

Analysis of the Efficacy of Humidified High-Flow Nasal Oxygen Therapy Combined with Alveolar Lavage in the Treatment of Patients with Severe Pneumonia Complicated with Respiratory Failure

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Abstract: *Objective:* To analyze the curative effect of humidified high-flow nasal oxygen therapy combined with alveolar lavage in patients with severe pneumonia and respiratory failure. *Methods:* 120 patients with severe pneumonia complicated with respiratory failure admitted to the Third People's Hospital of Xining from July 2021 to December 2022 were randomly divided into two groups: group A and group B. The patients in group A were given humidified high-flow nasal oxygen therapy combined with alveolar lavage, whereas those in group B were given humidified high-flow nasal oxygen therapy. The treatment efficacy, blood gas analysis results, and differences in inflammatory mediators were compared between the two groups. *Results:* The curative effect in group A (96.67%) was significantly higher than that in group B (81.67%), $P < 0.05$; the partial pressure of carbon dioxide (PaCO_2), partial pressure of oxygen (PaO_2), oxygen saturation (SpO_2), and Horowitz index (P/F) of group A were significantly better than group B, $P < 0.05$; the interleukin 6 (IL-6), tumor necrosis factor alpha (TNF- α), and C-reactive protein (CRP) levels, white blood cell (WBC) count, serum procalcitonin (PCT), and neutrophil (N) percentage of group A were significantly lower than those of group B, $P < 0.05$. *Conclusion:* For patients with severe pneumonia complicated with respiratory failure, alveolar lavage, on the basis of humidified high-flow oxygen therapy, can inhibit local inflammation, improve blood gas analysis results, promote disease recovery, and improve the clinical treatment effect.

Keywords: Alveolar lavage; High-flow oxygen therapy; Humidified nasal oxygen therapy; Severe pneumonia; Respiratory failure

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1. Introduction

Severe pneumonia is related to infection caused by bacteria or viruses. It reduces immunity and may cause serious complications, such as respiratory failure. Severe pneumonia needs to be treated as soon as possible to prevent mortality. The conventional treatment for severe pneumonia complicated with respiratory failure includes correcting acid-base balance, supplementing with oxygen, and administering anti-inflammatory drugs. Although it can alleviate the symptoms of respiratory failure and delay the progression of pneumonia, the overall curative effect is limited^[1]. In recent years, bronchoalveolar lavage, a safe and efficient method, has taken precedence in the early treatment of respiratory diseases. Drugs are directly injected into the diseased area, completely removing airway secretions and restoring the patient's respiratory function^[2]. In this study, 120 patients with severe pneumonia complicated with respiratory failure treated from July 2021

to December 2022 were included to explore the therapeutic effect of humidified high-flow nasal oxygen therapy combined with alveolar lavage.

2. Materials and methods

2.1. Patient information

A sample of 120 patients with severe pneumonia and respiratory failure treated from July 2021 to December 2022 was randomly divided into two groups. In group A, the ratio of male to female was 37:23, and the mean age was 62.43 ± 1.94 ; in group B, the ratio of male to female was 38:22, and the mean age was 62.51 ± 1.99 . There was no significant difference in baseline data between group A and group B ($P > 0.05$).

2.2. Inclusion and exclusion criteria

Inclusion criteria: (i) patients who met the diagnostic criteria for severe pneumonia in *Guidelines for the Diagnosis and Treatment of Community-Acquired Pneumonia* [31], and with respiratory failure; (ii) patients who voluntarily participated in this study and had given informed consent; (iii) patients with clear awareness and good compliance; (iv) patients with normal coagulation function.

Exclusion criteria: (i) patients with pulmonary fibrosis, lung tumor, pulmonary tuberculosis, pneumoconiosis, or upper airway obstruction; (ii) patients with immune dysfunction; (iii) patients with severe heart, liver, and kidney dysfunction.

During admission, the two groups of patients received conventional treatment for infection, cough, phlegm, and obstructive symptoms; maintenance of electrolyte balance; correction of acid-base balance; and other treatments.

2.3 Treatment methods

Group A received humidified high-flow nasal oxygen therapy combined with alveolar lavage.

(i) Humidified high-flow nasal oxygen therapy

The humidified high-flow nasal oxygen therapy system was used. The device was fixed in front of the patient's nose, and the oxygen therapy parameters were adjusted based on the patient's tolerance and arterial blood gas analysis results. The oxygen flow rate was adjusted to 40–60 L/min, temperature was maintained at 31–37°C, and the oxygen volume fraction, blood oxygen saturation, and oxygen partial pressure were adjusted to 35%–60%, 90%–98%, and 80–100 mmHg, respectively.

(ii) Alveolar lavage

Each patient in group A was required to fast for 2 h before treatment. Atomized lidocaine (2%, 5 mL) was administered, and after the anesthesia had taken effect, the patient was placed on electrocardiogram (ECG) monitoring, a fiberoptic bronchoscope was inserted through the patient's oral cavity or nasal cavity, and the patient was observed for airway lesions. After removing stagnant sputum in the airway, the bronchoscope was placed at the target lung segment, and 20 mL of normal saline at 37°C was prepared to lavage the infected area of the lung lobe for 4 times, with each lavage lasting about 30 s. During the lavage, the patient's vital signs were monitored, and if the saturation of oxygen was found to be $< 85\%$, the lavage was stopped immediately and oxygen was given. All operations were performed by the same group of medical staff. The patients were treated for 1 week.

Group B received humidified high-flow nasal oxygen therapy, and the operation was the same as that of group A. The patients in group B were also treated for 1 week.

2.4. Observation indicators

(i) Curative effect: “significantly effective” was denoted as improvement in clinical symptoms (cough, dyspnea, and hypoxia), normalization of blood gas analysis results, and resolved inflammation

(absorbed exudation) on chest radiograph; “effective” was denoted as improvement in clinical symptoms (cough, dyspnea, and hypoxia) and arterial blood gas analysis results, as well as less lung shadow on chest radiograph; “ineffective” was denoted as aggravation or no improvement in clinical symptoms and blood gas analysis results [4].

- (ii) Blood gas analysis: arterial blood samples were collected from the patients, and a blood gas analyzer was used to detect partial pressure of carbon dioxide (PaCO₂), partial pressure of oxygen (PaO₂), oxygen saturation (SpO₂), and Horowitz index (P/F).
- (iii) Inflammatory indicators: interleukin 6 (IL-6), tumor necrosis factor alpha (TNF- α), C-reactive protein (CRP), white blood cell (WBC) count, serum procalcitonin (PCT), and neutrophil (N) percentage were detected by enzyme-linked immunosorbent assay.

2.5. Statistical analysis

SPSS 21.0 was used for data processing. The count and measurement data were recorded in percentage (%) and mean \pm standard deviation, respectively, and tested by chi-square test (χ^2) and *t*-test. *P* < 0.05 indicates statistical significance.

3. Results

3.1. Curative effect

As shown in **Table 1**, the curative effect in group A (96.67%) was significantly higher than that in group B (81.67%), *P* < 0.05.

Table 1. Comparison of curative effects

Group	Significantly effective	Effective	Ineffective	Efficacy
Group A (n = 60)	43 (71.67%)	15 (25.00%)	2 (3.33%)	96.67%
Group B (n = 60)	26 (43.33%)	23 (38.33%)	11 (18.33%)	81.67%
χ^2	–	–	–	6.9878
<i>P</i>	–	–	–	0.0082

3.2. Blood gas analysis

Before treatment, there was no significant difference in PaCO₂, PaO₂, SpO₂, and P/F ratio between group A and group B, *P* > 0.05; after treatment, the PaCO₂, PaO₂, SpO₂, and P/F ratio of group A were significantly better than those of group B, *P* < 0.05. See **Table 2** for details.

Table 2. Comparison of blood gas analysis results

Group	PaCO ₂ (mmHg)		PaO ₂ (mmHg)		SpO ₂ (%)		P/F	
	Before treatment	After treatment	Before treatment	After treatment	Before treatment	After treatment	Before treatment	After treatment
Group A (n = 60)	52.87 \pm 4.81	35.77 \pm 2.73	54.17 \pm 4.25	84.11 \pm 8.25	90.14 \pm 1.85	98.41 \pm 2.71	212.84 \pm 18.43	328.41 \pm 21.43
Group B (n = 60)	52.91 \pm 4.83	41.26 \pm 3.86	54.21 \pm 4.27	77.69 \pm 7.43	90.12 \pm 1.87	94.36 \pm 2.52	212.91 \pm 18.39	298.67 \pm 19.62
<i>t</i>	0.0376	7.4353	0.0425	3.7026	0.0487	7.0077	0.0208	7.9286
<i>P</i>	0.9701	0.0000	0.9662	0.0004	0.9613	0.0000	0.9834	0.0000

3.3. Inflammatory mediators

Before treatment, there was no significant difference in IL-6, TNF- α , CRP, WBC, PCT, and N percentage between group A and group B, $P > 0.05$; after treatment, the IL-6, TNF- α , CRP, WBC, PCT, and N percentage of group A were lower than those of group B, $P < 0.05$. See **Table 3** for details.

Table 3. Comparison of inflammatory mediators

Group	IL-6 (pg/mL)		TNF- α (μ g/mL)		CRP (mg/L)	
	Before treatment	After treatment	Before treatment	After treatment	Before treatment	After treatment
Group A (n = 60)	30.98 \pm 2.42	10.48 \pm 1.38	9.64 \pm 1.52	2.74 \pm 0.78	124.11 \pm 15.25	46.11 \pm 5.15
Group B (n = 60)	30.87 \pm 2.48	17.96 \pm 1.87	9.68 \pm 1.49	5.39 \pm 1.15	124.25 \pm 15.31	61.38 \pm 6.36
<i>t</i>	0.2033	20.6084	0.1203	12.2112	0.0502	14.4533
<i>P</i>	0.8394	0.0000	0.9045	0.0000	0.9601	0.0000

Group	WBC ($\times 10^9$ /L)		Serum PCT (ng/mL)		N percentage (%)	
	Before treatment	After treatment	Before treatment	After treatment	Before treatment	After treatment
Group A (n = 60)	16.14 \pm 1.28	4.51 \pm 0.48	36.18 \pm 2.25	0.21 \pm 0.08	86.11 \pm 2.15	72.89 \pm 1.87
Group B (n = 60)	16.17 \pm 1.31	9.38 \pm 0.51	36.21 \pm 2.27	0.49 \pm 0.19	86.14 \pm 2.19	80.41 \pm 1.96
<i>t</i>	0.1269	53.8623	0.0727	10.5206	0.0757	21.5025
<i>P</i>	0.8993	0.0000	0.9422	0.0000	0.9398	0.0000

4. Discussion

Patients with severe pneumonia often have concomitant pulmonary ventilation disorder, resulting in impaired gas exchange and secondary respiratory failure; thus increases the mortality of patients [5]. Conventional comprehensive plans such as expectorant, anti-infective, and oxygen administration are used in the treatment of severe pneumonia complicated with respiratory failure, but the curative effect is limited. In order to restore the ventilatory function and increase the blood oxygen concentration in patients with severe pneumonia, humidified high-flow nasal oxygen therapy can be used to improve effective alveolar ventilation and end-expiratory lung volume, thereby improving the physiological comfort of patients [6]. However, it is difficult to achieve the desired effect with oxygen therapy alone. Therefore, the use of oxygen therapy in combination with alveolar lavage has been suggested. Repeated washing of airway secretions and removal of stagnant sputum, inflammatory mediators, toxins, pathogens, and other substances can improve atelectasis and restore pulmonary ventilation function [7].

According to our study, the curative effect in group A (96.67%) was higher than that in group B (81.67%), $P < 0.05$, indicating that humidified high-flow oxygen therapy combined with alveolar lavage can enhance the curative effect. High-flow oxygen humidifiers can constantly and continuously supply oxygen to patients, which is beneficial to improving oxygen saturation, while preventing the re-inhalation of carbon dioxide, thereby reducing PaCO₂ content and optimizing the oxygenation function. During the treatment, oxygen is heated and humidified, which can dilute sputum, promote sputum expulsion, and enhance the airway's cilia cleaning function. All these are beneficial to reducing the risk of lung infection [8]. This oxygen therapy, along with bronchial lavage under fiberoptic bronchoscopy, promotes the discharge of airway secretions, allows the sampling of the lesion area, and guides the later antibacterial treatment through bacteriological examination, which is beneficial to alleviating respiratory failure [9]. Another set of data showed that the PaCO₂ (35.77 \pm 2.73 mmHg), PaO₂ (84.11 \pm 8.25 mmHg), SpO₂ (98.41 \pm 2.71 %), and P/F ratio (328.41 \pm 21.43) in group A were significantly better than those in group

B, $P < 0.05$; moreover, the IL-6 (10.48 ± 1.38 pg/mL), TNF- α (2.74 ± 0.78 μ g/mL), CRP (46.11 ± 5.15 mg/L), WBC ($4.51 \pm 0.48 \times 10^9$ /L), PCT (0.21 ± 0.08 ng/mL), and N percentage ($72.89 \pm 1.87\%$) of group A were lower than those of group B, $P < 0.05$. Our findings suggest that high-flow humidified oxygen therapy combined with alveolar lavage can improve patients' blood gas analysis results and inhibit the progress of inflammation. At present, the role of inflammatory mediators such as IL-6 and TNF- α is unclear, and the levels of CRP, a non-specific inflammatory factor, vary in different autoimmune diseases and infectious diseases. On the basis of conventional inflammatory factors, WBC, PCT, and N percentage in clarifying the therapeutic effect of humidified high-flow nasal oxygen therapy combined with alveolar lavage, this treatment not only provides continuous and stable oxygen supply to meet the body's metabolic needs, but also improves the oxygenation state of the body, promotes the discharge of carbon dioxide, and relieves the ventilation barrier, while diluting airway secretions and reducing airway damage. In addition, repeated alveolar lavage can stimulate the airway mucosa and produce cough reflexes, thereby stimulating the body to remove inflammatory secretions and, at the same time, promote the absorption of edema caused by inflammation. This is conducive to the resolution of inflammation^[10].

In conclusion, humidified high-flow nasal oxygen therapy combined with alveolar lavage has clinical value, as its use in patients with severe pneumonia complicated with respiratory failure can inhibit local inflammation, improve blood gas indicators, and relieve symptoms of respiratory failure.

Disclosure statement

The authors declare no conflict of interest.

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