

# Comparison of high-flow nasal oxygen cannula therapy versus a standard oxygen face mask in patients with hypostatic pneumonia

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## Abstract

**Objective:** We assessed the clinical effects of high-flow nasal cannula (HFNC) oxygen therapy and a standard oxygen atomizer mask on the respiratory tract in patients with hypostatic pneumonia.

**Methods:** We included patients with hypostatic pneumonia in this retrospective cohort study. Patients were provided continuous airway humidification by continuous oxygen atomization using either an HFNC or standard oxygen mask. Arterial blood gas analysis, the dyspnea score, inflammatory-related parameters, and adverse events of patients in the two groups were compared.

**Results:** Fifty-five patients had HFNC delivery and 57 had a standard oxygen atomizer mask. After 7 days of treatment, patients in the HFNC group had a higher partial pressure of arterial blood oxygen/fraction of inspired oxygen ratio ( $268.12 \pm 28.44$  vs  $238.28 \pm 30.04$ ) and lower partial pressure of arterial blood carbon dioxide ( $38.02 \pm 8.84$  vs  $49.27 \pm 7.84$  mmHg) than those in the standard oxygen mask group. The dyspnea score and inflammatory-related parameters in the HFNC group were significantly lower than those in the standard oxygen mask group. The incidence of adverse events was lower in the HFNC group than in the standard oxygen mask group.

**Conclusion:** HFNC therapy relieves clinical symptoms more quickly than a standard oxygen mask and reduces the incidence of adverse events.

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**Keywords**

High-flow nasal cannula, hypoplastic pneumonia, oxygen atomization inhalation, critical care, oxygen mask, dyspnea score, inflammation

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**Introduction**

Hypostatic pneumonia is a type of pulmonary infection, which usually results from chronic congestion and edema at the bottom of the lungs in patients who are bedridden in the long term.<sup>1</sup> Respiratory secretions are difficult to remove and become a good culture medium for bacteria, which leads to development of infection. Hypostatic pneumonia is more common in elderly patients with cerebral apoplexy sequelae, postoperatively, in complicated clinical conditions, or with a long hospital stay.<sup>1</sup> Occurrence of hypostatic pneumonia not only leads to dysfunction of ventilation, aggravates symptoms of hypoxia, infection, and poisoning, and damages lung tissue and vascular endothelial cells, but also is not conducive to treatment and rehabilitation of patients with primary diseases. Patients with hypostatic pneumonia may die of multiple organ failure if they are not appropriately treated in time.<sup>2</sup>

Limited activity, a decline in lung function, and poor immune function of patients with hypostatic pneumonia result in difficulty in treatment and the mortality rate is high.<sup>3-7</sup> Strengthening management of the respiratory tract, especially effective airway humidification, is effective for patients with hypostatic pneumonia who are bedridden in the long term. This management significantly reduces the time of disappearance for lung rales and chest X-ray shadows, and effectively reduces the

incidence of tracheal intubation and tracheotomy.

Oxygen atomization inhalation with continuous airway humidification oxygen therapy produces tiny fog particles during oxygen inhalation, which directly deposit into bronchioles, terminal bronchioles, and alveoli.<sup>8</sup> This therapy can dilute sputum and promote discharge of sputum, but it cannot alleviate the occurrence of respiratory muscle fatigue. Additionally, a standard oxygen mask on the nose easily causes carbon dioxide retention and respiratory failure. Therefore, a standard oxygen mask has no obvious advantage in reducing the rate of endotracheal intubation.<sup>9</sup> High-flow nasal cannula (HFNC) oxygen therapy is a new type of oxygen inhalation device in clinical practice. HFNC therapy effectively humidifies sputum, promotes dilution and drainage of sputum, and reduces respiratory work. HFNC therapy promotes recovery of hypostatic pneumonia by reaching an appropriate temperature, proper flow rate, effective oxygen concentration, and reduces endogenous positive end-expiratory pressure.<sup>9-12</sup>

Currently, there is no clear evidence of comparison of an HFNC and standard oxygen atomizer mask in patients with hypostatic pneumonia. Therefore, this study aimed to assess the clinical effects of HFNC therapy and a standard oxygen atomizer mask on the respiratory tract in patients with hypostatic pneumonia.

## Patients and methods

### Patients

We retrospectively reviewed the medical records of patients with hypostatic pneumonia who were consecutively admitted to the Department of Respiratory and Critical Care Medicine in Harrison International Peace Hospital from January 2017 to October 2019. Eligible patients had a diagnosis of hypostatic pneumonia, required oxygen supplementation, and were aged 18 years or older. Patients with severe respiratory failure requiring endotracheal intubation were excluded. Hydrostatic pneumonia was diagnosed as follows: a white blood cell count  $>10 \times 10^9/L$  or  $<4 \times 10^9/L$ ; presence of clinical symptoms, such as cough, fever, expectoration, aggravation of the original respiratory symptoms, bedridden in the long term, and expectoration ability was weakened or disappeared; and a chest X-ray examination showed an irregular, small, patchy, high-density shadow in the lower part of the lungs, with a fuzzy edge and uneven density.

This study was conducted according to the Declaration of Helsinki and approved by the institutional ethics committee board of Harrison International Peace Hospital (Hengshui, China; date of approval, 21 December 2017; number: 2017-1-042). All patients provided signed consent to publish. The reporting of this study conforms to the STROBE statement.<sup>13</sup> We confirmed that fellow researchers may reproduce our methodology from the description provided.

### Procedure

All patients were provided conventional treatment of anti-infection and expectorant treatment, and symptomatic support. Continuous airway humidification was provided. Doctors helped patients turn over

and patted the back, and if necessary, aspirated sputum.

There are no guidelines for using certain masks in these patients in clinical practice. Additionally, owing to the difference in cost of an HFNC and standard oxygen mask, patients were able to choose which type of mask to use. In patients who received HFNC delivery, the flow rate was 30 to 45 L/minute and the temperature was 37°C. In patients with a standard oxygen mask, the PARI atomizer (Beyer, Munich, Germany) was connected to an oxygen supply port and the mask was connected to an atomizer. The humidification solution was 0.9% sodium chloride injection (4–6 mL) and the oxygen flow rate was 3 to 8 L/minute. Patients were provided continuous airway humidification by continuous oxygen atomization.

Arterial blood gas analysis, the dyspnea score, inflammatory index changes, and adverse events in patients in the two groups were recorded.

### Statistical analysis

All statistical analysis was conducted using IBM SPSS v22.0 (IBM Corp., Armonk, NY, USA). Attribute data were compared using the chi-square test and variables were compared by the t-test. The Wilcoxon rank sum test was used to compare ordinal data. A P value of  $<0.05$  was considered as statistically significant.

## Results

### Baseline characteristics

A total of 112 patients were enrolled in this study, 55 with HFNC delivery and 57 with a standard oxygen atomizer mask. The baseline demographic and clinical characteristics are shown in Table 1. The median age and sex were similar between patients in

**Table 1.** Baseline characteristics

|  | HFNC (n = 55)  | Standard oxygen mask (n = 57) | P value |
|--|----------------|-------------------------------|---------|
| Age (years)                              | 65.66 ± 7.29   | 66.74 ± 8.41                  | 0.646   |
| Male sex                                 | 27 (54)        | 26 (52)                       | 0.923   |
| PaO <sub>2</sub> /FiO <sub>2</sub> ratio | 147.28 ± 27.17 | 151.56 ± 29.72                | 0.875   |
| PaCO <sub>2</sub> (mmHg)                 | 54.31 ± 6.76   | 51.91 ± 5.32                  | 0.725   |
| mMRC dyspnea score                       | 3.62 ± 0.23    | 3.52 ± 0.17                   | 0.912   |
| WBC count (×10 <sup>9</sup> /L)          | 15.34 ± 2.36   | 14.55 ± 3.02                  | 0.723   |
| PCT (µg/L)                               | 2.35 ± 1.45    | 1.91 ± 1.62                   | 0.126   |
| CRP (mg/L)                               | 104.68 ± 30.75 | 110.22 ± 24.64                | 0.143   |

Data are mean ± standard deviation or n (%).

HFNC, high-flow nasal cannula; PaO<sub>2</sub>, partial pressure of arterial blood oxygen; PaCO<sub>2</sub>, partial pressure of arterial blood carbon dioxide; FiO<sub>2</sub>, fraction of inspired oxygen; mMRC, Modified Medical Research Council; WBC, white blood cell; PCT, procalcitonin; CRP, C-reactive protein.

**Table 2.** Antibiotics used during and after treatment

|   | HFNC (n = 55) | Standard oxygen mask (n = 57) | P value |
|---|---------------|-------------------------------|---------|
| Cefoperazone sodium and sulbactam sodium  | 25 (45.5)     | 26 (45.6)                     | 0.671   |
| Piperacillin sodium and tazobactam sodium | 30 (54.6)     | 31 (54.4)                     | 0.629   |
| 4-quinolones                              | 35 (63.6)     | 37 (64.9)                     | 0.423   |

Data are n (%).

HFNC, high-flow nasal cannula.

the HFNC and standard oxygen mask groups. With regard to the baseline clinical characteristics, there were no significant differences in the partial pressure of arterial blood oxygen/fraction of inspired oxygen (PaO<sub>2</sub>/FiO<sub>2</sub>) ratio, partial pressure of arterial blood carbon dioxide (PaCO<sub>2</sub>), Modified Medical Research Council dyspnea score, white blood cell count, procalcitonin levels, and C-reactive protein levels between the two groups.

### *Clinical parameters after 7 days of treatment*

Antibiotics were used during the study, and the proportion of patients with antibiotic use was similar between the HFNC and standard oxygen mask groups (Table 2). After 7 days of treatment, patients in the

HFNC group had a significantly higher PaO<sub>2</sub>/FiO<sub>2</sub> ratio (P=0.015) and lower PaCO<sub>2</sub> (P=0.019) compared with those in the standard oxygen mask group (Table 3). The Modified Medical Research Council dyspnea score in the HFNC group was significantly lower than that in the standard oxygen mask group (P=0.021).

After 7 days, inflammatory-related parameters, including the white blood cell count, procalcitonin levels, and C-reactive protein levels, were improved compared with those at baseline. The white blood cell count in the HFNC group was significantly lower than that in the standard oxygen mask group (P=0.007). Patients in the HFNC group had significantly lower levels of procalcitonin (P<0.001) and C-reactive protein (P=0.002) than those in the standard oxygen mask group.

**Table 3.** Clinical parameters after 7 days of treatment

|  | HFNC (n = 55)  | Standard oxygen mask (n = 57) | P value |
|--|----------------|-------------------------------|---------|
| PaO <sub>2</sub> /FiO <sub>2</sub> ratio | 268.12 ± 28.44 | 238.28 ± 30.04                | 0.015   |
| PaCO <sub>2</sub> (mmHg)                 | 38.02 ± 8.84   | 49.27 ± 7.84                  | 0.019   |
| mMRC dyspnea score                       | 1.58 ± 0.57    | 1.90 ± 0.43                   | 0.021   |
| WBC count (× 10 <sup>9</sup> /L)         | 7.15 ± 2.14    | 9.86 ± 2.75                   | 0.007   |
| PCT (μg /L)                              | 0.17 ± 0.15    | 0.43 ± 0.16                   | <0.001  |
| CRP (mg/L)                               | 31.46 ± 10.27  | 48.44 ± 15.32                 | 0.002   |

Data are mean ± standard deviation.

HFNC, high-flow nasal cannula; PaO<sub>2</sub>, partial pressure of arterial blood oxygen; FiO<sub>2</sub>, fraction of inspired oxygen; PaCO<sub>2</sub>, partial pressure of arterial blood carbon dioxide; mMRC, Modified Medical Research Council; WBC, white blood cell; PCT, procalcitonin; CRP, C-reactive protein.

**Table 4.** Adverse events

|                          | HFNC (n = 55) | Standard oxygen mask (n = 57) | P value |
|--------------------------|---------------|-------------------------------|---------|
| Total                    | 5 (9.1)       | 17 (30.0)                     | <0.001  |
| Abdominal distension     | 2 (3.6)       | 5 (8.8)                       | 0.020   |
| Carbon dioxide retention | 2 (3.6)       | 5 (8.8)                       | 0.017   |
| Dyspnea                  | 1 (1.8)       | 4 (7.0)                       | 0.005   |
| Facial dermatitis        | 1 (1.8)       | 5 (8.8)                       | 0.004   |

Data are n (%).

HFNC, high-flow nasal cannula.

### Comparison of adverse events between the HFNC and standard oxygen mask groups

We then compared the incidence of four mask/HFNC-related adverse events between the two groups. Five (9.1%) patients in the HFNC group and 17 (30.0%) patients in the standard oxygen mask group had adverse events after 7 days of treatment (Table 4). The incidence of adverse events in the HFNC group was significantly lower than that in the standard oxygen mask group ( $P < 0.001$ ). The incidence of each event was also significantly lower in the HFNC group than in the standard oxygen mask group (abdominal distension,  $P = 0.020$ ; carbon dioxide retention,  $P = 0.017$ ; dyspnea,  $P = 0.005$ ; facial dermatitis,  $P = 0.004$ ).

### Discussion

To the best of our knowledge, this is the first study to assess the effects of HFNC therapy and a standard oxygen atomizer mask on the respiratory tract in patients with hypostatic pneumonia. HFNC therapy relieved clinical symptoms more quickly than a standard oxygen mask. Using HFNC therapy also significantly reduced the incidence of adverse events.

We found that patients in the HFNC group had a higher PaO<sub>2</sub>/FiO<sub>2</sub> ratio and lower PaCO<sub>2</sub> than those in the standard oxygen mask group after 7 days of treatment. This finding might be explained by oxygen flow and oxygen volume fraction being set separately in HFNC therapy. Therefore, this therapy provided a low oxygen volume fraction and high flow gas, and had a good flushing effect on the

airway. A study on patients with chronic obstructive pulmonary disease and hypercapnia also showed that HFNC therapy and noninvasive ventilation reduced PaCO<sub>2</sub> levels in these patients.<sup>14</sup> Therefore, HFNC therapy has better effects in improving hypoxemia, effectively diluting sputum, and promoting excretion of sputum compared with continuous airway humidification with a standard oxygen mask for oxygen atomization.

We found that the Modified Medical Research Council dyspnea score in patients in the HFNC group was much lower than that in patients in the standard oxygen mask group. This result supports previous evidence showing that HFNC therapy reduces respiratory work and the respiratory rate through endogenous positive end-expiratory pressure.<sup>15</sup> This process reduces respiratory muscle fatigue, improves oxygenation, and relieves dyspnea.

We found that levels of inflammatory-related parameters and the incidence of adverse events were much lower in the HFNC group than in the standard oxygen mask group. These results are consistent with evidence on HFNC therapy in other lung diseases. A previous study reported that using HFNC therapy as the first ventilation strategy reduced the rate of tracheal intubation and mortality in patients with a limitation in immune function and bacterial pneumonia.<sup>16</sup> HFNC therapy also reduced the incidence of tracheal intubation in patients with type I respiratory failure.<sup>17–19</sup> Additionally, the incidence of adverse events in patients with chronic obstructive pulmonary disease and type II respiratory failure using HFNC therapy was lower compared with using a noninvasive ventilator.<sup>20</sup>

Nasal catheter oxygen inhalation in HFNC therapy is also more comfortable for patients compared with using a noninvasive ventilator nasal mask.<sup>15,21</sup> HFNC therapy is suitable for patients with acute

moderate to severe hypoxic respiratory failure who require sequential treatment after weaning or an airway examination/operation.<sup>22</sup> To a certain extent, HFNC therapy reduces application of noninvasive and invasive mechanical ventilation.<sup>23,24</sup>

There are several limitations to this study. The major limitation was its retrospective design and that it was an observational study. Another limitation was the small sample size and it being single-center study, which led to limited quality of statistical analysis. A further study with a higher number of cases and a prospective design is warranted.

In conclusion, HFNC therapy is a good tool for airway humidification. HFNC therapy has a better effect than a standard oxygen mask, and differences in terms of clinical parameters are significant. HFNC therapy also reduces the incidence of adverse reactions compared with a standard oxygen mask. Therefore, an HFNC is a safe and convenient noninvasive respiratory therapy with high efficiency in clinical practice.

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### Declaration of conflicting interest

The authors declare that there is no conflict of interest.

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