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ORIGINAL ARTICLE

Effects of an additional pressure support level on exercise duration in patients on prolonged mechanical ventilation

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exercise tolerance;
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Background/Purpose: Noninvasive positive pressure ventilation has been regarded as a strategy for improving exercise performance. Whether an increase in the ventilatory support level improves exercise performance in patients who have received invasive ventilation is unknown. The purpose of this study is to examine the effects of an additional level of pressure support (PS) ventilation on exercise tolerance in patients undergoing prolonged mechanical ventilation (PMV).

Methods: This study examined 15 patients who were undergoing PMV. All patients performed an upper-arm exercise test at three PS levels: the baseline PS level (PS), a level 2 cmH_2O higher than the baseline level (PS+2), and a level 4 cmH_2O higher than the baseline level (PS+4). The physiological response, reasons for discontinuing the exercise test, and exercise duration were recorded and analyzed.

Results: The tidal volume increased significantly from 271.7 ± 54.7 mL to 398.3 ± 88.7 mL at the PS+4 level ($p = 0.01$). Significant differences in exercise duration were observed at different PS levels. The exercise duration was significantly longer at the PS+4 level than at the PS and PS+2 levels (146.3 ± 139.9 seconds vs. 108.5 ± 85.9 seconds vs. 72.8 ± 43.9 seconds, $p = 0.038$) as their corresponding order. There were significant relationships between resting respiratory rate and exercise duration at the PS ($r = -0.639$, $p = 0.034$) and PS+2 levels ($r = -0.668$, $p = 0.025$).

Conflicts of interest: The authors have no conflicts of interest relevant to this article.

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Conclusion: In patients undergoing PMV, an additional PS level of up to 4 cmH_2O compared with the baseline setting may help to improve exercise tolerance by prolonging exercise duration.

Introduction

Patients with prolonged mechanical ventilation (PMV) have required at least 6 hours of mechanical ventilation for >21 consecutive days.[1] Because of the advancement of critical care medicine, the number of patients dependent on PMV has rapidly increased worldwide.[2] Studies have shown that 5—15% of patients with acute respiratory failure become reliant on PMV. Furthermore, 67% of patients undergoing PMV who were successfully weaned from a ventilator are readmitted within 3 months after discharge.[3]

Patients undergoing PMV are commonly immobilized and experience complications of critical illness and mechanical ventilation, including muscle wasting and diaphragm dysfunction, that may adversely affect their functional statuses, ventilator weaning, and survival rates.[4] Physical inactivity and deconditioning are common in mechanically ventilated patients with chronic respiratory failure. Scheinhorn et al[5] reported that 98.7% of patients were bedridden at admission to post-intensive care unit (ICU) weaning centers and that 69% of patients were still bedridden at discharge from the weaning center. Even 12 months after discharge, only 19% of patients undergoing PMV can be fully active during daily life.[5] All of the aforementioned complications may cause the mechanical ventilation dependency rates and hospitalization duration increase in patients undergoing PMV.[6]

Pulmonary rehabilitation programs have proved to improve exercise tolerance and quality of life in patients with chronic respiratory disease.[7] In one study, 85.6% of patients undergoing PMV were weaned from mechanical ventilators and were able to stand and ambulate after participating in a rehabilitation program.[8] Exercise training has been regarded as the cornerstone of pulmonary rehabilitation.[9] Most studies on exercise limitation and training have focused on spontaneously breathing patients with chronic obstructive pulmonary disease (COPD) because of the ventilatory and gas exchange impairment, along with the cardiac and skeletal muscle dysfunction that accompany this disease.[10] However, few studies have investigated exercise response and strategies for improving training efficiency in patients with PMV.

The American Thoracic Society (ATS) suggested that high-intensity training produces substantial physiological benefits and exert positive training effects on exercise capacity and cardiopulmonary function, in patients with chronic respiratory diseases.[9] However, high-intensity exercise is not always feasible in patients undergoing PMV, because they experience impaired pulmonary function and weak muscle. Applying additional noninvasive positive pressure ventilation (NIPPV) during exercise may enhance the exercise tolerance of nonintubated patients with COPD, and enable these patients to achieve greater training intensity because it acutely reduces exertional dyspna.[11,12] Applying additional NIPPV is thus regarded as a strategy for improving exercise performance according to the ATS statement on pulmonary rehabilitation.[9] Therefore, for intubated patients with severe cardiopulmonary impairment who are undergoing PMV, an increase in mechanical ventilatory support during exercise should improve exercise performance.

Pressure support ventilation (PSV) is a patient-triggered, pressure-limited, and flow-cycled mode of mechanical ventilation. When applied noninvasively to patients with COPD, PSV has been proven to consistently improve exercise endurance by reducing workload of breathing (WOB) during exercise.[13,14] Whether an additional increase in the baseline pressure support (PS) level during exercise can improve exercise performance of patients undergoing PMV is unknown. Therefore, the purpose of the study is to compare the effects of three PS levels on the exercise tolerance and physiological response of patients undergoing PMV.

Methods

Patients

We enrolled patients from a respiratory care center at the Chang Gung Memorial Hospital, Tao-Yuan, Taiwan. After patients were medically stable and their mechanical ventilator settings were shifted from the assist-control mode to pressure-support mode, we evaluated their eligibility for the study. The inclusion criteria are listed as follows: (1) mechanical ventilation for >6 hours/day for >21 days and failure to be weaned from mechanical ventilation in ICUs; (2) alertness and ability to cooperate with the researchers; (3) medical stability [arterial blood gas value pH: 7.35—7.45, partial pressure of oxygen (PaO_2): >60 mmHg at 40% fraction of inspiratory oxygen (FiO_2), absence of signs and symptoms of infection, and hemodynamic stability]; and (4) mechanical ventilation by PS with a mechanical ventilation weaning program scheduled. Patients with cancer or neurological or other systemic diseases were excluded from the study. Patients unable to perform arm ergometry or to maintain an upright sitting position because of musculoskeletal problems, cardiovascular instability, or other conditions were also excluded. The study was conducted according to the principles established in the Declaration of Helsinki, and informed consent was obtained from the patients or their relatives before the patients participated in the study.

Study design

During the initial screening visit, patients' medical histories, baseline weaning parameters [tidal volume (Vt),