Sequential treatment of severe pneumonia with respiratory failure and its influence on respiratory mechanical parameters and hemodynamics

Bing-Yin Niu, Guan Wang, Bin Li, Gen-Shen Zhen, Yi-Bing Weng

BACKGROUND
The pathophysiological characteristics of severe pneumonia complicated by respiratory failure comprise pulmonary parenchymal changes leading to ventilation imbalance, alveolar capillary injury, pulmonary edema, refractory hypoxemia, and reduced lung compliance. Prolonged hypoxia can cause acid-base balance disorder, peripheral circulatory failure, blood-pressure reduction, arrhythmia, and other adverse consequences.

AIM
To investigate sequential mechanical ventilation’s effect on severe pneumonia complicated by respiratory failure.

METHODS
We selected 108 patients with severe pneumonia complicated by respiratory failure who underwent mechanical ventilation between January 2018 and September 2020 at the Luhe Hospital’s Intensive Care Unit and divided them into sequential and regular groups according to a randomized trial, with each group comprising 54 patients. The sequential group received invasive and non-invasive sequential mechanical ventilation, whereas the regular group received invasive mechanical ventilation. Blood-gas parameters, hemodynamic parameters, respiratory mechanical parameters, inflammatory factors, and treatment outcomes were compared between the two groups before and after mechanical-ventilation treatment.

RESULTS
The arterial oxygen partial pressure and stroke volume variation values of the sequential group at 24, 48, and 72 h of treatment were higher than those of the conventional group ($P < 0.05$). The carbon dioxide partial pressure value of the
sequential group at 72 h of treatment and the Raw value of the treatment group at 24 and 48 h were lower than those of the conventional group (P < 0.05). The pH value of the sequential group at 24 and 72 h of treatment, the central venous pressure value of the treatment at 24 h, and the Cst value of the treatment at 24 and 48 h were higher than those of the conventional group (P < 0.05). The tidal volume in the sequential group at 24 h of treatment was higher than that in the conventional group (P < 0.05), the measured values of interleukin-6 and tumor necrosis factor-α in the sequential group at 72 h of treatment were lower than those in the conventional group (P < 0.05), and the total time of mechanical ventilation in the sequential group was shorter than that in the conventional group, with a statistically significant difference (P < 0.05).

CONCLUSION
Treating severe pneumonia complicated by respiratory failure with sequential mechanical ventilation is more effective in improving respiratory system compliance, reducing inflammatory response, maintaining hemodynamic stability, and improving patient blood-gas levels; however, from this study’s perspective, it cannot reduce patient mortality.

Key Words: Sequential treatment; Mechanical ventilation; Severe pneumonia; Respiratory failure; Compliance

INTRODUCTION
Severe pneumonia is a serious respiratory disease, predominantly caused by delayed treatment or improper treatment of pneumonia and typically affecting older adults, children, and people with relatively low immunity. Severe pneumonia not only causes severe respiratory symptoms and hypoxia, but also results in the dysfunction of other organs and even multiple organ failure, with a high fatality rate. Respiratory failure is one of the most important causes of mortality in patients with severe pneumonia[1]. Mechanical ventilation is a common method for the clinical treatment of severe pneumonia complicated by respiratory failure, and it can rapidly improve oxygenation, correct body hypoxia, and improve hypoxia in other organs[2].

Traditional mechanical ventilation methods involve invasive mechanical ventilation, in which patients undergo endotracheal intubation or tracheotomy. The duration of mechanical ventilation is long, with a high risk of ventilator-associated pneumonia and other complications, leading to ventilator dependence and disengagement difficulty[3]. Sequential mechanical ventilation is a combined ventilation mode that ensures a timely cessation of invasive mechanical ventilation after the patient’s condition is brought under control and subsequently shifts to non-invasive mechanical ventilation. This mode potentially shortens the duration of invasive mechanical ventilation and reduces the risk of complications[4,5]. Our study aimed to investigate the effect of sequential mechanical ventilation on severe pneumonia complicated by respiratory failure.

MATERIALS AND METHODS

Data
A total of 108 patients with severe pneumonia complicated by respiratory failure who underwent mechanical ventilation between January 2018 and September 2020 at the Luhe Hospital’s Intensive Care
Unit were selected and divided into sequential and regular groups according to a randomized trial. Each group comprised 54 patients. The inclusion criteria were as follows: (1) Diagnosis of severe pneumonia using the diagnostic criteria of pneumonia[6], with the patient requiring endotracheal intubation; (2) type II respiratory failure [arterial oxygen partial pressure (PaO₂) < 40.0 mmHg; arterial carbon dioxide partial pressure (PaCO₂) > 60 mmHg]; (3) patients aged 51–79 years; and (4) chest radiographs or computed tomography examinations revealing multiple pulmonary infiltration lesions. The exclusion criteria were as follows: (1) malignant tumor, leukemia, etc.; (2) thoracic fracture; (3) comorbid hemorrhagic disease; (4) complication by complete left ventricular block and malignant arrhythmia; (5) comorbid thyroid disease; and (6) ventilator-use time < 48 h or transfer to the hospital for treatment.

**Basic treatment**

All patients received regular treatment, such as anti-infection therapy; anti-inflammatory medication; expectorants; nutritional support; sputum aspiration when necessary; and maintenance of water, electrolyte, and acid-base balance. Broad-spectrum antibiotics or deep sputum were selected for drug-sensitivity tests, and sensitive antibiotics were selected for anti-infection treatment according to the drug-sensitivity test results. Intravenous dexamethasone infusion was used as an anti-inflammatory agent and ambroxol as an expectorant.

**Mechanical ventilation therapy**

Patients in the regular group were treated with invasive mechanical ventilation using a GE CARESCAPE R860 ventilator (GE Healthcare, Madison, WI, USA). Tracheal intubation or tracheotomy was performed to establish an artificial airway, and the ventilation mode was set as synchronous intermittent instruction ventilation (SIMV) + pressure support ventilation (PSV). Ventilator parameters were as follows: respiration rate of 8–14 times/min, inhaled oxygen concentration of 35%–55%, inhaling-to-breathing ratio of 1:2, and tidal volume of 8–10 mL/kg. Oxygen saturation was monitored and maintained at > 90% until decompression.

The sequential group received invasive and non-invasive sequential mechanical ventilation using a GE CARESCAPE R860 ventilator. Tracheal intubation or tracheotomy was performed to establish an artificial airway. The ventilation mode was set to the volume ventilation mode. Ventilator parameters were as follows: respiratory rate of 15–20 times/min, inhaled oxygen concentration of 35%–55%, inhalation-to-breath of ratio 1:2, and tidal volume of 5–12 mL/kg. Thereafter, the PSV + SIMV mode was altered, and the ventilator parameters were similar to those of the regular group. Lung-infection control was considered when the patient’s lung infiltration shadow became smaller, body temperature was < 38°C, patients discharged sputum by themselves, lung rales decreased, and white-blood-cell levels decreased. Spontaneous breathing tests were subsequently performed. If the patient tolerated spontaneous breathing, extubation was performed, and a two-level, positive pressure ventilation mode was applied. When the inspiratory pressure was ≤ 5 cmH₂O, the machine was removed and oxygen inhalation was switched to a nasal catheter. If the spontaneous breathing test found that the patient could not tolerate spontaneous breathing, the original treatment plan was continued.

**Observation indexes**

Blood-gas parameters (PaO₂, PaCO₂, and pH), hemodynamic parameters [central venous pressure (CVP), heart rate (HR), cardiac displacement (CO), cardiac index (CI), and stroke volume variation rate (SVV)], respiratory mechanical parameters [airway resistance (Raw), tidal volume, and respiratory static negative (Cst)], inflammatory factors [interleukin-6 (IL-6), IL-8, and tumor necrosis factor-α (TNF-α)], and treatment outcomes in the two groups of patients were compared at different times before and after mechanical ventilation.

Before treatment, patient radial artery blood was collected for post-treatment blood-gas analysis at 24, 48, and 72 h, and PaO₂, PaCO₂, and pH values were recorded. The Xp-100 blood gas analyzer (Shanghai Mingyuan Industrial Co., Ltd., Shanghai, China) was used as a detection instrument. Data regarding respiratory mechanics and hemodynamic parameters on the Mindray ECG monitor (Mindray Bio-Medical Electronics Co., Ltd., Nanshan, Shenzhen, China) were recorded.

Before treatment, 3 mL of fasting venous blood was extracted from patients 72 h after treatment and placed in an ethylenediaminetetraacetic acid anticoagulant tube; 1 h after centrifuge treatment (3000 r/min, 10 min), serum was collected, and IL-6, IL-8, and TNF-α were detected using an enzyme-linked immunosorbent assay kit (Shanghai Enzyme-linked Biotecnology Co., Ltd., Shanghai, China) and detection instrument (Shenzhen Mindray Medical Electronics Rt-96a Microplate reader; Sub-Co., Ltd., Shenzhen, China).

**Statistical analysis**

In this study, PaO₂, PaCO₂, pH, and other measurement indicators were consistent with an approximately normal or normal distribution according to the normal distribution test, and they were expressed as mean ± SD. Further, the repeated measurement variance analysis method was adopted by the t-test using SPPS software (IBM, Armonk, NY, USA). The χ² test was used to analyze the data, and
the inspection level was set at $\alpha = 0.05$.

RESULTS

**Single-factor analysis of the patient population and characteristic clinical parameters in the two groups**

The comparison of population and characteristic clinical parameters between the sequential and regular groups revealed favorable equilibrium and comparability ($P > 0.05$), as shown in Table 1.

**Comparison of blood-gas parameters between the two groups of patients before and after treatment**

Before treatment, the PaO$_2$, PaCO$_2$, and pH values in the sequential and regular groups were not statistically significant ($P > 0.05$). The PaO$_2$ values of the sequential group at 24, 48 and 72 h were higher than those of the regular group ($P < 0.05$), the PaCO$_2$ value of the sequential group at 72 h was lower than that of the regular group ($P < 0.05$), and the pH values of the sequential group at 24 and 72 h were higher than those of the regular group ($P < 0.05$, Table 2).

**Comparison of hemodynamic parameters before and after treatment between the two groups**

There were no significant differences in CVP, HR, CO, CI, and SVV values between the sequential and regular groups before treatment ($P > 0.05$). The CVP value of the sequential group at 24 h was higher than that of the regular group ($P < 0.05$), and the SVV values of the sequential group at 24, 48 and 72 h were higher than those of the regular group ($P < 0.05$), as shown in Table 3.

**Comparison of the respiratory system’s compliance indexes between the two groups of patients before and after treatment**

There were no significant differences in Raw, tidal volume, and Cst values between the sequential and regular groups before treatment ($P > 0.05$). The Raw values at 24 and 48 h in the sequential group were lower than those in the regular group ($P < 0.05$). The Cst values at 24 and 48 h in the sequential group were higher than those in the regular group ($P < 0.05$), and the tidal volume at 24 h in the sequential group was higher than that in the regular group ($P < 0.05$, Table 4).

**Comparison of serum inflammatory response indexes before and after treatment between the two groups**

There were no significant differences in IL-6, IL-8, and TNF-α levels between the sequential and regular groups before treatment ($P > 0.05$). After 72 h of treatment, the IL-6 and TNF-α levels in the sequential group were lower than those in the regular group ($P < 0.05$), as shown in Table 5.

**Comparison of treatment outcomes between the two groups**

The total mechanical-ventilation time in the sequential group was shorter than that in the regular group, and the difference was statistically significant ($P < 0.05$). There were no significant differences in reintubation rate and mortality between the sequential and regular groups ($P > 0.05$), as shown in Table 6.

DISCUSSION

Mechanical ventilation is an important means of treating severe pneumonia complicated by respiratory failure, as it potentially increases oxygen supply to body organs, promotes the discharge of excess carbon dioxide, reduces the work of respiratory muscles, and thus rapidly corrects body hypoxia. However, invasive mechanical ventilation requires the construction of an artificial airway; the longer it is used, the weaker the respiratory muscles and the higher the risk of infection[7,8]. Patients who undergo tracheotomy require routine placement of a nasogastric tube, which potentially increases the risk of food reflux, choking, and lung infection. The occurrence of complications can complicate the condition and is not beneficial to patient prognosis[3,10].

Previous studies have found that prolonged mechanical ventilation can cause alveolar atrophy and collapse, cause or aggravate atelectasis, reduce lung compliance, and further aggravate respiratory failure[11]. Clinical efforts have been made to identify a reasonable mechanical ventilation mode that not only ensures oxygen supply to the body, but also reduces ventilator-related complications as much as possible to improve disease outcome. Sequential mechanical ventilation refers to the administration of invasive mechanical ventilation for a period of time, terminating invasive ventilation before pulmonary infection control without achieving extubation and debridement standards, administering sequential treatment of non-invasive ventilation, and gradual debridement. This method can shorten the total time required for invasive mechanical ventilation and reduce the risk of complications[12,13].
Table 1 Single-factor analysis of patient population and characteristic clinical parameters in the two groups

| Index                        | Sequential group (n = 54) | Regular group (n = 54) | t/χ² | P value |
|------------------------------|---------------------------|------------------------|------|---------|
| Age (yr)                     | 65.9 ± 5.5                | 65.2 ± 6.5             | 0.604| 0.547   |
| Height (cm)                  | 165.8 ± 5.0               | 165.3 ± 4.4            | 0.552| 0.582   |
| Body weight (kg)             | 66.4 ± 6.2                | 65.8 ± 5.7             | 0.524| 0.602   |
| APACHE II score (scores)     | 19.8 ± 3.0                | 20.3 ± 3.4             | -0.810| 0.420   |
| CPIS score (scores)          | 9.9 ± 1.1                 | 10.1 ± 1.3             | -0.863| 0.390   |
| Heart rate (times/min)       | 74.3 ± 6.0                | 76.2 ± 7.4             | -1.466| 0.146   |
| Sex, n (%)                   |                           |                        |      |         |
| Male                         | 31 (57.41)                | 28 (51.85)             |      |         |
| Female                       | 23 (42.59)                | 26 (48.15)             |      |         |
| Hypertension, n (%)          |                           |                        |      |         |
| Yes                          | 14 (25.93)                | 7 (12.96)              |      |         |
| No                           | 40 (74.07)                | 47 (87.04)             |      |         |
| Diabetes, n (%)              |                           |                        |      |         |
| Yes                          | 4 (7.41)                  | 7 (12.96)              |      |         |
| No                           | 50 (92.59)                | 47 (87.04)             |      |         |
| Dyslipidemia, n (%)          |                           |                        |      |         |
| Yes                          | 28 (51.85)                | 36 (66.67)             |      |         |
| No                           | 26 (48.15)                | 18 (33.33)             |      |         |
| Smoking, n (%)               |                           |                        |      |         |
| Yes                          | 22 (40.74)                | 16 (29.63)             |      |         |
| No                           | 32 (59.26)                | 38 (70.37)             |      |         |

Table 2 Comparison of blood-gas parameters between the two groups of patients before and after treatment (mean ± SD)

| Group                        | Before treatment | Treatment 24 h | Treatment 48 h | Treatment 72 h |
|------------------------------|------------------|----------------|----------------|----------------|
| PaO₂ (mmHg)                  |                  |                |                |                |
| Sequential group (n = 54)    | 36.11 ± 2.88     | 74.31 ± 4.17   | 85.32 ± 5.40   | 93.84 ± 5.50   |
| Regular group (n = 54)       | 35.74 ± 3.01     | 70.58 ± 3.96   | 82.74 ± 4.86   | 91.70 ± 4.96   |
| t value                      | 0.653            | 4.766          | 2.610          | 2.123          |
| P value                      | 0.515            | 0.000          | 0.010          | 0.036          |
| PaCO₂ (mmHg)                 |                  |                |                |                |
| Sequential group (n = 54)    | 68.42 ± 3.03     | 54.29 ± 3.75   | 45.63 ± 3.80   | 37.03 ± 3.94   |
| Regular group (n = 54)       | 69.03 ± 2.96     | 55.70 ± 4.03   | 46.80 ± 4.25   | 38.64 ± 4.41   |
| t value                      | -1.058           | -1.882         | -1.508         | -2.001         |
| P value                      | 0.292            | 0.063          | 0.135          | 0.048          |
| pH (mmHg)                    |                  |                |                |                |
| Sequential group (n = 54)    | 7.22 ± 0.05      | 7.33 ± 0.05    | 7.37 ± 0.05    | 7.39 ± 0.04    |
| Regular group (n = 54)       | 7.23 ± 0.05      | 7.31 ± 0.04    | 7.36 ± 0.05    | 7.37 ± 0.05    |
| t value                      | -1.039           | 2.295          | 1.039          | 2.295          |
| P value                      | 0.301            | 0.024          | 0.301          | 0.024          |
Among the patients treated with sequential therapy in this study, the \( \text{PaO}_2 \) values were found to be higher at 24, 48, and 72 h; \( \text{PaCO}_2 \) values were lower at 72 h; and \( \text{pH} \) values were higher at 24 and 72 h than those of patients treated with regular therapy, suggesting that sequential mechanical ventilation for the treatment of severe pneumonia complicated with respiratory failure exhaustion is more beneficial in correcting hypoxia and relieving acidosis than regular methods. This is due to the fact that sequential mechanical ventilation potentially protects alveoli, prevents their atrophy and collapse, reduces the work of respiratory muscles, improves lung compliance, and improves patients’ respiratory failure [14, 15].

This study also detected differences in hemodynamic parameters and respiratory mechanical parameters between the two groups before and after treatment. The CVP value of patients receiving sequential treatment at 24 h was higher than that of those receiving regular treatment, and the SVV values at 24, 48, and 72 h were higher than those of patients receiving regular treatment. In the sequential treatment group, the Raw values at 24 and 48 h were lower, Cst values at 24 and 48 h were higher, and tidal volume at 24 h was higher than those in the regular treatment group, indicating that sequential mechanical ventilation in the treatment of severe pneumonia complicated by respiratory failure is the standard, more effective method of improving respiratory system compliance and maintaining hemodynamic stability. This is due to the high peak inspiratory pressure and tidal volume.
Table 4 Comparison of the respiratory system’s compliance indexes between the two groups of patients before and after treatment (mean ± SD)

| Group                  | Before treatment | Treatment 24 h | Treatment 48 h | Treatment 72 h |
|------------------------|------------------|----------------|----------------|---------------|
| Raw [cmH$_2$O/(L·S)]   |                  |                |                |               |
| Sequential group (n = 54) | 23.85 ± 2.74     | 18.63 ± 2.58   | 17.40 ± 2.44   | 18.18 ± 2.60  |
| Regular group (n = 54)  | 23.33 ± 2.60     | 19.94 ± 2.71   | 18.87 ± 2.73   | 18.83 ± 2.84  |
| \( t \) value          | 1.012            | -2.573         | -2.950         | -1.241        |
| \( P \) value          | 0.314            | 0.011          | 0.004          | 0.218         |

| Tidal volume (mL/kg)   |                  |                |                |               |
| Sequential group (n = 54) | 6.58 ± 1.04     | 9.58 ± 1.14    | 9.40 ± 0.96    | 9.62 ± 1.20   |
| Regular group (n = 54)  | 6.82 ± 0.95      | 8.81 ± 1.23    | 9.13 ± 1.02    | 9.32 ± 0.98   |
| \( t \) value          | -1.252           | 3.374          | 1.416          | 1.423         |
| \( P \) value          | 0.213            | 0.001          | 0.160          | 0.158         |

| Cst (mL/cmH$_2$O)      |                  |                |                |               |
| Sequential group (n = 54) | 22.84 ± 2.60     | 24.73 ± 2.94   | 26.58 ± 3.02   | 25.72 ± 2.54  |
| Regular group (n = 54)  | 23.36 ± 2.72     | 23.60 ± 2.76   | 24.81 ± 3.13   | 25.00 ± 2.62  |
| \( t \) value          | -1.016           | 2.059          | 2.990          | 1.450         |
| \( P \) value          | 0.312            | 0.042          | 0.003          | 0.150         |

Table 5 Comparison of serum inflammatory response indexes before and after treatment between the two groups (mean ± SD)

| Group                      | n    | IL-6 (ng/L) Before treatment | IL-6 (ng/L) Treatment 72 h | IL-8 (ng/L) Before treatment | IL-8 (ng/L) Treatment 72 h | TNF-\( \alpha \) (ng/L) Before treatment | TNF-\( \alpha \) (ng/L) Treatment 72 h |
|----------------------------|------|-------------------------------|---------------------------|-------------------------------|---------------------------|---------------------------------------|---------------------------------------|
| Sequential group           | 54   | 169.5 ± 24.8                  | 97.4 ± 16.3               | 209.5 ± 38.6                  | 118.7 ± 19.5              | 249.5 ± 48.5                         | 131.8 ± 24.0                         |
| Regular group              | 54   | 173.4 ± 26.1                  | 108.0 ± 23.5              | 202.7 ± 35.4                  | 126.2 ± 23.0              | 260.3 ± 51.2                         | 150.8 ± 27.5                         |
| \( t \) value             |      | -0.796                        | -2.724                    | 0.954                         | -1.828                    | -1.125                               | -3.825                               |
| \( P \) value             |      | 0.428                         | 0.008                     | 0.342                         | 0.070                     | 0.263                                | 0.000                                |

IL-6: Interleukin-6; TNF-\( \alpha \): Tumor necrosis factor-\( \alpha \).

Table 6 Comparison of treatment outcomes between the two groups, n (%)

| Group                      | n    | Total time of mechanical ventilation (d) | Reintubation rate | Case fatality rate |
|----------------------------|------|------------------------------------------|-------------------|-------------------|
| Sequential group           | 54   | 12.7 ± 2.9                               | 1 (1.85)          | 2 (3.70)          |
| Regular group              | 54   | 14.1 ± 3.2                               | 3 (5.6)           | 4 (7.41)          |
| \( t/\chi^2 \)             |      | -2.382                                   | 1.038             | 0.706             |
| \( P \) value             |      | 0.019                                    | 0.308             | 0.401             |

in the regular mechanical ventilation mode, which easily leads to lung injuries, such as the barometric and biological injuries. Moreover, patients often experience problems such as alveolar atrophy, pulmonary interstitial edema, and sporadic lung alveolar overinflation, conditions that are not conducive to the recovery of spontaneous respiratory function\[16\]. In contrast, sequential mechanical ventilation has a relatively low tidal volume, which reduces airway pressure, pressure injury, and ventilator-related lung injury. Dual-level positive pressure ventilation potentially facilitates the reopening of nonventilatory alveoli, maintains an open airway, and improves the ventilation/blood-flow ratio and hemodynamic parameters\[17\].

Patients with severe pneumonia experience lung inflammation and can develop the systemic inflammatory response syndrome. IL-6, a proinflammatory factor secreted by macrophages and lymphocytes,
can promote the generation of neutrophils, induce a systemic immune response, and promote inflammation\cite{18}. IL-8 is an inflammatory chemokine that potentially activates neutrophils, increases lysozyme release, induces phagocytic effects, and causes inflammatory tissue damage\cite{19}. TNF-α, a proinflammatory factor synthesized by mononuclear macrophages, can promote the activation of proinflammatory factors and aggravate the inflammatory response\cite{20}. At present, there are many studies on sequential treatment of severe pneumonia and respiratory failure which have confirmed its advantages over traditional treatment. On this basis, the present study uses inflammatory factors as indicators to explore the effect of sequential treatment on the degree of inflammatory response in patients. We found that the measured values of IL-6 and TNF-α at 72 h of treatment in the sequential treatment group were lower than those in the conventional treatment group, suggesting that sequential mechanical ventilation in the treatment of severe pneumonia complicated by respiratory failure is more effective in reducing the inflammatory response than regular therapy. This is related to sequential mechanical ventilation, which potentially improves respiratory system compliance more effectively, corrects the hypoxic state of the body, and facilitates infection control.

This study also found that the total duration of mechanical ventilation was shorter in patients treated with sequential therapy than in those treated with regular therapy. There were no significant differences in the reintubation rate and mortality between the two groups, suggesting that sequential mechanical ventilation in the treatment of severe pneumonia complicated by respiratory failure potentially reduces the total mechanical-ventilation time, but does not significantly increase the reintubation rate and mortality of patients, thus conferring a favorable application value to the procedure.

There were some limitations to this study. The sample size was small, and it was conducted in a single-center. In the future, a large-sample, multi-center study should further explore the advantages of sequential mechanical ventilation in the treatment of severe pneumonia complicated with respiratory failure.

**CONCLUSION**

In summary, sequential mechanical ventilation in the treatment of severe pneumonia complicated by respiratory failure is more effective in improving respiratory system compliance, reducing inflammatory response, maintaining hemodynamic stability, and thus improving patient blood-gas level more effectively; however, from this study’s perspective, it cannot reduce patient mortality. To further explore the advantages of sequential mechanical ventilation in the treatment of severe pneumonia complicated with respiratory failure, a large-sample, multi-center study is warranted.

**ARTICLE HIGHLIGHTS**

**Research background**
Prolonged hypoxia can cause acid-base balance disorder, peripheral circulatory failure, blood-pressure reduction, arrhythmia, and other adverse consequences.

**Research motivation**
Blood-gas parameters, hemodynamic parameters, respiratory mechanical parameters, inflammatory factors, and treatment outcomes were compared between the two groups before and after mechanical-ventilation treatment.

**Research objectives**
This study aimed to investigate sequential mechanical ventilation’s effect on severe pneumonia complicated by respiratory failure.

**Research methods**
Before treatment, patient radial artery blood was collected for post-treatment blood-gas analysis at 24, 48, and 72 h, and oxygen partial pressure, carbon dioxide partial pressure, and pH values were recorded. The Xp-100 blood gas analyzer was used as a detection instrument. Data regarding respiratory mechanics and hemodynamic parameters on the Mindray ECG monitor were recorded. Before treatment, 3 mL of fasting venous blood was extracted from patients 72 h after treatment and placed in an ethylenediaminetetraacetic acid anticoagulant tube; 1 h after centrifuge treatment, serum was collected, and interleukin-6 (IL-6), IL-8, and tumor necrosis factor-α were detected using an enzyme-linked immunosorbent assay kit and detection instrument.

**Research results**
Sequential mechanical ventilation potentially protects alveoli, prevents their atrophy and collapse,
reduces the work of respiratory muscles, improves lung compliance, and improves patients’ respiratory failure. Dual-level positive pressure ventilation potentially facilitates the reopening of nonventilatory alveoli, maintains an open airway, and improves the ventilation/blood-flow ratio and hemodynamic parameters. Sequential mechanical ventilation, which potentially improves respiratory system compliance more effectively, corrects the hypoxic state of the body, and facilitates infection control. Sequential mechanical ventilation in the treatment of severe pneumonia complicated by respiratory failure potentially reduces the total mechanical-ventilation time, but does not significantly increase the reintubation rate and mortality of patients, thus conferring a favorable application value to the procedure.

**Research conclusions**
Sequential mechanical ventilation in the treatment of severe pneumonia complicated by respiratory failure is more effective in improving inspiratory system compliance, reducing inflammatory response, maintaining hemodynamic stability, and thus improving patient blood-gas level more effectively.

**Research perspectives**
To further explore the advantages of sequential mechanical ventilation in the treatment of severe pneumonia complicated with respiratory failure, a large-sample, multi-center study is warranted.

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**FOOTNOTES**

**Author contributions:** Niu BY and Weng YB designed this study; Niu BY wrote this manuscript; Niu BY, Wang G, Li B, and Zhen GS were responsible for sorting the data; and all authors have read and approve the final manuscript.

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