Review Article

Pulmonary Rehabilitation Strategies for Pathological Air-Filled Spaces: From Blebs to Pneumothorax

Nurulhuda Zakari[1], Siti Chandra Widjanantie[2], Sa'ari Mohamad Yatim[1]

[1]Department of Rehabilitation Medicine, Hospital Sultan Idris Shah, Serdang, Malaysia
[2]Department of Physical Medicine and Rehabilitation Persahabatan Hospital, Faculty of Medicine University of Indonesia, Jakarta, Indonesia.

Abstract

Background: Pulmonary rehabilitation is an effective non-pharmacological approach for respiratory conditions. However, its use in patients with bullae, blebs, or pneumothorax requires modification to balance therapeutic benefits against the risk of further lung injury. This review outlines strategies for implementing pulmonary rehabilitation in these high-risk populations.

Methods: A literature review was conducted using PubMed and Google Scholar, focusing on articles and studies on rehabilitation in cases of emphysema, bullae, bleb parenchyma, and pneumothorax.

Results: Most articles on this topic were case studies, except for one multicenter trial examining pulmonary rehabilitation in patients with advanced emphysema. Pulmonary rehabilitation strategies can be divided into the very acute phase and the early phase. Most importantly, pulmonary rehabilitation must be delivered through a multidisciplinary approach, and the team needs to assess medical suitability and tailor the exercises accordingly. The program should be progressed and continued in an outpatient setting to achieve functional benefits and improve quality of life.

Conclusion: Pulmonary rehabilitation is both feasible and beneficial for patients with bullae or pneumothorax and critically progressed. Current strategies are largely based on the case-level evidence and clinical reasoning.

Keywords: Pulmonary, Rehabilitation, Pneumothorax

Corresponding Author:
Nurulhuda Zakari
Department of Rehabilitation Medicine, Hospital Sultan Idris Shah, Serdang, Malaysia
drnurulhuda.z@moh.gov.my

Submitted: June 2026
Accepted: June 2026
Published: June 2026

Cite this:
Zakari N, Widjanantie SC, Yatim SM. Pulmonary Rehabilitation Strategies for Pathological Air-filled Spaces: From Blebs to Pneumothorax. Persahabatan Respirology Journal. 2026;2(1)

Persahabatan Respirology Journal
Vol. 2 No.1
e-ISSN: 3124-0518
DOI:

INTRODUCTION

Pulmonary rehabilitation (PR) has emerged as an essential component of comprehensive care for patients with chronic respiratory disease. According to the American Thoracic Society and European Respiratory Society (ATS/ERS), PR is defined as a comprehensive intervention based on a thorough patient assessment followed by tailored therapies that include, but are not limited to, exercise training, education, and behavior change, designed to improve the physical and psychological condition of people with chronic respiratory disease and to promote the long-term adherence to health-enhancing behaviors. However, for patients with underlying bullae, blebs, or pneumothorax, rehabilitation presents unique challenges that require careful clinical consideration. These anatomical variations fundamentally alter the physiological responses to exercise and breathing maneuvers, necessitating a specialized rehabilitation approach that balances the therapeutic benefits of PR with the inherent risks of increased intrathoracic pressure.[1]

Bullae, blebs, and emphysema are distinct manifestations of pathological air collections in the lungs. Blebs are small subpleural air collections that originate in the distal bronchiolar tree, typically less than 1 cm in diameter, while bullae are larger air-filled cavities, often exceeding 1 cm (Kenny & Kuschner, 2013). Both represent areas of structural weakness in the lung parenchyma where the normal elastic architecture has been disrupted (Sihoe, 2018). Emphysema is characterized by destruction of the lung parenchyma and alveolar septa, and loss of elastic recoil, which results in airway collapse, expiratory airflow obstruction, lung hyperinflation, and gas trapping.[2] These damaged air spaces may enlarge, forming bullae.[3]

Under normal conditions, the intrapleural pressure is negative relative to atmospheric pressure. This difference causes lung recoil, and the negative pressure prevents the lungs from collapsing. Pneumothorax occurs when air enters the pleural space, disrupting surface tension and causing loss of negative pressure.[4] Pneumothorax can be categorized as primary spontaneous pneumothorax (PSP) and secondary spontaneous pneumothorax (SSP). PSP commonly occurs in adolescents and young adults with an annual incidence ranging from 155 to 227 cases per 100,000 people and a variable recurrence rate of 25% to 54%[5]. It usually occurs in patients without prior lung diagnosis, but most patients have emphysema-like changes in the parenchyma. The spontaneous rupture of subpleural apical blebs or bullae is thought to be due to the prolonged exposure to cigarette or cannabis smoking, predisposing genetic disorders, or atmospheric alterations.[5,6] The SSP commonly occurs in diseased lungs, including tuberculosis, COPD, pulmonary emphysema, asthma, COVID-19, and other systemic immunological conditions such as SLE.[7,8] The main symptoms associated with pneumothorax typically include sudden onset of pleuritic chest pain and dyspnea, with severity depending on the extent of lung collapse.[9]

METHODS

An online literature search was conducted using PubMed and Google Scholar. The search was restricted to full-text PDFs available from 2000 to 2026. The keywords were as follows: “pulmonary rehabilitation”, “respiratory rehabilitation", “chest exercise", “physiotherapy", “breathing exercise", “pneumothorax", “bullae”, and “bleb". The Boolean logic was employed to generate different combinations of search strings. We excluded articles that described clinical features, epidemiology, treatment of the illness, and consequences or complications of non-rehabilitation-related issues. Articles limited to abstracts only were excluded.

RESULTS

A total of 546 articles were initially identified from the search, with 60 duplicates removed, resulting in 486 unique articles for further screening. Only 410 were further retrieved, all of which were human cases. Following this, 295 articles were excluded based on title and abstract review for not meeting the inclusion criteria, leaving 84 articles for full-text assessment. Of these, 54 articles were excluded because they did not focus on pulmonary rehabilitation interventions in the specified patient populations, resulting in 30 articles being included for qualitative synthesis in this review (Fig 1). The studies were mostly case report series, and only one study was a multicenter randomized trial of a pulmonary rehabilitation service in patients with advanced emphysema.[10] Based on studies and case reports, we conclude that PR in cases of bullae, blebs, and a history of pneumothorax, or for patients currently receiving treatment for pneumothorax, is feasible and beneficial but requires careful assessment and modification.[11,12] In this review, we proposed strategies that healthcare professionals could adapt when performing PR in this high-risk group.

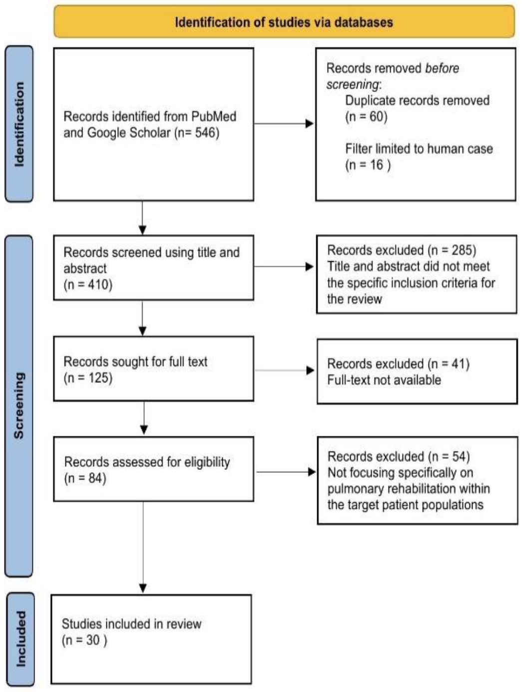

Figure 1. PRISM Diagram on how the review is synthesized

GOALS OF REHABILITATION IN HIGH-RISK POPULATIONS

In patients with bullae, blebs, or pneumothorax, the rehabilitation goals shift slightly to prioritize safety alongside traditional outcomes. Primary goals in the acute setting include preventing and minimizing postsurgical complications, optimizing lung function, and improving cough effectiveness. These progress to secondary goals of reducing dyspnea, enhancing exercise tolerance, and facilitating the return to functional activities, ultimately aiming to improve quality of life.

The main concern for PR in this cohort is the high risk of complications in a very fragile lung parenchyma. This usually happens during the acute phase of care, where physical exertion or improper thoracic expansion may exacerbate existing bullae or trigger a secondary pneumothorax. In this article, we further divided the rehabilitation strategies for the very acute phase, mainly in Phase 1 of PR while in the hospital, ensuring that exercise intensity is titrated to avoid excessive fluctuations in intrathoracic pressure. Subsequent PR in Phase 2 will not be much different than the conventional PR program in general.

ACUTE MANAGEMENT

1. Contraindication during the acute phase of pneumothorax

During the acute phase (Phase I of PR) with an undrained pneumothorax, specific physiotherapy interventions are contraindicated because they could cause tension pneumothorax and further impair gas exchange. The literature clearly highlights procedures that increase intrathoracic pressure as risky in this situation. Mechanically induced interventions such as mechanical insufflation-exsufflation (MIE), positive expiratory pressure (PEP), intrapulmonary percussive ventilation, and continuous positive airway pressure (CPAP) are contraindicated in the presence of an undrained pneumothorax.[13] These restrictions are based on the physiological principle that increased intrathoracic pressure can worsen air leakage and hinder lung re-expansion.[14]

This represents a significant departure from standard rehabilitation protocols used in other conditions, reflecting the unique constraints of managing undrained air in the pleural space. Furthermore, aggressive use of incentive spirometry has been documented to cause iatrogenic pneumothorax in patients with emphysema, suggesting that even after drainage, careful titration and patient education regarding device use is essential.[3]

2. Safety Precautions for High-Risk Patients:

These are the critical modifications for patients with known emphysematous parenchyma, bullae, or a history of pneumothorax:

- Avoid Valsalva maneuvers and high intrathoracic pressure activities
  The Valsalva maneuver, heavy-weight lifting, or breath-holding activities should be avoided during the early acute phase of rehabilitation.
- Avoid forceful coughing
  Patients should be encouraged to clear the airways through huffing or assisted cough techniques.
- Monitor oxygen saturation continuously during exercise; stop if SpO_2 drops below 88% to 90%.
- Low-intensity aerobic training
  Start with low intensity (e.g., 40% to 60% of peak capacity) and progress only with close monitoring.
- Monitor for warning signs
  like sudden chest pain, acute dyspnea, and subcutaneous emphysema, which may signal recurrent pneumothorax.
- Chest tube management

If an intercostal drain is in situ, the breathing exercises need to be coordinated with drainage status, and clamping should be avoided.[15,16] For a persistent air leak, it is important to reduce the pressure gradient between the airways and the pleural cavity to promote full lung re-expansion.[17] This can be done by two maneuvers: 1) decreasing negative pressure in the drainage system (using pressures of -5 to -2 cm H2O rather than typical -8 cm H2O)[18] 2) avoiding aggressive respiratory maneuvers that would increase intrathoracic pressure.[19]. Kinking of the tube can be avoided by placing soft rollers on the sides.[14]

3. Pain Management:

While specific breathing and mobilization techniques are restricted during the acute, undrained phase, pain management is a critical early intervention. Evidence indicates that bed rest leads to the development of atelectasis and that chest pain further reduces lung volume through antalgic and restricted chest expansion.[13] Therefore, concurrent with drainage management, pain control through pharmacological intervention, physical therapy, and physical modalities becomes a priority. One study that used electrical stimulation (TENS) and high-intensity laser therapy (dose: configured for analgesic effect, 3 W, 20 J/cm²) alleviated pain in a post-tuberculosis patient with pneumothorax and bilateral hydropneumothorax.[20] Early pain management facilitates the subsequent initiation of better breathing patterns, improved thoracic mobility, and safe mobilization once the pneumothorax is drained.

EARLY POST-OPERATIVE AND POST-DRAINAGE PHASE 1 PULMONARY REHABILITATION

Once a pneumothorax is managed through drainage or surgical intervention, a comprehensive multidisciplinary rehabilitation program should be initiated. Evidence from case series describes that a multidisciplinary pulmonary rehabilitation program can be initiated as early as postoperative day two once the patient is hemodynamically stable.[11,21] The core components of pulmonary rehabilitation that can be applied are as follows:

1. Breathing exercises and airway clearance

Breathing exercises form the foundation of early pulmonary rehabilitation for lungs affected by emphysema and bullae[22] Diaphragmatic breathing and segmental expansion exercises specifically target recruitment of the lower lung zones, which is critical in emphysema, where upper-lobe predominance of disease is common.[23] Pursed-lip breathing creates back pressure over alveoli, thereby allowing prolonged perfusion and the development of collateral channels for ventilation.[24]T hese techniques work synergistically to promote more efficient breathing mechanics and improved gas exchange.

Segmental breathing exercises, focusing on specific lung segments affected by bullae or air trapping, have demonstrated usefulness in improving ventilation distribution.[25] When combined with thoracic expansion exercises, these breathing techniques offer comprehensive strategies for lung re-expansion. Slow, deep inhalation with active arm raising and slow exhalation while lowering the arms cause the respiratory muscles to contract, mobilizing the thoracic cage and allowing the lung cavity to expand more effectively.[26] Improving the range of motion in the thoracic region not only boosts lung function and ventilation efficiency but also relieves pain after thoracotomy procedures. The literature highlights that pursed-lip breathing specifically helps reduce dyspnea in patients with lung disease who experience shortness of breath.[26] For patients recovering from pneumothorax, these techniques support the gradual re-expansion of the collapsed lung and teach sustainable breathing patterns to reduce dyspnea.[11]

The active cycle of breathing technique (ACBT) merits special emphasis because it has proven effective in enhancing mucus clearance, lung function, and promoting breathing relaxation. Studies comparing ACBT with other breathing methods in patients with obstructive lung disease have shown notable improvements in peak expiratory flow rate (PEFR) and forced expiratory volume when ACBT is consistently used.[24] This technique involves cycles of controlled breathing, deep breaths with breath holds, and forced expiratory maneuvers by huffing (Shen et al., 2021). The use of incentive spirometry helps to expand the lungs and reduce air trapping.[14,27] However, its application requires careful consideration in patients with a recent pneumothorax due to the risk of increasing intrathoracic pressure[24]

Effective airway clearance becomes increasingly important as patients transition from the acute, undrained phase to active rehabilitation. Medically supervised cough training, combined with adjunctive chest physiotherapy, represents a structured approach to secretion management. The evidence indicates that during acute phases with exudation, passive techniques are initially appropriate; however, once patients present with mild to moderate symptoms or have transitioned beyond the acute phase, active cough training becomes feasible[28]

Cough assistance strategies include stimulated cough maneuvers and mechanical cough-assist devices in suitable settings. Research has shown that assisted or stimulated cough maneuvers, especially when combined with breathing exercises, improve mucus clearance[28]. For patients in the postoperative period after bullae repair or pleurodesis, cough training should be combined with splinting techniques—such as using pillows or hand placement to stabilize the chest wall—to reduce pain and increase effectiveness. Traditional manual percussion and postural drainage, while potentially raising intrathoracic pressure, can be used cautiously with proper positioning adjustments to reduce stress on fragile lung tissue. A balanced approach favors gravity-assisted and gentle manual techniques, reserving mechanical oscillatory devices for cases where the benefits clearly outweigh the risks. In cases of severe fragility, manual chest physiotherapy with gentle techniques and careful positioning may provide sufficient clearance without the risks linked to high-frequency oscillatory devices. Although high-frequency oscillatory devices and percussive techniques are advanced airway clearance options, their use in emphysema and bullae requires careful evaluation. Auto drainage technique can also be an alternative; it is self-managed and promotes lung re-expansion with positive expiratory pressure, avoiding forced coughing.[29]

2. Posture, Graded Aerobic and Resistance exercise training: Start low, progress slowly

Body positioning significantly influences respiratory mechanics and lung re-expansion in the early postoperative period. Semi-recumbent positioning at 30-45 degrees has been incorporated into rehabilitation protocols to optimize ventilation-perfusion matching. This position balances the need to facilitate drainage while promoting gravitational effects on lung expansion and reducing aspiration risk. As the patient progresses, positioning strategies should be varied to prevent complications and promote mobilization of different lung zones.

Current guidelines recommend multidisciplinary strategies that combine breathing control, aerobic conditioning, and strength training as cornerstones of recovery from pneumothorax. However, the intensity and progression of aerobic exercise must be tailored to the unique pathophysiology of emphysematous bullae. The exercises should be initiated cautiously, with intensity based on individual tolerance and respiratory response.

Early mobilization begins with bed mobility and ankle pumps to prevent thrombosis, then progresses to sitting up with support, followed by sitting upright without support (usually achievable 24 hours after major surgery), and ultimately to walking around the bed or room.[23] The schedule for advancing mobilization should be tailored to each patient's hemodynamic stability and pain management. This variation emphasizes the need to evaluate each patient's clinical status rather than strictly following rigid protocols.

Exercise typically begins with very low-intensity activities (in-bed limb exercises, bed mobility, sitting balance) in the ICU or early postoperative period, progressing to walking and eventually ergocycle or treadmill training. A recent case report of a patient with bilateral bullae post-LVRS described initiating pulmonary rehabilitation in the ICU as early as medically possible, continuing to the general ward, with no adverse effects (Tifany & Tambunan, 2025). In a multidisciplinary rehabilitation program started on postoperative day 2 after VATS bullectomy, FEV1 improved from 27.5% predicted preoperatively to 55.4% at discharge (POD 48), and ADL scores doubled from 40 to 80 points. For preoperative conditioning, home-based exercise training in patients with severe emphysema (FEV1 = 29% predicted) awaiting LVRS significantly increased the 6-minute walk distance (+44m) and quality of life, demonstrating that even minimally supervised programs are feasible[10]

In addition to aerobic training, progressive strength training addresses the general deconditioning that accompanies acute lung complications. Isometric lower extremity strengthening programs with appropriate repetitions and hold durations represent feasible early interventions. These exercises prevent the complications of immobility, including deep vein thrombosis and general deconditioning, while preserving the functional capacity needed for mobilization and respiratory exercises. However, it is important to control the breathing during this resistance exercise and avoid straining or prolonged breath-holding maneuvers during concentric muscle action. One study prescribed resistance exercise as three sets of 10 repetitions with a 6-second hold, which can be tolerated in the early postoperative period[23]

As recovery progresses, the intensity of resistance training can be increased. The literature documents successful progression from early isometric work to more dynamic strength training, with improvements in exercise tolerance and functional capacity correlating with systematic progression.[23] The integration of strength training with aerobic exercise creates a comprehensive conditioning program addressing both respiratory and systemic physiology.

Inspiratory muscle training (IMT) has been demonstrated to improve respiratory function and exercise capacity. However, in the context of post-pneumothorax management, inspiratory muscle training should be implemented cautiously and only after the acute phase has resolved and pneumothorax drainage is complete.[30,31] he physiological rationale concerns the increased intrathoracic pressures generated during resistive breathing training.[32], which could theoretically promote recurrence in the very early recovery phases.[33] Consequently, current evidence suggests using pressure threshold devices at lower initial loads—typically below 30% of maximal predicted inspiratory pressure—before gradually titrating upward based on patient tolerance and radiological stability[34] Furthermore, incorporating incentive spirometry protocols alongside slow, controlled breathing exercises promotes lung re-expansion while minimizing the risk of high transpulmonary pressure spikes that could stress fragile parenchyma.[35] Monitoring for symptoms of chest discomfort or increased dyspnea during these maneuvers remains essential, as these indicators provide immediate clinical feedback regarding the patient's individual threshold for respiratory muscle loading.

During the rehabilitation program, an appropriate target Borg Scale should be set based on the patient's current condition. In the early stages of exercise, a target Borg Scale of 11-13 (light exertion) should be used. This can be gradually increased as the patient progresses. Once the patient is able to walk, the 6-minute walk test can be employed to assess and monitor endurance throughout the program. In addition to these outcome measures, the single-breath-counting test or sit-to-stand test can also be utilized. The Barthel Index may be used to evaluate functional improvement during the program. Some studies have observed improvements in physiological tests, such as lung function tests, but this was not always consistent due to the nature of the illness; however, patients reported functional and psychological improvements following pulmonary rehabilitation.[7,10,21,23]

The outpatient phase II begins after hospital discharge and lasts for several months, focusing on exercise progression, returning to work or activities, and long-term management of risk factors. One study recommended that patients who experienced a pneumothorax within the past 4 weeks should avoid exercising in remote or satellite-based settings.[30] Therefore, center- or hospital-based sessions are preferred during the initial outpatient phase. Throughout all stages, the principle of personalized progression based on clinical status rather than strict timelines guides decision-making. Hemodynamic stability, oxygenation levels, pain control, and patient tolerance determine when to move between phases. Exercise intensity, especially for walking, often starts at symptom-limited levels or around 60% of maximum heart rate, then progresses based on Borg scale ratings.[36] For aerobic activities, intensities of 60–85% of maximum heart rate or a Borg dyspnea score of 4–6 are typically targeted, with sessions lasting 30–60 minutes, 2–5 times weekly over 6–12 weeks.[37] Resistance training should be gradually increased, usually from 20% to 40% of a 1-repetition maximum, and performed in sets of 8 to 12 repetitions to improve muscle strength while avoiding excessive strain.[38]

3. Patient Education and Self-Management

Patient education forms an essential but often under-emphasized component of comprehensive pulmonary rehabilitation. This should begin at the initial contact with the patient while the patient is in the hospital and continue during each outpatient session. Education should address disease pathophysiology, medication management, oxygen therapy principles, breathing and coughing techniques, rationale for exercise prescription, signs and symptoms warranting immediate medical attention, and risk factor modification.[10] Additionally, advance directives and shared decision-making regarding future management should be discussed, particularly for patients with extensive bullae at high risk for recurrent pneumothorax.

The evidence consistently shows that smoking or vaping cessation programs should be incorporated into pulmonary rehabilitation protocols for all patients with emphysema and bullae, regardless of whether pneumothorax has occurred. The significant benefit—reduction in recurrence risk—strongly motivates patients and justifies providing intensive cessation support as part of the rehabilitation teams' responsibilities. Patients with underlying emphysematous lungs should avoid activities like high-altitude exposure, underwater activities, or contact sports, especially during the early recovery period. Heavy lifting or breath-holding activities should be approached with caution. Proper breathing techniques should be employed when engaging in such activities.[13]

Written instruction accompanied by demonstration facilitates understanding and home program adherence.[39,40] In the post-discharge period, telehealth monitoring and periodic in-person clinic visits reinforce home program compliance and allow protocol adjustments based on recovery trajectory (Ries et al., 2008). Patient engagement in shared goal-setting increases motivation and improves long-term outcomes.[41,42]

Furthermore, integrating collaborative self-management plans enables patients to recognize early symptoms of exacerbations, facilitating timely communication with healthcare providers and proactive treatment modifications.[43]

OUTCOMES

The primary outcomes consistently reported across the included studies were improvements in exercise tolerance, typically assessed by the 6-minute walk distance (6MWD), and reductions in dyspnea, often measured using the modified Medical Research Council (mMRC) scale.[44] Secondary endpoints frequently encompass health-related quality-of-life measures, such as the St. George's Respiratory Questionnaire, as well as improvements in patient-reported functional independence and long-term adherence to self-management strategies.[45]

SAFETY CONSIDERATION

Only one study mentioned the presence of arrhythmias and recurrent pneumothorax during the therapy session; however, it was unclear whether the event was due to a post-operative complication or the direct effect of the exercise.[18] Given the heightened risk of barotrauma in patients with emphysematous bullae or a history of pneumothorax, rigorous screening for clinical deterioration must precede any exercise session.[24] Implementation of intensity-titrated protocols must be accompanied by comprehensive pre-participation screening to identify absolute and relative contraindications, ensuring that interventions remain within safety margins. [46,47]

LIMITATION

While comprehensive guidelines exist for pulmonary rehabilitation in various chronic respiratory conditions, evidence specifically addressing its role and efficacy in post-pneumothorax recovery, particularly in cases involving bullous lung disease or cystic lung pathologies, remains limited.[21] This paucity of dedicated research necessitates a thorough examination of current practices and outcomes in this specific patient cohort, particularly given the potential for exacerbation of underlying conditions by inappropriate rehabilitative interventions.[48]

Given these considerations, rehabilitation programs for patients with emphysematous lungs, blebs, or bullous parenchyma, or pneumothorax, must be meticulously individualized and adapted to mitigate the risks associated with increased intrathoracic pressures and potential barotrauma.[48,49] This adaptation frequently involves a progressive, low-intensity aerobic exercise regimen, often incorporating treadmill or cycle ergometer training at 60-90% of maximum heart rate, coupled with strict monitoring for adverse events.[50]

Future research should focus on long-term studies that evaluate the lasting effects of multidisciplinary rehabilitation on physiological resilience and the prevention of pneumothorax recurrence in patients with severe emphysematous changes.[21] Additionally, future investigations need to develop standardized systems to assess risks and benefits, clearly defining safety limits for exercise protocols, especially regarding the physiological stress placed on bullous segments.[51]

CONCLUSION

Pulmonary rehabilitation in high-risk patients with parenchymal and pleural issues is effective and safe during both Phase 1 and Phase 2 of the program. However, healthcare professionals must be aware that precautions and vigilant monitoring should be followed throughout rehabilitation. Education remains crucial, especially when the condition is irreversible, as the risk of recurrence is high. Early rehabilitation promotes functional recovery and may help reduce long-term physical decline in this vulnerable group.

DISCLAIMER

Acknowledgments

The authors gratefully acknowledge all participants who contributed to this study and to the preparation of this manuscript.

Conflict of Interest

The authors declare that they have no conflict of interest.

Funding

This research received no external funding.

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