoid deterioration of nutritional status, and achieve the purpose of maintaining and gradually improving nutritional status [34].

5. Limitations of Postoperative Pulmonary Rehabilitation

While the extant literature demonstrates the potential benefits of pulmonary rehabilitation (PR) in enhancing lung function and exercise capacity among post-lung cancer surgery patients, several limitations persist.

Methodological Challenges:

Heterogeneity of Study Designs: The existing body of evidence is characterized by heterogeneity in study designs, including variations in participant selection criteria, intervention modalities, and outcome measures. This heterogeneity impedes the establishment of robust conclusions regarding the optimal PR program and its effectiveness.

Small Sample Sizes: Many studies suffer from limited sample sizes, which can reduce statistical power and limit the generalizability of findings. Larger-scale randomized controlled trials (RCTs) are needed to provide more definitive evidence.

Lack of Long-Term Outcomes: Most studies focus on short-term outcomes, such as changes in pulmonary function and exercise capacity. There is a dearth of research investigating the long-term effects of PR on quality of life, survival, and healthcare utilization.

Adherence Challenges: Ensuring patient adherence to PR programs remains a significant obstacle. Factors such as physical limitations, comorbidities, psychological distress, and lack of social support can hinder patient engagement.

Clinical Implementation Gaps:

Standardized Protocols: The absence of standardized PR protocols hampers the ability to compare outcomes across studies and implement evidence-based practices consistently.

Access and Delivery: Geographic disparities in access to PR services and variations in the delivery of care models contribute to inconsistent outcomes.

Integration with Cancer Care: Integrating PR into the continuum of cancer care is essential but remains a challenge. Effective collaboration between surgeons, oncologists, and rehabilitation specialists is crucial for optimal patient management.

Resource Constraints: Limited resources, including personnel, facilities, and funding, can impede the widespread implementation of PR programs.

Future Research Directions:

Addressing these limitations requires a concerted effort to conduct well-designed RCTs with larger sample sizes, investigate long-term outcomes, and develop standardized PR protocols. Moreover, research focused on identifying patient-specific factors influencing PR adherence and developing strategies to enhance engagement is warranted. By overcoming these challenges, the field can advance the implementation of effective PR programs for post-lung cancer surgery patients.

6. Summary and Outlook

Pulmonary rehabilitation (PR) has emerged as a critical component of post-lung cancer surgery care. Accumulating evidence underscores its efficacy in improving pulmonary function, exercise tolerance, and quality of life, thereby enhancing patient outcomes and reducing the burden of postoperative complications.

However, the current body of evidence on PR for post-lung cancer patients remains limited. While existing studies have demonstrated the benefits of PR, the optimal program design, including intensity, duration, and components, requires further investigation. Additionally, the long-term effects of PR on patient outcomes, such as survival and recurrence, warrant exploration.

To advance the field of pulmonary rehabilitation in post-lung cancer care, several key areas warrant future research:

Large-scale randomized controlled trials: Conducting rigorously designed randomized controlled trials with adequate sample sizes is essential to establish the efficacy and cost-effectiveness of PR programs.

Standardized PR protocols: Developing standardized PR protocols tailored to the specific needs of post-lung cancer patients will facilitate the implementation and evaluation of PR programs across different healthcare settings.

Longitudinal studies: Investigating the long-term impact of PR on patient outcomes, including quality of life, functional status, and survival, is crucial to inform clinical practice and healthcare policy.

Patient-reported outcomes: Incorporating patient-reported outcome measures into future research will provide valuable insights into the patient experience and the impact of PR on their overall well-being.

Multidisciplinary collaboration: Fostering collaboration among pulmonologists, surgeons, rehabilitation specialists, and other healthcare providers is essential for optimizing PR delivery and outcomes.

By addressing these research priorities, the field can move towards evidence-based guidelines for PR in post-lung cancer care, ultimately

improving patient outcomes and enhancing the quality of life for lung cancer survivors.

Conflicts of Interest Statment: All authors declare that there is no conflict of interest.

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