Case Report

Combined Institutional and Telerehabilitation Programs for A Post-Tuberculosis Lung Disease Patient with Low Cardiorespiratory Endurance: A Case Report

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Abstract

Background: Post-tuberculosis lung disease (PTLD) can lead to long-term respiratory issues and impaired lung function, which can impact quality of life. Pulmonary rehabilitation (PR) is a personalized strategy designed to address these problems and improve overall well-being. It is administered by a diverse team of experts.

Case: A 28-year-old female patient with a history of tuberculosis (TB) presented with breathing difficulty. The physical examination revealed decreased chest expansion, shoulder asymmetry, a slight forward neck, and a rounded shoulder. The radiologic findings and bronchoscopy showed PTLD, atelectasis in several parts of the right lung, and regional destruction of the right lung.

Discussion: The patient underwent pulmonary rehabilitation (PR), which included endurance exercises, strength training, several types of breathing exercises, breath-stacking exercises, thoracic expansion exercises, physical agents for rehabilitation modalities, education on posture correction, and energy conservation in daily activities. The patient was also monitored remotely through telerehabilitation from home. There were significant improvements in pulmonary function tests. Measurement of FVC, FEV_1, the six-minute walking test (6MWT), and the PCF after two weeks of follow-up. After eight weeks of training, there were improvements in cardiopulmonary endurance, muscle endurance, and reduced dyspnea.

Conclusion: Comprehensive pulmonary rehabilitation programs, including a combination of institutional and telerehabilitation synchronous approaches, can help improve cardiopulmonary endurance, muscle strength-endurance, and the overall patient's functional life who was suffering from chronic respiratory diseases, such as post-TB sequelae.

Keywords: cardiorespiratory endurance, chronic respiratory diseases, pulmonary rehabilitation, tuberculosis

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INTRODUCTION

Tuberculosis (TB) continues to be a major concern in global public health, affecting approximately 10 million people and leading to 1.3 million fatalities in 2020.[1] Patients with post-tuberculosis lung disease (PTLD) experience lasting health challenges. They face long-term health challenges and an increased risk of mortality compared to the general population.[2] A history of TB increases the chance of enduring respiratory issues over the long term. It has been reported that up to 50% of individuals who complete TB treatment experience PTLD disability after their TB treatment concludes.[3]

Impairment in lung function following TB is a common occurrence that is often overlooked. This can negatively impact an individual's quality of life. PTLD causes respiratory dysfunction, ranging from minor abnormalities to severe breathlessness, and is linked with an increased mortality risk of chronic respiratory disease. Dysfunctions in chronic respiratory illness, such as PTLD, can lead to inadequate ventilation, improper gas exchanges, reduced functional status, muscle loss due to atrophy or sarcopenia, and impairment of available capacity.

As a result, individuals experience a decline in their ability to participate in everyday tasks and a reduction in their overall quality of daily living.[4]

Pulmonary rehabilitation (PR) is a personalized, tailor-made, and thorough approach administered by a multidisciplinary team designed for individuals with chronic respiratory diseases, including post-TB complications.[5,6] While international guidelines mostly recommend PR programs for managing chronic obstructive pulmonary disease (COPD) and other respiratory conditions, it is still not given adequate recognition in specific TB rehabilitation management guidelines. PR can help increase cardiorespiratory and muscle endurance, help alleviate lower back pain and spasms, conserve energy in daily living activities (ADLs), and control dyspnea, resulting in improved quality of life for the patient.[3,4]

Therefore, PR use in PTLD patients is essential for a better functional outcome. This article presents a case of a 28-year-old female patient who was experiencing difficulty breathing. The patient had a history of pulmonary TB, which resulted in decreased chest expansion and PTLD. Physical medicine and rehabilitation programs were given to alleviate the symptoms and enhance the patient's functional capacity.

CASE

A 28-year-old female came to the Physical Medicine and Rehabilitation Department at Persahabatan Hospital on March 17th, 2022, due to shortness of breath that started one and a half years ago and worsened in the last three months. She first felt a persistent and worsening cough in March 2019, with white phlegm challenging to expel and shortness of breath. These symptoms caused fatigue, especially at work, making performing activities like motorcycle riding difficult. She had no prior history of respiratory diseases.

In May 2020, she visited a pulmonologist, who suggested that she do a thoracic X-ray and a sputum examination. She was found to have contracted tuberculosis in her lungs and had to undergo treatment with anti-tuberculosis medication for six months. The cough frequency had decreased, but the shortness of breath persisted.

In December 2020, she felt worsening shortness of breath and back pain and noticed that her right shoulder was lower than her left shoulder. She had a thoracic X-ray and was diagnosed with atelectasis. However, no specific treatment was administered for this condition. In April 2021, she visited an internist and got an echocardiogram. She was diagnosed with an infection of the heart valve and prescribed medication.

On May 5, 2021, she was referred to Dr. M. Jamil Hospital in Padang for a thoracic X-ray and a bronchoscopy examination. The result was atelectasis and a closed primary bronchus. She did a sputum examination, and there was no *Mycobacterium tuberculosis* was detected. She was then referred to Persahabatan Hospital in Jakarta.

Due to the COVID-19 outbreak, she postponed going to Jakarta. As her condition worsened, she resigned from her job due to worsening back pain and impaired activity. On February 2, 2022, she finally went to Persahabatan Hospital, where cardiothoracic and vascular surgeons had planned to do a pneumonectomy. However, it was canceled because of the high risk. She was then referred to the physical medicine and rehabilitation department.

At that time, she still felt shortness of breath and back pain with a visual analog scale (VAS) equal to seven. She got physical modality using the LASER (Light Amplification by Stimulated Emission of Radiation) therapy on her thoracolumbar muscles and diaphragm's area in the lower thoracic for immediate effect on anti-inflammation and relaxation, administered chest expansion exercise, infrared treatment, ergocycle exercise prescription as an institutional (hospital-based) rehabilitation program, and breath-stacking exercise as part of the exercise home-based program.

Besides following the rehabilitation program in the hospital, she also went to pilates classes. Now, she felt the back pain had reduced to VAS 4, and her shortness of breath improved.

At the initiation of the pulmonary rehabilitation program, the patient previously reported episodes of shortness of breath during daily activity. At the time of the physical examination, the patient had undergone initial evaluation following consultation with the rehabilitation medicine team.

The patient seemed alert and scored on the Glasgow Coma Scale (GCS) equal to 15 (E4V5M6). Vital signs measured during this early rehabilitation phase were as follows: normal blood pressure at 112/70 mmHg, a heart rate of 72 beats per minute, a rate of respiration of 20 times per minute, body temperature that remained normal at 36ºC, and a finger pulse saturation of oxygen at 96%.

The absence of dyspnea during the physical examination may be attributed to the patient's resting condition and partial improvement following medical management prior to rehabilitation. The patient weighed 40 kg and had 155 cm of body height, resulting in a body mass index (BMI) of 16.65 kg/m^2, considered underweight for nutritional status.

Thoracic examination revealed a rightward shift of the heart and reduced chest expansion. The patient's posture in the standing position showed the head in midline, asymmetrical shoulders (right side lower than the left side), no pelvic obliquity, genu varus, slight forward neck, rounded shoulders, and slight hyperlordosis. The patient was independent in mobility and ambulation activities, with adequate balance and proprioception.

Functional tests showed an average sit-to-stand test (STST) result of 12 times in 30 seconds, an average time-up and go test (TUGT) of 8.6 seconds, a single breath count test (SBCT) of 28 counts, a result of 439 meters in a six-minute walking test (6MWT) equal to 16.02 mL/kg/min, a maximum oxygen consumption (VO_{2max}) prediction of 4.58 METs, a Barthel index score of 20 (independent), a modified medical research council (mMRC) dyspnea scale of 1, and a fatigue severity scale of 40 (fatigue). The initial complaint of exertional dyspnea was consistent with reduced respiratory efficiency noted in the functional test results.

Figure 1. Patient's posture

Laboratory examination showed normal results. The chest CT scan and chest X-ray results indicated that the right lung had collapsed due to a lack of air (atelectasis). Additionally, the heart was on the right side of the chest instead of the left. During a bronchoscopic examination, the right main bronchus was observed to be obstructed by stenosis. Spirometry data revealed a vital capacity of 2.735 mL (66% of predicted), FVC of 2.735 mL (69% of predicted), FEV_1 of 2.434 mL (58% of predicted), FEV_1/FVC 74% (predicted 90%), and peak expiratory flow (PEF) of 7.05 L/mL, concluding a combination of mild restriction and mild obstruction. These spirometric findings indicate a mixed ventilatory impairment pattern suggestive of early airway limitation and reduced lung compliance.

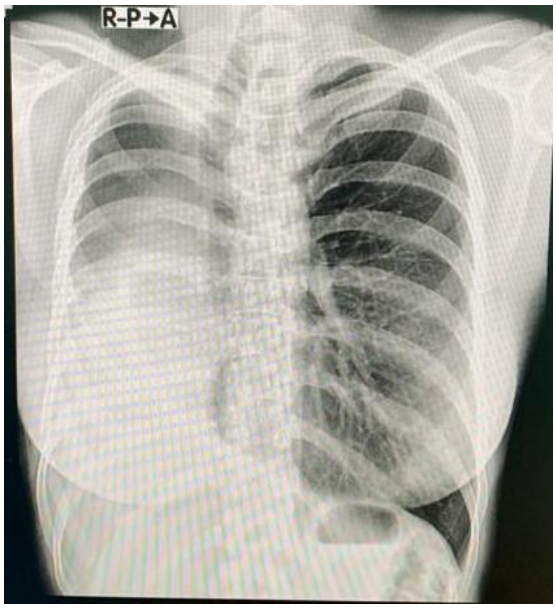

Figure 2. A chest X-ray taken on 11 March 2022 showed right lung atelectasis and left lung herniation

The patient was having a medical condition involving lung damage caused by a past case of TB, diagnosed as PTLD, alongside collapsed lung tissue (atelectasis) and right lung deterioration due to parenchymal destruction. Rehabilitation problems of the patient include limited chest expansion, low cardiorespiratory endurance, low muscle endurance, lower back pain caused by thoracolumbar spasms, postural issues, and fatigue.

A series of rehabilitation programs was given to the patient. To help improve chest expansion, the patient had to do a breath-stacking exercise (3 x 5 repetitions), a chest expansion exercise with ROM upper extremities (3 x 10 repetitions), a thoracic mobility exercise, a segmental breathing exercise, and a diaphragmatic breathing exercise. To release the thoracolumbar spasm which was causing the lower back pain and limiting the respiratory muscles in the thoracic region, the patient was administered physical modalities such as LASER and heating modality (diathermy), plus stretching three times a day for ten repetitions to release thoracolumbar spasm and postural correction.

To decrease fatigue, increase cardiorespiratory endurance (5 METs), and increase muscle endurance evaluated with 6MWT, the patient performed ergo-cycle 20-watt for five minutes three times a week and must increase the duration every week, did sit-to-stand test exercise, and did aerobic exercise at home in the form of moderate-intensity walking for 30 minutes a day 3–5 times a week with a target heart rate of 143-162 beats per minute. The patient was advised to use breathing control with energy conservation techniques to control fatigue-resistant techniques. A multidisciplinary team should monitor the patient, consisting of pulmonologists, pulmonologists, physiatrists (physical medicine and rehabilitation specialists), the medical rehabilitation team of therapists (physical therapist, occupational therapist, and rehabilitation nurse), and nutritionists.

Also conducted telerehabilitation for this patient at home. Telerehabilitation sessions were carried out once a day at the patient's home, guided by a physiatrist and a physical therapist through WhatsApp® video calls. Each session lasted around 30 to 40 minutes and consisted of breathing exercises, endurance training, and energy-conservation techniques tailored to the patient's condition. The program employed telemonitoring systems that included oxygen saturation (SpO_2) and pulse rate measurements taken before and after each session, allowing synchronous physiatrist-patients' monitoring of self-conducted home exercise.

After completing an eight-week training program, her physical exam revealed an average blood pressure result of 120/88 mmHg, a rate of respiration at 18 times per minute, a heart rate of 95 beats per minute, SpO_2 of 96%, and a fatigue severity scale score of 37 (indicating fatigue). Respiromotor status showed an SBCT of 34 by metronome 120, a STS of 17 times per 30 seconds, and SpO_2 during STS of 93–94%.

In the 6MWT, the blood pressure pre-test was 122/76 mmHg, the respiratory rate was 18 times per minute, the heart rate was 95 beats per minute, the SpO_2 was 98%, and the Borg Scale was 7-0.5-0.5. Blood pressure post-test was 130/87 mmHg, respiratory rate was 25 times per minute, heart rate was 119 beats per minute, SpO2 was 97%, and Borg Scale was 13-4-4. The SpO_2 during 6MWT was 93-95%, with the distance of 498 meters, the maximum oxygen consumption (VO_{2max}) of 17.18, and the METs of 4.91. These clinical parameter results improved cardiopulmonary and muscle endurance, reduced dyspnea, and led to better functional outcomes.

DISCUSSION

Between 1995 and 2015, around 66 million cases of pulmonary TB were effectively treated, which accounts for approximately 85% of reported cases. This indicates that pulmonary tuberculosis treatment has a high success rate.[4] It is important to mention that a significant number of individuals who have had TB may face long-term pulmonary issues, with up to 50% of TB survivors experiencing some level of persistent dysfunction of the pulmonary system. This dysfunction can vary from minor

abnormalities to major ones like severe dyspnea, which in turn increases the risk of mortality from respiratory-related causes.[4,7]

Pulmonary impairment after tuberculosis in PTLD can take the form of either restricted breathing or obstructed airflow, which can lead to difficulties in the exchange of respiratory gas in the small airways.[8] The diagnostic test to detect the airflow defect is spirometry, which assesses respiratory airflow during inhalation-exhalation periods and can identify an abnormality in breathing patterns. The inability to fully exhale the air and empty the lungs is a common sign of airflow obstruction, often caused by inflammation that can induce constriction of the airways. Conversely, a reduced capacity to fully inhale may indicate restriction, typically caused by severe fibrosis and lung tissue stiffening.[4] In our patient, there were both obstructive and restrictive lung diseases that were proven by spirometry.

Understanding the precise mechanisms of immune pathology for treating lung impairment associated with TB is crucial. One significant challenge in studying the immunopathogenesis of TB over time in humans is the difficulty in obtaining serial lung biopsies throughout the progression of the disease and treatment. Studying the immunopathogenesis of TB in humans is challenging due to the difficulty in maintaining serial biopsies of the lung parenchyma throughout the disease progression and cure. Such biopsies could offer insights into the local immune pathways contributing to tissue injury. While getting these biopsies in humans is nearly impossible, non-human primates and specific animal models share similarities with human TB.[9]

Despite these limitations, studies in humans and animal models strongly indicate the critical role of host immunity ability in lung remodeling caused by *Mycobacterium tuberculosis* (MTB). It is important to note that the interactions between a host and the pathogen can persist long after the complete treatment.[9]

A recent study that used the scanning of positron emission tomography (PET) and CT to evaluate local inflammation of the lung in pulmonary TB patients revealed that they had developed new inflammatory lesions or experienced an increase in the existing ones. This occurred in the six months of anti-TB treatment or even years after therapy. Patients with MTB culture-negative after their treatment ended were discovered to have MTB messenger RNA (mRNA) in their samples of respiratory fluids. This suggests that the persistent bacteria; transcription may contribute to inflammatory reactions inside the lungs.[4,10]

There may be specific mechanisms in the patient's immunology that cause dysfunction in the airway, such as airflow obstruction or dysfunction in the parenchyma due to restrictive impairment in TB patients. Moreover, the collateral damage due to immune mediator responses and pathways that play a role in necrosis and developing cavitation during TB may also be involved in long-term lung fibrosis.[4,10]

The patient was diagnosed with atelectasis of the right lung. Atelectasis is the partial or total collapse of the lung's small airways, which can impede the exchange of CO_2 and O_2.[11] There are three main ways this medical condition is caused: the lung tissue gets compressed, the alveolar air is absorbed, or there is a problem with the production or function of pulmonary surfactant. These three types of atelectasis are compressive, resorptive, or impaired surfactant.[12]

The cicatrization type of atelectasis usually occurs due to the lung parenchymal fibrotic healing process, which leads to scarring and contraction of the lung parenchyma. Conditions such as TB, PTLD, or other chronic respiratory illnesses affecting lung parenchymal destruction may develop cicatrization, leading to atelectasis, which can be caused by conditions such as TB and other chronic lung-destructive processes.[11,12]

A comprehensive multidisciplinary team for managing this patient was completed with a PR program. PR is a personalized and comprehensive intervention conducted by a set of interdisciplinary teams designed for individuals dealing with chronic respiratory diseases, including post-TB sequelae. PR programs are recommended for patients exhibiting

symptoms, impaired exercise tolerance, and a diminished quality of life.[13]

Post-TB complications can lead to inadequate ventilation, improper gas exchanges, a decline in functional status, muscle hypotrophy due to sarcopenia, and impaired exercise tolerance and capacity, consequently diminishing overall exercise tolerance or performance, activities in daily living, and the patient's quality of life. The PR comprises endurance training, breathing exercises, and patient education.[14]

Exercise should involve all extremities or limbs. After a stable medical condition, the patient can be given a six-minute walk test, which can be conducted in the hospital and followed by gradual walk training to improve patient tolerance. Other exercise programs involving extremities, such as static bikes or strength training, can be administered. The exercise intensity being prescribed gradually increased, depending on the patient's latest ability to perform.[15]

Energy conservation techniques, along with controlled breathing and relaxation and posture correction for ergonomic activity at a low energy level of wasting, can improve the effectiveness of exercise training. Diaphragmatic breathing, which applies conscious control of abdominal relaxation during contraction, aims to improve the efficiency of the diaphragm.[15]

The patient was also taught breath-stacking exercise, an inhalation-assisted exercise aimed at improving lung capacity and exercise tolerance.[16] Pulmonary function test interpretation showed significant improvement in FEV_1 and FVC immediately after intervention, as well as improvements in 6MWT and Peak Cough Flow (PCF) after two weeks of follow-up, which continued to improve throughout the eight-week rehabilitation program.

Individuals with a low BMI face a higher risk of developing TB compared to those with a high BMI.[17] Furthermore, underweight TB patients are susceptible to the delayed process of healing, increased cases of relapses, or mortality.[15,18] The deterioration parameter, through the decline of body weight and sarcopenic muscle, contributes to increased fatigability and diminished exercise tolerance, raising concerns about the patient's ability to regain lost weight even after receiving appropriate medication. The general assessment of these patients should encompass an evaluation of nutritional status or BMI (including body height, weight, and composition).[15]

The postural disturbances related to positional body dysfunction, such as forward head, rounded shoulders, hyperlordosis, and genu varus, contribute to muscle imbalances that impact overall body posture. Abnormality of posture can hinder core stabilization of the trunkal body system, limiting chest expansion mobility while breathing.[19] The imbalance of core muscles has a significant risk of developing functional dysfunction of musculoskeletal origin, causing pain or altered cardiorespiratory endurance among adults.[19,20]

Specific exercise in tailored, targeted musculoskeletal-related tasks had the potential benefit of fixing the postural dysfunction, decreasing pain, and preventing other possible injuries. Respiratory muscle training can be added to the breathing exercise regimen to gain optimal respiratory functional capacity, prevent further deterioration, and enhance cardiorespiratory endurance. Studies about slow-paced breathing also show that it can control the vagus tone to enhance relaxation, effectively address musculoskeletal complaints induced by sedentary behavior, and manage stress and anxiety.[19,20]

After eight weeks of training, there was improvement in cardiopulmonary endurance, muscle endurance, and reduced dyspnea. The alleviation of dyspnea can be attributed to various factors, including improved breathing patterns, decreased ventilatory demand, and improved characteristics of the ventilatory muscle. Psychological factors may also contribute to the reduction of dyspnea.[14]

Synchronous telerehabilitation for this patient was conducted using the WhatsApp® media platform. Telerehabilitation involves providing therapeutic rehabilitation remotely, utilizing the aid of technologies in telecommunication.[21] Remote

pulmonary rehabilitation offers an innovative modality designed to address the inherent limitations of conventional, center-based programs. In many contexts, particularly within rural or resource-constrained settings, patients encounter substantial barriers such as restricted access to specialized rehabilitation services, transportation difficulties, and financial constraints, all of which contribute to reduced adherence to therapy.[22]

Through the integration of telecommunication and multimedia technologies, telerehabilitation enables the structured delivery of supervised, individualized rehabilitation sessions within the patient's home environment. This approach not only enhances the accessibility and continuity of pulmonary rehabilitation services but also allows for real-time monitoring and individualized program modifications, thereby promoting sustained patient engagement and optimizing clinical outcomes.[22]

Recent evidence supports the integration of telerehabilitation as an effective adjunct to traditional pulmonary rehabilitation programs. Dai et al conducted a meta-analysis demonstrating that telerehabilitation significantly improves physiological parameters, exercise tolerance, and symptom management in patients with chronic respiratory diseases, with comparable outcomes to conventional, center-based PR. This finding underscores the feasibility and clinical relevance of remote supervision for patients with limited access to healthcare facilities.[22]

The broadening implication of PR is a critical issue in the respiratory community. Access to maintaining PR for patients with respiratory illness by telerehabilitation at home using telecommunication-telemonitoring systems, including measurements of oxygen saturation (SpO_2) and pulse rate, is both feasible and safe. Recent studies on patients with COPD and idiopathic pulmonary fibrosis (IPF) indicate that resistance training during PR can be successfully performed without a significant increase in adverse events. The small number of reported adverse events suggests that administering a telerehabilitation PR is feasible and safe for patients with respiratory illness, including those with PTLD.[23,24]

In addition, Seo et al proposed a long-term, individualized follow-up strategy for PTLD patients, emphasizing the continued role of PR and remote monitoring in preventing disease progression and maintaining functional capacity. This perspective aligns with the approach implemented in the present case, where a combination of institutional and home-based telerehabilitation interventions successfully enhanced cardiopulmonary endurance and overall functional outcomes.[25]

Furthermore, the long-term management of PTLD should not only focus on respiratory mechanics but also include nutritional optimization and individualized strategies. Adequate nutritional support, combined with structured rehabilitation, enhances recovery and strengthens immune resilience, ultimately improving treatment outcomes in TB survivors.[26] Similarly, a comprehensive and multidisciplinary approach is essential to address the multifactorial outcomes of post-PTLD, integrating physical rehabilitation, nutritional care, and psychosocial support to optimize long-term recovery and quality of life.[27]

LIMITATION

This case report emphasizes the importance of PR in managing PTLD. However, there is still a lack of evidence in PR programs for PTLD, especially among the Asia-Pacific population. Another limitation of this case is the restricted assessment during telerehabilitation sessions, as some evaluations and exercises could not be performed as accurately as in-person sessions.

CONCLUSION

Combined pulmonary rehabilitation programs consisting of institutional and telerehabilitation can enhance comprehensive PLTD patient management to help improve cardiopulmonary endurance, muscle endurance, and overall activity in daily living in chronic respiratory illnesses, such as post-TB sequelae, which cause many disabling conditions.

Telerehabilitation offers a convenient way to synchronously monitor patients at home using the most familiar telemonitoring systems by the WhatsApp® media platform with measurements of SpO_2, pulse rate, SBCT, STS, Borg Scale, and 6MWT; it is likely to be feasible and concern the safety of patients with respiratory diseases.

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CONFLICT OF INTEREST

The authors declared there is no conflict of interest.

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