Diaphragm electromyography guidance for a lung transplant recipient with difficult weaning from mechanical ventilation

A case report

Yuanda Xu, PhD\textsuperscript{a}, Qi Qing, MD\textsuperscript{a}, Minyong Liang, MD\textsuperscript{b}, Weibo Liang, MD\textsuperscript{c}, Zhimin Lin, MD\textsuperscript{a}, Weiliang Wu, MD\textsuperscript{c}, Weiqun He, BD\textsuperscript{a}, Xiaoqing Liu, BD\textsuperscript{a}, Yuanming Luo, PhD\textsuperscript{c}, Yimin Li, PhD\textsuperscript{a},* Jianxing He, PhD\textsuperscript{d},\footnote{Correspondence: Yimin Li, Department of Critical Care Medicine, First Affiliated Hospital of Guangzhou Medical University, No. 151 Yanjiang Xi Road, Yuyexiu District, Guangzhou 510120, Guangdong, China (e-mails: yiminli@vip.163.com, drymin@163.com). Jianxing He, Department of Thoracic Surgery, The First Affiliated Hospital of Guangzhou Medical University, No. 151 Yanjiang Xi Road, Yuyexiu District, Guangzhou 510120, Guangdong, China (e-mail: hejx163@163.com).}

Abstract

Rationale: Many factors contribute to a complicated postoperative course following difficult weaning off a ventilator after lung transplantation.

Patient concerns: A female patient underwent a successful surgery but received a size-mismatched lung graft. The graft had been rejected before transplantation. She experienced delayed ventilator weaning 3 days after lung transplantation.

Diagnoses: A postoperative X-ray revealed a normal mediastinal structure and diaphragm position. Diaphragmatic function was assessed by diaphragm electromyography (EMG\textsubscript{di}) via esophageal and surface electrodes. EMG\textsubscript{di} showed decreased left compound motor action potentials (CMAPs), prolonged left phrenic nerve conduction time (PNCT), failure to induce right CMAPs and PNCT under bilateral magnetic stimulation, and right phrenic nerve injury.

Interventions: She was treated with neural nutritional support and prescribed rehabilitation measures such as strengthening limb activities on the bed.

Outcomes: The patient finally achieved satisfactory outcomes after an early diagnosis and medical interventions.

Lessons: Lung size mismatch before transplantation and phrenic nerve injury during surgery should be avoided wherever possible.

Abbreviations: BiPAP = bilevel positive airway pressure, CMAPs = compound motor action potentials, COPD = chronic obstructive pulmonary disease, DBD = donation after brain death, EMG\textsubscript{di} = diaphragm electromyography, IPPV = intermittent positive-pressure ventilation, MRC = Medical Research Council, NIF = inspiratory force, PaCO\textsubscript{2} = partial pressure of carbon dioxide, PEEP = positive-end expiratory pressure, PNCT = phrenic nerve conduction time, PSV = pressure support ventilation, RR = respiratory rate, RSBI = rapid shallow breathing index, TV = tidal volume, TwPdi = twitch transdiaphragmatic pressure.

Keywords: diaphragm electromyography, end-stage lung disease, lung transplantation, weaning

1. Introduction

Lung transplantation is one of the most effective therapies for patients with end-stage lung disease.\textsuperscript{[1]} Many factors contribute to a complicated postoperative course after difficulty in weaning a patient off a ventilator, such as development of severe infection, application of intraoperative cardiopulmonary bypass, basic disease status and medication, severe malnutrition, use of immunosuppressive agents, high dose of corticosteroids, graft dysfunction, graft size mismatching, and intensive care unit (ICU)-acquired myasthenia. These factors may result in prolonged postoperative ventilator use, increased comorbidities, and unfavorable prognoses. Thus, efforts should be made to identify risk factors that predict delayed ventilator weaning after lung transplantation.

In this study, our patient underwent uneventful surgery, but experienced delayed ventilator weaning 3 days after lung transplantation. The diaphragmatic dysfunction was assessed by diaphragm electromyography (EMG\textsubscript{di}) via esophageal and surface electrodes under magnetic stimulation of the phrenic nerves. The patient finally achieved satisfactory outcomes after an early diagnosis and subsequent interventions.

2. Case presentation

This study was approved by the Scientific Research Project Review Ethics Committee of the First Affiliated Hospital of Guangzhou Medical University (ethics batch number 2017 No. 34). Written consent was obtained.
2.1. At admission
A 44-year-old female patient (weight 47 kg, height 158 cm) was admitted to our hospital in September 2016 complaining mostly of repeated cough, sputum, and shortness of breath during the previous 5 years. She had an acute exacerbation of these symptoms as recently as 10 months ago. Five years ago, she started coughing up small amounts of white phlegm for no obvious reason and had recurrent and progressive shortness of breath after walking (less than 30 m) and physical activities. In May 2013, the chest computed tomography (CT) showed bilateral interstitial fibrosis in the lungs. The patient was treated with prednisolone and cyclophosphamide, but failed to achieve an optimal therapeutic response. Another chest CT in July 2015 indicated that her interstitial fibrosis had worsened. The patient developed aggravating dyspnea and shortness of breath 10 months before admission, which required continuous oxygen therapy. The patient was finally diagnosed with end-stage, connective tissue disease-associated interstitial lung disease (systemic sclerosis or Sjögren syndrome suspected).

2.2. Transplantation
After routine preoperative assessment for lung transplantation, the patient underwent a right side, allologeneic lung transplantation on September 20, 2016. The lung donor was a male aged 21 years old and with a height of 172 cm. The donor died due to a severe craniocerebral injury, and the graft was per-served following donation after brain death (DBD). The lung transplantation procedure was uneventful, and the total operation time was 5.25 hours.

The patient exhibited good postoperative diastolic function with the grafted lung. The patient was transferred into ICU with a tracheal cannula, and was given ventilator-assisted breathing with the following parameters: mode, intermittent positive-pressure ventilation (IPPV); tidal volume (TV), 320 mL; respiratory rate (RR), 20/minute; positive-end expiratory pressure (PEEP), 6 cm H2O. She was treated against acute rejection and preventive antimicrobial therapy. The echocardiography revealed normal cardiac function. Considering possible diaphragmatic dysfunction, EMGdi was recorded from both esophageal and surface electrodes. The twitch transdiaphragmatic pressure (TwPdi) measurements under magnetic stimulation of the phrenic nerves showed a bilateral phrenic nerve conduction time (PNCT) of 13 milliseconds and bilateral diaphragmatic compound motor action potentials (CMAPs) of 0.508 mV (Table 1). After adjustment of the PSV of the ventilator from 12 cm H2O to 10 cm H2O, the diaphragm electromyogram (EMGdi) value was elevated from 16.9 ± 0.71 μV to 14.6 ± 1.22 μV, achieving a statistical significance (P < .05), and the rapid shallow breathing index (RSBI) was increased from 78.1 ± 6.05 to 120.7 ± 14.70 (P < .05). Two hours later, the EMGdi value increased from 16.9 ± 1.06 μV to 17.1 ± 1.28 μV, without statistical significance (P = .548); RSBI fluctuated in a

### Table 1
The unilateral and bilateral PNCT and CMAPs recorded by diaphragm electromyography.

|                      | Esophageal electrodes | Surface electrodes | Surface electrodes after 3 mo |
|----------------------|-----------------------|--------------------|------------------------------|
| Left PNCT (normal < 8 ms) | 12                    | 11                 | 10                           |
| Right PNCT (normal < 8 ms) | Absent               | Absent             | 11                           |
| Left CMAPs (normal > 1 mV) | 0.551                | 1.010              | 0.970                        |
| Right CMAPs (normal > 1 mV) | Absent               | Absent             | 0.837                        |
| Bilateral PNCT (normal < 8 ms) | 13                   |                    |                              |
| Bilateral CMAPs (normal > 1 mV) | 0.508                |                    |                              |

CMAPs = compound motor action potentials, PNCT = phrenic nerve conduction time.

2.3. Treatment in ICU
At the 4th day posttransplantation, the patient exhibited a stable cardiovascular circulation, and sedative analgesia was discontinued. The ventilation mode was adjusted to pressure support ventilation (PSV) 12 cm H2O, with PEEP at 5 cm H2O, PaO2/FiO2 ratio of 280 mm Hg, negative inspiratory force (NIF) 13 cm H2O, and a normal partial pressure of carbon dioxide (PaCO2) in arterial blood. She was then given bilevel positive airway pressure (BiPAP) ventilation by noninvasive nasal BiPAP mask.

However, the patient suffered the reestablishment of mechanical ventilation via an artificial airway 6 hours later due to hypoxemia and hypercapnia. A bedside chest X-ray showed a normal mediastinal structure, without increase in exudation of both lungs. The position of the right hemidiaphragm was normal. The echocardiography revealed normal cardiac function.

### Table 2
EMGdi and RSBI under different levels of pressure support ventilation.

| PSV, cm H2O | 12 cm H2O | 10 cm H2O 2h | 8 cm H2O 30 min | 8 cm H2O 2h | P     |
|-------------|-----------|--------------|----------------|------------|-------|
| EMGdi, μV   | 9.8 ± 0.71| 14.6 ± 1.22  | 16.9 ± 1.06    | 17.1 ± 1.28| .05   |
| RSBI, bpm/L | 78.1 ± 6.05| 120.7 ± 14.70| 146.7 ± 14.00  | 134.8 ± 8.88| .05   |

Data were analyzed by 1-way analysis of variance (ANOVA).

EMGdi = diaphragm electromyography, PSV = pressure support ventilation, RSBI = rapid shallow breathing index.

1. P = .548 for 8 cm H2O 30 min vs 8 cm H2O 2h; otherwise, P < .001 between any 2 groups.
2. P = .370 for 8 cm H2O 30 min vs 8 cm H2O 2h; otherwise, P < .001 between any 2 groups.
Thus a significant improvement in her right diaphragmatic paralysis had occurred.

3. Discussion

This case is a patient who failed to wean from mechanical ventilation 3 days after lung transplantation, and then suffered the reestablishment of mechanical ventilation via an artificial airway. The phrenic nerve injury following lung transplantation may result in prolonged postoperative mechanical ventilation and weaning difficulty. This patient had a low PSV of 12 cm H2O, and a reduction of 2 cm H2O in PSV, monitored by diaphragmatic EMG, resulted in significant increase in EMGdi value and RSBI revealing insufficient respiratory muscle strength and declined TV. The signals were sent to the respiratory center to produce a stronger feedback electrical signal. The EMGdi showed a decreased left CMAPs and prolonged left PNCT and failure to induce right CMAPs and PNCT under bilateral magnetic stimulation, revealing right phrenic nerve injury.

Damage to the phrenic nerve, either unilaterally or bilaterally, is a well-documented complication of cardiac operations, largely because the nerve is close to the pericardium. However, phrenic nerve injury is less commonly reported after lung transplantation. It has been reported that among retrospective data of 49 lung transplantations, phrenic nerve paralysis was found in 4 (8.2%) patients (unilateral in 3 patients and bilateral in 1). Pulmonary and other factors that should be considered in difficult-to-wean patients following lung transplantation include unstable cardiac function, sepsis, anastomotic dehiscence, airway secretions, hemotherax or pneumothorax, and mediastinal swing.

In addition, the chest cavity of the recipient was (too) small to accommodate the lung of the donor. Moreover, the patient had end-stage, connective tissue disease-associated interstitial lung disease (systemic sclerosis or Sjögren syndrome suspected), which made the chest even smaller. However the graft had been pruned before transplantation, and a postoperative X-ray indicated a normal mediastinal structure and diaphragm position, without mediastinal shift or raised or collapsed diaphragm on the right side. There were also no signs of abnormal breathing under positive pressure ventilation.

On the other hand, implanting an excessively sized lung carries a high risk of prolonged mechanical ventilation. Thus, while it is reasonable for patients with end-stage chronic obstructive pulmonary disease (COPD) to receive a larger lung graft, a relatively smaller lung graft is more appropriate for patients with advanced pulmonary fibrosis.

4. Conclusion

For patients with delayed weaning from mechanical ventilation following lung transplantation, EMGdi under magnetic stimulation can be applied to accurately evaluate phrenic nerve and diaphragm function. Efforts should be made to achieve early diagnoses and interventions in these difficult-to-wean patients. A lung size mismatch before transplantation and phrenic nerve injury during surgery should be avoided wherever possible.

Author contributions

Conceptualization: Yuanda Xu, Qi Qing.

Data curation: Yuanda Xu, Qi Qing, Minyong Liang, Zhimin Lin, Weiliang Wu.

Formal analysis: Weiqun He, Xiaoqing Liu, Yunming Luo.

Funding acquisition: Yimin Li, Jianxing He.

Investigation: Weibo Liang, Zhimin Lin.

Methodology: Yuanda Xu, Qi Qing, Minyong Liang.

Project administration: Yimin Li, Jianxing He.

Resources: Yunming Luo, Yimin Li, Jianxing He.

Software: Yuanda Xu, Qi Qing, Minyong Liang.

Supervision: Yuanda Xu, Qi Qing, Yimin Li, Jianxing He.

Validation: Yuanda Xu, Qi Qing.

Visualization: Yuanda Xu, Qi Qing.

Writing – original draft: Yuanda Xu, Qi Qing.

Writing – review & editing: Yuanda Xu, Qi Qing.

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