Effect of Two Different Ventilation Methods on Ventilation Function in Preterm Infants during Recovery Period of RDS

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Abstract: Objective: To investigate the effects of two different ventilation methods on ventilation function in preterm infants with respiratory distress syndrome (RDS) during the recovery period. Methods: 100 preterm infants with respiratory distress syndrome (RDS) admitted to the neonatal intensive care unit of our hospital from January 2022 to January 2025 were selected as the study subjects. According to the random number table method, they were divided into high-frequency oscillatory ventilation combined with volume guarantee (HFOV-VG) group (50 cases) and conventional mechanical ventilation (CMV) group (50 cases). Compare the invasive mechanical ventilation time and total respiratory support time, arterial blood gas analysis results [arterial oxygen partial pressure (PaO_2), carbon dioxide partial pressure ($PaCO_2$), inspired oxygen fraction (FiO_2)], and the occurrence of adverse reactions between the two groups. Results: Both invasive mechanical ventilation time and total respiratory support time in HFOV-VG group were shorter than those in CMV group ($P<0.05$). The PaO_2 levels in the HFOV-VG group at 6h, 12h, and 24h were all lower than those in the CMV group ($P<0.05$). The $PaCO_2$ levels in the HFOV-VG group at 6h, 12h, and 24h were all lower than those in the CMV group ($P<0.05$). The FiO_2 levels in the HFOV-VG group at 30 minutes, 6 hours, 12 hours, and 24 hours were all lower than those in the CMV group ($P<0.05$). The incidence of hypocapnia, bronchopulmonary dysplasia, and intraventricular hemorrhage in the HFOV-VG group was significantly lower than that in the CMV group ($P<0.05$), and there was no difference in the incidence of other complications ($P>0.05$), but there was a tendency to decrease in the HFOV-VG group. Conclusion: HFOV-VG demonstrated significant advantages compared with CMV in the management of ventilatory function during the recovery period of RDS in preterm infants, including shortening ventilation time, improving oxygenation, and reducing the incidence of key complications.

***Keywords*:** high-frequency oscillatory ventilation; volume guarantee; conventional mechanical ventilation; respiratory distress syndrome; preterm infants

1. Introduction

Respiratory distress syndrome (RDS) in preterm infants is a common disease caused by lung surfactant deficiency. It is closely related to alveolar collapse and gas exchange disorders, and is one of the major challenges in neonatal intensive care [1]. Mechanical ventilation is essential for treating RDS; however, conventional mechanical ventilation (CMV) may induce lung injury due to high airway pressure and high tidal volume, potentially compromising ventilation function during recovery [2]. To reduce iatrogenic lung injury, lung-protective ventilation strategies have gained increasing attention, with high-frequency oscillatory ventilation with volume guarantee (HFOV-VG) emerging as a potential alternative. HFOV-VG provides high-frequency, low-tidal volume ventilation by combining high-frequency oscillation and volume guarantee technology, which helps stabilize tidal volume and reduces the risk of lung overinflation and collapse, thereby optimizing gas exchange [3]. Studies have shown that this model can shorten invasive ventilation time, reduce the incidence of hypocapnia and periventricular leukomalacia, and improve cerebral blood flow perfusion [4]. Comparing HFOV-VG and CMV in preterm infants with RDS during the recovery phase is critical for optimizing ventilation strategies and enhancing pulmonary recovery. Future research should further explore differences in ventilation parameters, blood gas monitoring, and long-term neurological outcomes.

2. Objects and Methods

2.1 Study Subjects

This study is a prospective study, selecting 100 preterm infants in the recovery stage of RDS admitted to the neonatal intensive care unit of our hospital from January 2022 to January 2025 as the study subjects. According to random number table, they were divided into HFOV-VG group (50 cases) and CMV group (50 cases). Inclusion criteria: (1) Gestational age 26 to 36 weeks; (2) birth weight ≥1000g; (3) meet the diagnostic criteria of RDS [5]; (4) require mechanical ventilation within 24 hours after birth; (5) parents sign informed consent. Exclusion criteria: (1) Congenital heart disease, congenital malformation or inherited metabolic disease; (2) Severe asphyxia (Apgar score≤ 3 at 1 minute after birth) or early-onset

sepsis; (3) Treatment with pulmonary surfactants before admission; (4) The condition is critical and requires abandonment of treatment or automatic discharge. The two groups of general data were comparable (P>0.05), as shown in Table 1.

Table 1. Comparison of baseline data of children in the two groups

Indicators	HFOV-VG group (n=50)	CMV group (n=50)	t/χ^2	P
Male [cases (%)]	28(56.00)	26(52.00)	0.161	0.688
Fetal age($\bar{x}$±s, weeks)	30.54±1.41	30.32±1.67	0.712	0.478
Birth weight($\bar{x}$±s, kg)	1.25±0.18	1.22±0.21	0.767	0.445
Cesarean section [cases (%)]	32(64.00)	34(68.00)	0.178	0.673
Pre-natal hormone use [cases (%)]	38(76.00)	36(72.00)	0.208	0.648
1-minute Apgar score ($\bar{x}$±s, points)	6.22±1.37	6.01±1.53	0.723	0.471
In-hospital oxygenation index($\bar{x}$±s)	10.34±2.19	10.82±2.43	1.038	0.302

2.2 Treatment

In the HFOV-VG group, a high-frequency oscillating ventilator (babylogVN500, Drager, Germany) was used. Initial parameters were set: average airway pressure 6-10cmH_2O, oscillation frequency 8-15Hz, amplitude 15-20cmH_2O, inspiratory time percentage 33%, offset airflow 15-20L/min, and amplitude was adjusted according to blood gas target to maintain ventilation. The CMV group was treated with a constant frequency infant ventilator (SLE, Germany, SLEbaby5000). The parameters included respiratory rate of 40 to 60breaths/min, inhaled oxygen fraction of 60% to 100%, positive end-expiratory pressure of 4 to 6 cmH_2O, tidal volume of 5 to 8mL/kg, average airway pressure of 4 to 8 cmH_2O, inspiration-to-exhalation ratio of 1: 2, and flow rate of 6 to 10L/min. During treatment, both groups of parameters were dynamically adjusted based on arterial blood gas analysis results, with the goal of maintaining blood oxygen saturation of 90% to 94% and arterial blood carbon dioxide partial pressure of 35 to 50mmHg, and the level of support was gradually reduced according to clinical progress until it met weaning criteria.

2.3 Observation Indicators

2.3.1 Invasive mechanical ventilation time and total respiratory support time

Invasive mechanical ventilation time was assessed by recording the time interval from the beginning of invasive ventilation to successful extubation. The total respiratory support time includes the duration of all respiratory assistance, including invasive ventilation and non-invasive ventilation, and is calculated by summarizing the cumulative time from initial ventilatory support to complete disengagement from oxygen support.

2.3.2 Arterial blood gas analysis results

Including arterial oxygen partial pressure (PaO_2), carbon dioxide partial pressure ($PaCO_2$), and inspired oxygen fraction (FiO_2) Blood samples were collected from the radial artery, and arterial blood gas analysis was performed (Radometer, ABL90FLEX) at specific time points after ventilation (30 minutes, 6 hours, 12 hours, and 24 hours).

2.3.3 Adverse reactions

These include hypocapnia, bronchopulmonary dysplasia, intraventricular hemorrhage, retinopathy of prematurity, late-onset sepsis, pneumothorax, ventilator associated pneumonia, necrotizing enterocolitis, and pulmonary bleeding.

2.4 Statistical Analysis

Data statistics and analysis were performed using Excel and SPSS21.0. The normal distribution was tested by Shapiro-Wilk test. All measurement data complied with the normal distribution and were presented in the form of mean ± standard deviation ($\bar{x}$±s). The inter-group comparison analysis was performed using independent sample t-test, and the intra-group comparison analysis was performed using paired t-test. Counting data were presented in the form of number of cases and percentages (n/%), and comparative analysis was performed using $\chi 2$ test. When P<0.05, the difference was statistically significant.

3. Results

3.1 Comparison of invasive mechanical ventilation time and total respiratory support time between two groups of children

The invasive mechanical ventilation time and total respiratory support time in HFOV-VG group were shorter than those in CMV group (P<0.05), as shown in Table 2.

Table 2. Comparison of invasive mechanical ventilation time and total respiratory support time in children in the two groups ($\bar{x}\pm s$, days)

Group	Invasive Mechanical ventilation time	Total respiratory support time
HFOV-VG group (n=50)	5.41 ± 1.25	29.35 ± 4.52
CMV group (n=50)	7.12 ± 1.87	37.65 ± 5.94
t	5.376	7.863
P	<0.001	<0.001

3.2 Comparison of arterial blood gas analysis results between the two groups of children at different time points

The PaO_2 levels in the HFOV-VG group at 6h, 12h, and 24h were all higher than those in the CMV group (P<0.05). The $PaCO_2$ levels in the HFOV-VG group at 6h, 12h, and 24h were all lower than those in the CMV group (P<0.05). The FiO_2 levels in the HFOV-VG group at 30min, 6h, 12h, and 24h were all lower than those in the CMV group (P<0.05), as shown in Table 3.

Table 3. Comparison of arterial blood gas analysis results between the two groups of children at different time points ($\bar{x}\pm s$)

Group	PaO_2 (mmHg)			
	30min	6h	12h	24h
HFOV-VG group (n=50)	58.24 ± 5.67	66.53 ± 6.12*	72.89 ± 5.94*	78.45 ± 6.33*
CMV group (n=50)	56.87 ± 5.92	62.34 ± 5.76*	68.45 ± 6.03*	74.26 ± 6.51*
t	1.182	3.525	3.709	3.263
P	0.240	0.001	<0.001	0.002
Group	$PaCO_2$ (mmHg)			
	30min	6h	12h	24h
HFOV-VG group (n=50)	55.31 ± 4.85	46.85 ± 4.12*	41.26 ± 3.87*	38.92 ± 3.45*
CMV group (n=50)	56.84 ± 5.12	49.67 ± 4.35*	44.83 ± 4.06*	42.15 ± 3.92*
t	1.534	3.328	4.501	4.374
p	0.128	0.001	<0.001	<0.001
Group	FiO_2 (%)			
	30min	6h	12h	24h
HFOV-VG group (n=50)	52.33± 4.15	30.56 ± 3.28*	25.11 ± 2.83*	23.47 ± 2.15*
CMV group (n=50)	54.72 ± 4.51	35.22 ± 3.64*	30.89 ± 3.12*	28.36 ± 2.72*
t	2.757	6.725	9.703	9.973
p	0.007	<0.001	<0.001	<0.001

Note: * indicates P<0.05 compared to 30 minutes.

3.3 Comparison of the incidence of adverse reactions during treatment between the two groups of children

The incidence of hypocapnia, bronchopulmonary dysplasia, and intraventricular hemorrhage in the HFOV-VG group was significantly lower than that in the CMV group (P<0.05), and there was no difference in the incidence of other complications (P>0.05), but there was a tendency to decrease in the HFOV-VG group, as shown in Table 4.

Table 4. Comparison of the incidence of adverse reactions during treatment between the two groups [cases (%)]

Group	Hypocapnia	Bronchopulmonary dysplasia	Intraventricular hemorrhage	Retinopathy of prematurity
HFOV-VG group (n=50)	4(8.00)	10(20.00)	2(4.00)	5(10.00)
CMV group (n=50)	12(24.00)	21(42.00)	8(16.00)	9(18.00)
χ^2	4.762	5.657	4.000	1.329
P	0.029	0.017	0.046	0.249

Group	Late-onset sepsis	Pneumothorax	Ventilator associated pneumonia	Necrotizing enterocolitis
HFOV-VG group (n=50)	6(12.00)	1(2.00)	3(6.00)	2(4.00)
CMV group (n=50)	10(20.00)	4(8.00)	6(12.00)	5(10.00)
χ^2	1.190	1.895	1.099	1.382
P	0.275	0.169	0.295	0.240

4. Discussion

RDS is a common disease in neonatal intensive care, and the core of its treatment is to provide effective respiratory support to improve gas exchange and reduce lung damage [6]. HFOV-VG and CMV are two commonly used mechanical ventilation strategies, but their impact on ventilation function during the recovery period of RDS is controversial. This study compared HFOV-VG and CMV in preterm infants with RDS, evaluating their effects on ventilation duration, oxygenation, and safety to guide clinical optimization of ventilation strategies.

HFOV-VG was associated with shorter invasive mechanical ventilation and total respiratory support durations compared to CMV, indicating enhanced recovery of respiratory function in preterm infants. By providing a high-frequency, low-tidal ventilation mode, HFOV-VG helps maintain alveoli open and reduces atelectasis, thereby shortening mechanical ventilation dependence time [7]. This advantage may be related to the volume assurance function of HFOV-VG, which accurately controls tidal volume to avoid excessive lung inflation, reduce the risk of volume injury, and thereby speed up the weaning process [8]. In addition, HFOV-VG is more efficient at stabilizing gas exchange and may reduce the overall need for respiratory support by improving lung compliance [9]. In terms of arterial blood gas indicators, the HFOV-VG group showed better oxygenation function during treatment. This suggests that HFOV-VG can more effectively improve lung oxygenation efficiency and reduce oxygen dependence. The mechanism may be that the high-frequency oscillation characteristics of HFOV-VG can promote alveolar reexpansion and increase functional residual volume, thereby optimizing the ventilation/blood flow ratio [10]. At the same time, the volume assurance function helps maintain stable tidal volume, avoid uneven ventilation, and further support improvement in oxygenation. Compared with CMV, HFOV-VG has potential advantages in reducing intrapulmonary shunt and reducing hyperoxia injury, which may be important for preventing long-term lung injury. In terms of safety, the incidence of hypocapnia, bronchopulmonary dysplasia and intraventricular hemorrhage in the HFOV-VG group was lower than that in the CMV group, indicating that HFOV-VG has better safety. The reduction in hypocapnia is closely related to the volume-assurance function of HFOV-VG, which stabilizes the partial pressure of carbon dioxide by avoiding excessive ventilation, thereby reducing the risk of cerebral vasospasm [11]. The reduction in the incidence of bronchopulmonary dysplasia may be attributed to the lung protective effect of HFOV-VG, which delays the process of pulmonary fibrosis by inhibiting inflammatory responses [12]. In addition, the reduction in intraventricular hemorrhage may be related to the improvement of cerebral hemodynamics. HFOV-VG optimizes cerebral perfusion by stabilizing the partial pressure of carbon dioxide and reduces the risk of bleeding [13]. There were no significant differences in other complications between the two groups, and the incidence in the HFOV-VG group tended to decrease, indicating that HFOV-VG did not increase additional risks.

In summary, HFOV-VG has demonstrated significant advantages compared with CMV in the management of ventilatory function during the recovery period of RDS in Preterm infants, including shortening ventilation time, improving oxygenation, and reducing the incidence of key complications. HFOV-VG optimizes gas exchange through its lung protective mechanisms and may have a positive impact on neurological outcomes. Multi-center studies are needed in the future to further verify its long-term efficacy.

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