Pulmonary rehabilitation after lung transplantation with severe complications: A case report

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INTRODUCTION
Lung transplantation is an effective treatment for end-stage lung disease [1]. However, a recent meta-analysis demonstrated that pretransplant patients who were underweight had 1.36 times higher risk for post-transplant mortality than patients with a normal body mass index (BMI) [2]. Patients with poor nutrition had higher in-hospital mortality rates after lung transplant due to a higher rejection rate and a higher rate of infectious episodes [3, 4]. Thus, a nutritional disorder is considered as a relative contraindication for a lung transplant [1].

According to a recent study by Hadem et al. [5], the need for postling transplantation mechanical ventilation for more than 21 days is commonly required in 13.8% (95/690) of cases. Prolonged mechanical ventilation increases the possibility of acquiring infection and ventilator-induced diaphragm dysfunction, which worsens weaning difficulties [5]. However, with early intervention, multidisciplinary teams—including respiratory therapists (RTs)—can help lung transplant patients’ rehabilitation and accelerate weaning [6].

In the case presented here, pursuant to the American Thoracic Society/European Respiratory Society Statement on Pulmonary Rehabilitation [7], a rehabilitation plan was made and implemented by RTs in conjunction with a multidisciplinary team for a patient after lung transplantation. A variety of movement exercises in the statement were applied to the plan, which included interval strength and endurance training for upper and lower extremities as well as inspiratory muscle training. Moreover, bronchial hygiene was utilized to improve secretion clearance and reduce airway resistance as well as to minimize work of breathing for this particular case due to his muscle weakness and surgical injury. As for ventilator management, careful progressive attempts at weaning were the key to the success. It should be noted that most hospitals in mainland China do not have RTs [8]; therefore, the participation of an RT in our team plays a very important role in this patient’s rehabilitation.

Ethical approval was sought for this case study through Beijing Chaoyang Hospital’s institutional review board and it was deemed unnecessary (06/02/2017).

CASE PRESENTATION
A 59-year-old male with a BMI of 14.36 kg/m² (40/1.67)² was admitted to the hospital for a lung transplant in March 2014. He was diagnosed with interstitial lung disease, pneumoconiosis, and severe pulmonary hypertension five prior to admission. One year prior, he started home oxygen (nasal cannula) and his six-minute walk distance was less than 100 m. On admission, his muscle strength was found to be very weak. His upper limbs could not defend against resistance by the examiner, and his lower extremities could move, but not against gravity. Echocardiography showed mild to moderate systolic tricuspid valve regurgitation, with systolic pulmonary artery pressure (sPAP) of 93 mm Hg. Before surgery, he was placed on veno-arterial extracorporeal membrane oxygenation (VA-ECMO) with settings of 2531 rpm/min, blood flow 1.89 L/min, and oxygen flow 2 L/min to assist with the bilateral lung transplant. Three hours after surgery, the patient returned for a second thoracotomy surgery to stop the bleeding.

On the first postop day, sPAP was 26 mm Hg and hemoglobin was 84 g/L. ECMO was weaned 34 hours later. However, the attempt to switch ventilator mode from pressure-assist control (PAC) to pressure support ventilation (PSV) failed. Electrical activity of the diaphragm showed weak neuromuscular drive. A chest computed tomography (CT) scan found bilateral collusive pneumothorax (Figure 1). Percutaneous tracheotomy was performed at the bedside on postop day five.

The patient’s muscle strength decreased after surgery (muscle strength grade 2) due to immobility for a period of time (Figure 2). Passive limb functional exercise was initiated, followed by combined passive and active limb exercises four times a day. Daily therapeutic bronchoscopy was performed to help clear the copious amount of secretions. Ventilator settings were carefully titrated based on vital signs and subjective complaint. Eight days later, he was placed on Optiflow via a T-piece with FiO2 0.40–0.60 and flow 30–50 L/min. However, his PaCO2 gradually increased from 35 mm Hg to 66 mm Hg in the following three days. He also felt short of breath and was diaphoretic and was then placed back on the ventilator with P/A/C. A chest CT showed some improvement in the rightside pneumothorax, but worsening consolidation and a

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persistent left-side pneumothorax (Figure 1). Five days later, the T-piece with Optiflow was again attempted intermittently. However, on day three the patient became drowsy, with diminished and coarse breath sounds in the left lung. Arterial blood gas (ABG) showed hypercapnia (pH 7.279; PaCO$_2$ 85.7 mmHg; PaO$_2$ 206.9 mmHg). He then was placed back on mechanical ventilation with PSV: PS 16 cm H$_2$O, positive end-expiratory pressure (PEEP) 6 cmH$_2$O, FiO$_2$ 30%.

Nutritional support was reevaluated and adjusted, and a percutaneous gastrointestinal ostomy was performed at bedside on week six. Slight suction pressure was connected with a left chest tube to help drain gas and his paradoxical breathing gradually improved. His cough ability was still weak, but the need for bronchoscopy decreased. We initiated as aggressive bronchial-hygiene therapy as he was able to tolerate, such as postural drainage and chest percussion three to four times a day. He was mobilized to the chair at bedside and given active resistance muscle exercises. Ventilator settings were gradually reduced, and he was intermittently switched from the ventilator to the T-piece with Optiflow, and his ABG became stable.

The patient was able to sit on a chair without assistance and stand up at bedside on week eight (limb muscle strength grade 4). At week 10, he was able to perform assisted walking with ventilator support. Ventilator settings were adjusted based on his vital signs and subjective complaint. A chest CT on week 11 displayed no presence of pneumothorax, and consolidation in the right lower lobe had improved. However, a bronchoscopy showed copious secretions in the right main bronchus. Chest wall oscillation was used to clear secretions. During this time, the patient started exhibiting insomnia and anxiousness. An antidepressant and sleep medication were prescribed by a consulting psychologist. The patient was weaned intermittently from the ventilator to the T-piece (FiO$_2$ 24%–28%) on week 13. Finally, a cuffless tracheostomy tube was placed on week 14 and capped 5 days later. He was decannulated with 2 L/min nasal cannula on week 15, and discharged from the intensive care unit with a BMI of 16.06 kg/m$^2$.

**DISCUSSION**

This patient was a poor candidate for a lung transplant due to severe malnutrition, advanced age, the need for ECMO support during surgery, and the need for long-term mechanical ventilation after the transplant. Additionally, this patient had numerous complications immediately after the transplant, such as bleeding and bilateral collusive pneumothorax. Pulmonary rehabilitation has a vital role in the treatment of lung transplantation patients [7]. After a full evaluation of this case, the multidisciplinary team listed and prioritized 5 key treatable problems: secretion retention, respiratory dysfunction, skeletal muscle weakness, malnutrition, and psychological anxiety. A multidisciplinary rehabilitation program was created specifically for this difficult patient.

**Secretion retention**

Tomkiewicz et al. [9] reported that ciliary function, or mucus properties, were significantly altered in a canine model of single lung autotransplantation, and that this abnormality lasted four months postoperation. Our case was also found to have secretion retention, especially in the early phase postoperation. Esguerra-Gonzales et al. [10] found that

![FIGURE 1](image1.png)

Chest CT on postoperative days 4, 11, 24, and 73 (from left to right). CT, computed tomography.

![FIGURE 2](image2.png)

Patient information timeline.
four daily bronchial hygiene treatments provided to lung transplant patients improved peak expiratory flow from 205 L/min to 225 L/min as well as improving patients’ dyspnea scores and oxygenation. For this patient, chest percussion combined with postural drainage and high-frequency chest wall oscillation were provided to help mobilize secretions; cough assist and bronchoscopy were also used to assist with secretion clearance.

Respiratory dysfunction
The possibility of weaning this patient from the ventilator was monitored closely, and weaning was progressively attempted. Physical signs, symptoms, and subjective feelings were utilized to evaluate the patient’s tolerance and to determine the next step in weaning attempts.

Skeletal muscle weakness
For this specific patient, physical therapy was introduced early, immediately after the patient was removed from ECMO. Passive exercises were provided when his muscle strength was low and active exercises were initiated as he was gaining muscle strength. To encourage the patient to exercise, ventilator support was increased during exercise to provide sufficient ventilation and oxygen delivery. Ventilator settings were carefully titrated by the RT, based on the patient’s progress. At the late phase, the RT walked the patient with the ventilator and adjusted settings for the patient. Every time the patient was doing exercises, the RT always stayed aside and made decisions on when to discontinue and when to resume exercises.

Malnutrition
Nutrition disorder is one of the major issues in this individual case, as malnutrition limited his rehabilitation. After a full assessment by the physician, different ways of feeding (intravenous and enteral nutrition support) were utilized in different phases of recovery. A nutrition plan was evaluated and revised daily. Also, a high-protein, high-fat, and low-carbohydrate diet was given to reduce carbon dioxide production along with oxygen consumption on the metabolic process.

Psychological anxiety
Psychological counseling helps lung transplant recipients improve rehabilitation and their life quality [11]. When the patient reported insomnia and anxiousness, a psychologist was consulted, and an antidepressant and sleep medication were prescribed.

In this case, a multidisciplinary intervention played a key role. As part of the team, RTs spent a vast amount of time and effort in the patient’s rehabilitation, including the patient’s physical therapy needs. The explanation as to why the RT was more involved in the physical therapeutics is because of the physical therapist’s unfamiliarity with ventilator support. In addition, the physical therapist’s time with the patient was limited, only working with the patient twice a day during the week. Importantly, the RTs in our hospital were designated to a specific ICU and built a relationship with this patient over extensive time, thus the RTs were more familiar with the patient’s needs and preferences.

CONCLUSION
This case demonstrated that careful evaluation and an individual systematic rehabilitation program from a multidisciplinary team with early intervention may help lung transplanted patients’ rehabilitation and accelerate weaning. Most hospitals in China do not have access to the services of RTs. This novel case study importantly records the role of the RT within the evolving context of Chinese healthcare and rehabilitation systems. The RTs involved in this case demonstrated their ability to provide a unique and indispensable role within the team, including careful evaluation, airway clearance, breathing exercises, early mobility, and physical intervention.

ACKNOWLEDGEMENTS: We thank J. Brady Scott MSc RRT-ACCS FAARC and Tyler Weiss MSc RRT-ACCS AE-C for reviewing the manuscript.

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