Original Article

Sequential invasive-noninvasive mechanical ventilation weaning strategy for patients after tracheostomy

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BACKGROUND: Because the continuity and integrity of the trachea are likely damaged to some extent after tracheostomy, the implementation of sequential ventilation has certain difficulties, and sequential invasive-noninvasive ventilation on patients after tracheostomy is less common in practice. The present study aimed to investigate the feasibility of invasive-noninvasive sequential weaning strategy in patients after tracheostomy.

METHODS: Fifty patients including 24 patients with withdrawal of mechanical ventilation (conventional group) and 26 patients with sequential invasive-noninvasive weaning by directly plugging of tracheostomy (sequential group) were analyzed retrospectively after appearance of pulmonary infection control (PIC) window. The analysis of arterial blood gases, ventilator-associated pneumonia (VAP) incidence, the total duration of mechanical ventilation, the success rate of weaning and total cost of hospitalization were compared between the two groups.

RESULTS: Arterial blood gas analysis showed that the sequential weaning group was better than the conventional weaning group 1 and 24 hours after invasive ventilation. The VAP incidence was lowered, the duration of mechanical ventilation shortened, the success rate of weaning increased, and the total cost of hospitalization decreased.

CONCLUSION: Sequential invasive-noninvasive ventilator weaning is feasible in patients after tracheostomy.

KEY WORDS: Respiratory failure; Weaning; Tracheostomy; Sequential invasive-noninvasive ventilation

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INTRODUCTION

The withdrawal of mechanical ventilator is a process of sudden or gradual weaning from supportive ventilation after the improvement or remission of underlying causes of respiratory failure.^[1–3] The ultimate purpose of mechanical ventilation is to help the patient achieve independent respiration off the ventilator. Therefore, from the moment a patient with the ventilator on, we must be prepared to create conditions to withdraw the mechanical ventilator early, safely and rapidly.^[4–6] But there are few studies to guide the choice of ventilation mode during weaning.^[7–9] Sequential

invasive-noninvasive ventilation is a strategy to undergo noninvasive mechanical ventilation, and gradually weaning to shorten the invasive ventilation time before weaning criteria have not yet reached. Researches on sequential invasive-noninvasive ventilation strategy mainly focus on the direct tracheal extubation of patients after their intubation.^[10,11] Because the continuity and integrity of the trachea were damaged to some extent after tracheostomy, sequential ventilation has certain difficulties. Sequential invasive-noninvasive ventilation of patients after tracheostomy was less common in practice. In this study, we conducted a retrospective

analysis of patients who were subjected to weaning from invasive ventilation by directly plugging tracheostomy and with a nasal or full-face mask connected to patients to implement noninvasive ventilation. We investigated the feasibility of invasive-noninvasive sequential weaning in patients after tracheostomy.

METHODS

Patients

In the 50 patients, 36 were male and 14 female. The age of these patients ranged from 54 to 90 years old. They were admitted to our respiratory department between January 1, 2012 and October 31, 2014 because of acute respiratory failure. The patients had acute exacerbation of chronic obstructive pulmonary disease (37 patients), cerebral vascular accident (8 patients), acute respiratory distress syndrome (3 patients) and severe pneumonia (2 patients). Totally 26 patients were withdrawn from invasive mechanical ventilation by sequential weaning mode, and 24 patients by a conventional weaning approach consisting of daily weaning attempts.

General care

The patients with respiratory failure were subjected to tracheotomy intubation and invasive mechanical ventilation. Ventilation modes and parameters included inspired oxygen fraction (FiO_2), tidal volume (Vt), positive end expiratory pressure (PEEP), respiratory ratio (I:E) and respiratory frequency (f). They were adjusted to achieve the desired levels according to patient situation, ventilation, arterial blood gas analysis. At the same time, the respiratory function of the patients was optimized with the appropriate use of antibiotics, bronchodilators and expectorants as indicated. The management of coexisting medical problems was reviewed, and metabolic abnormalities were corrected. When pulmonary infection control (PIC) window appeared, patients of the sequential weaning group were connected with a nasal or full-face mask to implement noninvasive ventilation by plugging tracheostomy and deflating the cuff directly. The patients of the conventional weaning group received invasive PSV with an initial level of pressure support that was decided on the basis of achieving acceptable arterial blood gas (ABG) parameters, respiratory rates (RR) $<25/\text{min}$, and patient's tolerance and comfort. Subsequently, the pressure support was decreased by 2 cmH_2O every 4 hours while close monitoring the worsening of oxygen saturation (SaO_2) and RR. When the pressure support and PEEP

reached 10 and 5 cmH_2O respectively with satisfactory blood gases and absence of severe dyspnea, patients were weaned and allowed to breathe spontaneously. Weaning success was defined as the complete withdrawal of an invasive mechanical ventilator, with or without continuing requirement for a nocturnal noninvasive ventilator.

Collection of data

The changes of arterial blood gases were retrospectively analyzed 1 and 24 hours before and after off invasive ventilation respectively. The incidence of ventilator-associated pneumonia (VAP), the total duration of mechanical ventilation, the success rate of weaning, and total cost of hospitalization were also analyzed. The various episodes and complications during sequential noninvasive ventilation process were recorded.

Statistical analysis

All data were analyzed using SPSS software version 17.0 for Windows, Chicago, IL, USA. Student's t test or the Chi-square test was used between the two groups. Paired t tests were used for data analysis in each group, and measurement data were presented as $\text{mean} \pm \text{SD}$. $P < 0.05$ was considered statistically significant.

RESULTS

Comparison of data between the two groups

There were no statistical significant differences in gender, age, primary disease, duration of disease, rapid shallow breathing index (RSBI) and arterial blood gas analysis before withdrawal of the mechanical ventilator between the two groups (Table 1) ($P > 0.05$).

Comparison of arterial blood gases between the two groups

PaO_2 in the sequential weaning group was better than in the conventional weaning group 1 and 24 hours respectively after withdrawal of mechanical ventilation

Table 1. Comparison of gender, age, duration of disease, RSBI and arterial blood gases between the two groups

Variables	Conventional weaning ($n=24$)	Sequential weaning ($n=26$)
Gender (male/female)	18/6	18/8
Age (year)	69.45 ± 6.57	70.82 ± 7.02
Duration (days)	26.70 ± 8.65	27.10 ± 6.54
RSBI (bpm/L)	67.8 ± 16.4	70.5 ± 14.6
PaCO_2 (mmHg)	46.56 ± 8.63	51.08 ± 7.85
PaO_2 (mmHg)	80.73 ± 9.64	79.61 ± 8.86

($P<0.05$), whereas pH value and PaCO_2 were not significantly different between the two groups ($P>0.05$) (Table 2). These results indicated that noninvasive mechanical ventilation could maintain respiratory ventilatory function effectively.

Comparison of main medical index between the two groups

The VAP incidence was lowered, the total duration of mechanical ventilation shortened, the success rate of weaning increased, and the cost of hospitalization decreased in the sequential weaning group than in the conventional weaning group ($P<0.05$) (Table 3). These results indicated that sequential weaning ventilation is more effective and superior to conventional weaning ventilation.

The main complications seen during sequential invasive-noninvasive ventilation included thirsty, difficult expectoration of thick sputum, flatulence, minor facial injury and aspiration.

DISCUSSION

As life-support means, invasive and noninvasive positive pressure ventilations are indispensable and comprehensive measures for critical patients.^[12-14] After the establishment of artificial airway, invasive positive pressure ventilation can effectively control hypoxemia and hypercapnia. Moreover it can improve the efficacy of antibiotics by sputum drainage and gain the time for the treatment of primary diseases.^[15,16] Noninvasive positive pressure ventilation has undergone a remarkable

evolution in the past decade, showing an important role in the management of both acute and chronic respiratory failure. This ventilation can be used as a bridge or reduce the intensity of assisted ventilation and contribute to successful weaning with efficient respiratory support for the improvement of ventilation.^[17,18] With the technological development of noninvasive positive pressure ventilation and the progress of clinical research, invasive and noninvasive mechanical ventilation have been closely coordinated.^[19,20] In the present study, 80.76% of the patients were successfully weaned using this strategy. It shortened the total mechanical ventilation time, reduced the incidence of VAP, and decreased the cost of hospitalization.

There are two kinds of noninvasive assisted ventilation schemes: one is the use of noninvasive positive pressure ventilation immediately after the extubation (sequential invasive-noninvasive strategy);^[21] the other is the use of noninvasive positive pressure ventilation when exacerbations of respiratory failure post extubation (noninvasive positive pressure ventilation as remedial strategy).^[22] Many studies support the sequential invasive-noninvasive strategy, but researches on sequential invasive-noninvasive ventilation strategy mainly focused on the direct tracheal extubation of patients after their intubation. Because of the continuity and integrity of the trachea were subjected to damages to some extent after tracheostomy, sequential ventilation has certain difficulties, and sequential invasive-noninvasive ventilation for patients after tracheostomy was less common in practice. A breakthrough was made in the mode noninvasive positive pressure ventilation in our study. When the pulmonary infection control window appeared, we connected the patients with a nasal or full-face mask to implement noninvasive ventilation by deflating the cuff and plugging tracheostomy tubes directly. The advantages of this ventilation are as follows: (1) It can give patients effective breathing support and improve ventilation; (2) If the patient cannot accomplish airway clearance independently and effectively, respiratory secretions can be effectively removed by retained tracheostomy tubes; (3) Once noninvasive ventilation fails, we can immediately and easily re-open

Table 2. Comparison of arterial blood gases

Variables	pH	PaCO_2 (mmHg)	PaO_2 (mmHg)
Conventional weaning			
Before weaning	7.32±0.43	49.69±12.35	87.46±9.68
Weaning 1 hour later	7.36±0.24	50.52±13.53	65.54±7.26
Weaning 24 hours later	7.28±0.43	62.26±11.68	75.06±8.76
Sequential weaning			
Before weaning	7.42±0.27	51.54±10.62	85.67±8.76
Weaning 1 hour later	7.35±0.38	56.78±9.60	79.79±9.43*
Weaning 24 hours later	7.32±0.62	60.75±10.37	88.04±9.85*

Compared with the conventional weaning group, * $P<0.05$.

Table 3. Comparison of main medical indexes

Groups	Duration of ventilation (days)	VAP incidence	Success of weaning	Cost (Yuan)
Conventional weaning	6.4±0.63	9	16	$(8.4\pm3.76)\times 10^3$
Sequential weaning	3.4±0.23*	4*	21*	$(5.3\pm2.62)\times 10^3$

Compared with the conventional weaning group, * $P<0.05$.

the tracheostomy tubes to implement invasive ventilation for the safety of patients.

Noninvasive positive pressure ventilation may fail because the continuity and integrity of the trachea were damaged to some extent after tracheostomy, the missing of air from the tracheal cut, the occupation of airway space by the tracheostomy tube and deflated cuff. In this study, we found that noninvasive positive pressure ventilation can be accomplished by deflating the cuff and plugging the tracheostomy tubes directly, even if the patients had not yet completely recovered from sputum clearance ability. Quinell et al^[23] reported that a specialist weaning service using noninvasive ventilation (NIV) for patients requiring prolonged invasive ventilation after recovery from acute illness could be successful in weaning most COPD patients from prolonged invasive ventilation. Song et al^[24] implemented sequential invasive to noninvasive ventilation by plugging tracheostomy tubular sinus directly or replacement for silver metal tubes plugged and demonstrated that it could improve the success rate of weaning, shorten the duration of mechanical ventilation and ICU stay, reduce expenses of hospitalization as well. These results showed a promising clinical application of sequential invasive-noninvasive ventilation strategy. We therefore suggest that tracheostomy tube should be designed with a cap-like accessory which will make it more convenient to switch invasive to noninvasive ventilation by plugging the tracheal tube. Though the similar cap had existed for decades and widely used by patients on fenestrated tracheostomy tubes. But its use in non-fenestrated tracheostomy tube was not approved by regulating bodies. The mode of sequential invasive-noninvasive mechanical ventilation weaning strategy on patients with tracheostomy provided an applicable alternative.

The successful implementation of sequential invasive to noninvasive ventilation depends on the accurate hold of switching point. Premature decision of switching may lead patients to experience relapses, but if you were asleep at the switching point, the patients may suffer from ventilator-associated pneumonia, ventilator dependence and failure of treatment. Many researchers^[25–28] have tested spontaneous breathing trial, heart-rate variability and the pulmonary infection control window as weaning time. In our study, we applied the pulmonary infection control window as the critical switching point. At this time, sputum expectoration markedly reduced, severe respiratory failure was corrected, but there were somewhat respiratory muscle fatigue and respiratory

dynamic abnormality.^[29,30] Non-invasive positive pressure ventilation is more conducive to the recovery of respiratory muscle fatigue.^[31] Luo et al^[32] provide experimental evidence that most AECOPD patients can breathe independently at the pulmonary infection control window, but develop respiratory distress and noninvasive positive pressure ventilation is required after extubation. The major complications in the process of sequential invasive-noninvasive ventilation are thirsty and difficulty in expectoration of thick sputum, flatulence, facial injury and mis-aspiration. These complications may be ascribed to improper use of noninvasive ventilator, bad choice of nasal or full-face mask and intensive care unit acquired weakness. The symptoms of these complications can be ameliorated after corresponding treatment. This study demonstrates that the method is safe and reliable and can be used extensively in clinical practice. Since the study included a limited number of cases, larger sample size studies are needed to confirm the conclusion.

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Ethical approval: The study was approved by the Ethical Committee of First Affiliated Hospital of Anhui Medical University, Hefei, China.

Conflicts of interest: The authors declare that there is no competing interest and nor personal relationship with other people or organizations that could inappropriately influence their work.

Contributors: Pu XX proposed the study and wrote the first draft. All authors read and approved the final manuscript.

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