Original Article

Effect of sequential high-flow nasal cannula oxygen therapy on blood gas parameters and prognosis after weaning from mechanical ventilation in neonates

Juan Ji, Ping Li, Lanlan Zhu, Mei Xue, Shirui Zhu

Department of Neonatal Intensive Care Unit, Taizhou People’s Hospital, Taizhou, Jiangsu Province, China

Received August 29, 2020; Accepted September 27, 2020; Epub January 15, 2021; Published January 30, 2021

Abstract: Objective: To investigate the effect of sequential high-flow oxygen therapy on blood gas parameters and prognosis after extubation from mechanical ventilation in neonates. Methods: By using a random number table, 88 neonates undergoing mechanical ventilation were divided into the research group (n=44) and the control group (n=44). After weaning, the control group was given oxygen inhalation using a headbox, and the research group was given sequential high-flow nasal cannula (HFNC) oxygen therapy. The clinical efficacy, blood gas parameters at extubation and after therapy, incidences of weaning failure and complications, and prognosis were compared between the two groups. Results: The total effective rate in the research group was higher than that in the control group, and the incidences of weaning failure and complications were lower than those in the control group (P<0.05). Partial pressure of oxygen (PaO₂), arterial oxygen saturation (SaO₂) and oxygen index (OI) in the two groups were higher after oxygen therapy than those at extubation, and these indexes were significantly higher in the research group than those in the control group (all P<0.01). There were more neonates with normal growth in the research group than in the control group (P<0.05). Conclusion: Sequential HFNC oxygen therapy after extubation from mechanical ventilation in neonates can significantly improve blood gas parameters, reduce the incidence of complications, and achieve a favorable prognosis, which is worthy of clinical application.

Keywords: High-flow oxygen therapy, sequential intervention, mechanical ventilation, blood gas parameters, prognosis

Introduction

Mechanical ventilation is one of the important rescue treatments of critically ill patients, which is conducive to maintaining oxygenation and ensuring ventilation of the patients. However, after ventilation weaning and extubation, some patients still need a short duration of continuous oxygen therapy to support respiration [1]. While for mechanically ventilated patients, it has been demonstrated that sequential intervention is helpful to increase the success rate of weaning from mechanical ventilation [2]. High-flow nasal cannula (HFNC) is a device used for regulating oxygen concentration, which can heat and humidify the gas to normal body temperature and humidity. At the same time, it can regulate the gas flow to provide the body with oxygen at constant and accurate concentrations [3]. HFNC oxygen therapy is a non-invasive oxygen therapy. Huang et al. found that compared with traditional oxygen therapy and positive pressure ventilation, HFNC oxygen therapy can significantly reduce the rate of reintubation 72 hours after ventilation weaning and extubation [4]. Numerous studies have shown that HFNC oxygen therapy can effectively improve oxygenation, pulmonary function, and prognosis in patients undergoing non-intubated thoracoscopic surgery, respiratory failure, and chronic obstructive pulmonary disease (COPD) on acute-phase [5-7]. In recent years, with rapid development of medical technology, sequential high-flow oxygen therapy after mechanical ventilation has been gradually applied in the treatment of premature infants and newborns, but there is no consensus on whether it can affect the long-term prognosis and complications of...
the neonates [8]. Therefore, the present research mainly investigated the effect of sequential HFNC oxygen therapy on blood gas parameters and prognosis after extubation from mechanical ventilation in neonates, intending to provide a reference for respiratory support to neonates after clinical extubation and weaning in clinical practice.

Materials and methods

General data

This was a prospective, randomized, and controlled investigation. Eighty-eight neonates who received mechanical ventilation in Taizhou People's Hospital from February 2018 to January 2020 were included in and divided into the research group (n=44) and the control group (n=44) by using a random number table. This research was reviewed and approved by the Medical Ethics Committee of Taizhou People's Hospital.

Inclusion criteria: Neonates who had idiopathic diseases such as respiratory distress syndrome, severe pneumonia, or respiratory failure; neonates who met weaning criteria from mechanical ventilation, and were ready for weaning; neonates who underwent mechanical ventilation not less than 24 hours; neonates who's family members had signed an informed consent.

Exclusion criteria: Neonates born either at <34 weeks or >42 weeks of gestation; neonates with birth weight <1500 g; neonates with pulmonary malformations, or those who were combined with other congenital diseases such as lung diseases.

Methods

After weaning, the control group was treated with oxygen inhalation inside the incubators until the patients' spontaneous breathing was stable and various blood gas parameters were completely normal. After weaning, the observation group was given HFNC sequential intervention using a humidified high-flow nasal cannula oxygen respirator (Fisher & Paykel MR850AEA), and specific parameters were oxygen flow rate 2-6 L/min, airway humidification temperature 37°C, initial fractional inspired oxygen concentration (FiO₂) 0.4, and gradual adjusted oxygen saturation (SaO₂) between 90%-95%. Cannula size was determined according to the size of nasal cavities of the neonates, with care to leave some space in nasal cavity. The oxygen therapy was gradually discontinued when the neonates’ spontaneous breathing was stable with a FiO₂ of ≤0.25.

Outcome measures

Primary outcome measures: (1) The clinical efficacy was compared between the two groups three days after weaning, and was scored as follows; effective: the clinical symptoms and pulmonary crackles of the neonates disappeared after treatment, oxygen saturation was ≥95%, and arterial blood gas results returned to normal; markedly effective: the clinical symptoms were improved, the pulmonary crackles were reduced, and oxygen saturation was 93%-95%; ineffective: the clinical symptoms did not change or were even aggravated [9]. The total effective rate (%) = (effective cases + markedly effective cases)/total case number * 100.

(2) At extubation and the completion of oxygen therapy, blood gas parameters, including arterial partial pressure of oxygen (PaO₂), SaO₂ and oxygen index (OI), were detected using a blood gas analyzer (GEM Premier 3000) and were compared between the two groups. OI = PaO₂/FiO₂.

(3) Telephone follow-up was performed for 6 months. There was no individual lost to follow-up in the two groups. The neonates' growth and long-term complications at 6 months after discharge were compared between the two groups. The neonates' growth was assessed by a growth curve for weight, height and head circumference. Complications were evaluated mainly including severe bronchopulmonary dysplasia, retinal atrophy, empyema, lung abscess, toxic encephalopathy, and heart failure.

Secondary outcome measures: (1) The incidence of ventilation weaning failure was compared between the two groups.

(2) The incidence of complications, such as nosocomial infection, nasal mucosal injury, nasal and facial pressure ulcers, were compared between the two groups.
Effect of HFNC oxygen therapy on blood gas parameters and prognosis of neonates

Table 1. Comparison of baseline data between the two groups (n, X ± sd)

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Research group (n=44)</th>
<th>Control group (n=44)</th>
<th>χ²/t</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender (n)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>26</td>
<td>22</td>
<td>0.733</td>
<td>0.392</td>
</tr>
<tr>
<td>Female</td>
<td>18</td>
<td>22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gestational age (weeks)</td>
<td>38.50±2.1</td>
<td>38.10±1.8</td>
<td>0.959</td>
<td>0.340</td>
</tr>
<tr>
<td>Birth weight (kg)</td>
<td>3.74±0.82</td>
<td>3.66±0.77</td>
<td>0.472</td>
<td>0.638</td>
</tr>
<tr>
<td>Idiopathic diseases (n)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Respiratory distress syndrome</td>
<td>19</td>
<td>22</td>
<td>0.421</td>
<td>0.810</td>
</tr>
<tr>
<td>Severe pneumonia</td>
<td>14</td>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Respiratory failure</td>
<td>11</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mode of delivery (n)</td>
<td></td>
<td></td>
<td>0.409</td>
<td>0.522</td>
</tr>
<tr>
<td>Vaginal delivery</td>
<td>20</td>
<td>23</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-section</td>
<td>24</td>
<td>21</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Comparison of clinical efficacy between two groups (n (%))

<table>
<thead>
<tr>
<th>Group</th>
<th>Effective</th>
<th>Markedly effective</th>
<th>Ineffective</th>
<th>Total effective rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research group (n=44)</td>
<td>21 (47.73)</td>
<td>20 (45.45)</td>
<td>3 (6.82)</td>
<td>41 (93.18)</td>
</tr>
<tr>
<td>Control group (n=44)</td>
<td>14 (31.82)</td>
<td>20 (45.45)</td>
<td>10 (22.73)</td>
<td>34 (77.27)</td>
</tr>
<tr>
<td>χ²</td>
<td>5.159</td>
<td></td>
<td></td>
<td>4.423</td>
</tr>
<tr>
<td>P</td>
<td>0.075</td>
<td></td>
<td></td>
<td>0.035</td>
</tr>
</tbody>
</table>

Statistical analysis

Statistical analysis was conducted using SPSS 20.0 statistical software. Enumeration data were expressed as the number of cases (%) and examined by χ² test. Measurement data were presented as mean ± standard deviation (X ± sd); independent-samples t-test was used for comparison at the same time point between the two groups; a paired sample t-test was performed for comparison before and after treatment in the same group. The difference was statistically significant at P<0.05.

Results

Baseline data

There was no significant difference in baseline data such as gestational age and birth weight between the two groups (P>0.05), and they were comparable. See Table 1.

Clinical efficacy

The total effective rate of the research group was higher than that of the control group (93.18% vs 77.27%; P<0.05). See Table 2.

Blood gas parameters

After oxygen therapy, PaO₂, SaO₂ and OI in the two groups were both higher than those at extubation, and the increases were higher in the research group than in the control group (all P<0.01). See Table 3.

Incidence of weaning failure

There were 2 cases (4.55%) of weaning failure in the research group, and 8 cases (18.18%) in the control group. The incidence of weaning failure in the research group was lower than that in the control group (P<0.05). See Figure 1.

Complications during treatment

During treatment, the total incidence of complications in the research group was lower than that in the control group (P<0.05). See Table 4.

Prognosis

The proportion of neonates with normal growth rates in the research group was greater than that in the control group (P<0.05). There was
Table 3. Comparison of blood gas parameters at extubation and after intervention between the two groups (X ± sd)

<table>
<thead>
<tr>
<th>Group</th>
<th>Time</th>
<th>PaO$_2$ (mmHg)</th>
<th>SaO$_2$ (%)</th>
<th>OI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research group (n=44)</td>
<td>At weaning and extubation</td>
<td>69.68±2.88</td>
<td>93.70±2.30</td>
<td>174.20±10.55</td>
</tr>
<tr>
<td></td>
<td>At the completion of oxygen therapy</td>
<td>98.80±1.05***,###</td>
<td>97.40±2.05***,###</td>
<td>411.67±14.84****##</td>
</tr>
<tr>
<td>Control group (n=44)</td>
<td>At weaning and extubation</td>
<td>69.16±2.10</td>
<td>93.17±2.66</td>
<td>172.90±12.98</td>
</tr>
<tr>
<td></td>
<td>At the completion of oxygen therapy</td>
<td>81.90±2.80***</td>
<td>95.56±2.04***</td>
<td>341.25±15.50***</td>
</tr>
</tbody>
</table>

Note: ***P<0.001 as compared with that at extubation; **P<0.01 and ***P<0.001 as compared with the control group. PaO$_2$: partial pressure of oxygen; SaO$_2$: arterial oxygen saturation; OI: oxygen index.
Effect of HFNC oxygen therapy on blood gas parameters and prognosis of neonates

no significant difference in the incidence of long-term complications between the two groups (P>0.05). No complications, including empyema, lung abscess, toxic encephalopathy, and heart failure occurred in the two groups. See Table 5.

Discussion

Mechanical ventilation is the main method for the treatment of respiratory failure or respiratory distress syndrome in neonates, who, however, are less tolerable to body positioning, and there are some difficulties in performing long-term machine therapy [10, 11]. Therefore, it is useful to choose appropriate oxygen therapy after ventilator withdrawal to improve the patients’ tolerance of positioning and reduce the incidence of weaning failure.

In recent years, HFNC oxygen therapy has been a newly emerging non-invasive ventilation technique. It can simulate physiological respiration of the body, reduce nasal mucosal injuries, and improve treatment compliance [12, 13]. Our research found that compared with at extubation, PaO₂ and SaO₂ after the therapy were increased in the two groups, and the increases were more remarkable in the research group than in the control group. Also, the total effective rate after treatment in the research group was higher than that in the control group, suggesting that sequential HFNC oxygen therapy can improve blood gas parameters after extubation from mechanical ventilation in neonates and improve therapeutic effect, which is consistent with the results reported by Lee et al., who found that HFNC can effectively dilate airways of patients, increase pulmonary tidal volume, and ensure adequate oxygen flow, both increasing PaO₂ and decreasing PaCO₂ [14]. Besides, Franklin et al. also found that children with severe bronchiolitis who received high-flow oxygen therapy had a significantly higher treatment success rate than those who received standard oxygen therapy, which also led to markedly different levels of care [15].

The results of our research showed that OI after intervention of the two groups was significantly higher than that at weaning and extubation, and it was better in the research group than in the control group, suggesting that sequential HFNC oxygen therapy is beneficial to improve the oxygenation of neonates after mechanical ventilation and extubation, which was also confirmed by the research of Ricard et al. [16]. It could be speculated that the application of HFNC helps the body to produce an effect similar to continuous positive airway pressure and promote alveolar recruitment, which is conducive to improve oxygenation of patients [17]. However, the specific mechanism behind this hypothesis still needs to be tested with further research.

Prolonged mechanical ventilation can increase the risk of complications such as pulmonary infection [18]. Therefore, for neonates on mechanical ventilation, the ventilation time should be shortened as much as possible, so as to reduce the incidence of ventilation weaning failure. In this research, the incidence of weaning failure was 4.55% in the research group, which was significantly lower than 18.18% in the control group, and the difference was statistically significant, suggesting that sequential HFNC oxygen therapy can significantly reduce the incidence of weaning failure in neonates. This result was consistent with that of Betters et al. [19]. The reason may be that HFNC oxygen therapy provides stable pressure support during treatment, and also increases respiratory drive. Therefore, it can alleviate the issues caused by sudden decrease in the pressure after weaning, thus effectively avoiding apnea [20, 21]. In terms of complications, this research found that both groups of patients had complications of nosocomial infection, nasal mucosal injury, nasal and facial pressure ulcers during treatment. The incidence of complications in the research group was lower than that in the control group.

Figure 1. Comparison of weaning failure between the two groups. *P<0.05 as compared with the control group.
Effect of HFNC oxygen therapy on blood gas parameters and prognosis of neonates

Table 4. Comparison of complications between the two groups (n (%))

<table>
<thead>
<tr>
<th>Group</th>
<th>Nosocomial infections</th>
<th>Nasal mucosal injury</th>
<th>Nasal and facial pressure ulcers</th>
<th>Total incidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research group (n=44)</td>
<td>1 (2.27)</td>
<td>1 (2.27)</td>
<td>1 (2.27)</td>
<td>3 (6.82)</td>
</tr>
<tr>
<td>Control group (n=44)</td>
<td>3 (6.82)</td>
<td>3 (6.82)</td>
<td>4 (9.09)</td>
<td>10 (22.73)</td>
</tr>
<tr>
<td>(\chi^2)</td>
<td>1.048</td>
<td>1.048</td>
<td>1.011</td>
<td>4.423</td>
</tr>
<tr>
<td>P</td>
<td>0.306</td>
<td>0.306</td>
<td>0.315</td>
<td>0.035</td>
</tr>
</tbody>
</table>

Also, there were significantly more patients with normal development in the research group than in the control group (95.45% vs. 81.82%), indicating that sequential HFNC oxygen therapy could reduce the incidence of complications during treatment and improve the prognosis of patients. However, this research also has some shortcomings such as a small observation sample size, being a single-center study and short follow-up time. Furthermore, it remains unknown what the long-term effects are of HFNC oxygen therapy in patients after ventilator withdrawal. Therefore, studies with enlarged sample sizes, multicenter in nature and deeper insights are needed for further confirmation.

To sum up, sequential HFNC oxygen therapy after weaning from mechanical ventilation can significantly improve blood gas parameters, reduce incidence of complications, and achieve a favorable prognosis in neonates, which is worthy of clinical application.

Disclosure of conflict of interest

None.

Address correspondence to: Ping Li, Department of Neonatal Intensive Care Unit, Taizhou People’s Hospital, No. 399 Hailing Road, Hailing District, Taizhou 225300, Jiangsu Province, China. Tel: +86-13801430544; E-mail: lipings1tz@163.com

References


Effect of HFNC oxygen therapy on blood gas parameters and prognosis of neonates


