

# The Effect of Prophylactic Application of Noninvasive Ventilator in High Risk Patients after Cardiac Surgery and Improvement of Nursing Intervention

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## Abstract

**Objective:** To investigate the efficacy, safety and nursing improvement of non-invasive positive pressure ventilation (NPPV) in high-risk patients with acute respiratory failure after cardiac surgery. **Methods:** From September 2018 to October 2019, high-risk patients who may develop acute respiratory failure after cardiac surgery were selected and randomly divided into non-invasive ventilation group and conventional treatment group (control group). The reintubation rate, tracheotomy rate, fatality rate, 24 h intake and output, respiratory rate, arterial blood gas PaO<sub>2</sub> and PaCO<sub>2</sub> were compared between the two groups of patients; at the same time, the patient comfort and mask leakage after improved nursing technology were compared. **Results:** The preoperative and intraoperative conditions of the two groups of patients were basically similar, but the reintubation rate, tracheotomy rate, fatality rate, and respiratory rate of the patients in the preventive application of NPPV group were significantly lower than those of the control group, and the 24 h input and output and arterial blood gas PaO<sub>2</sub> were also excellent in the control group. **Conclusion:** NPPV used prophylactically in high-risk patients after cardiac surgery can significantly reduce the re-intubation rate, improve patient outcomes, and is markedly more effective than the conventional treatment group.

## Keywords

Noninvasive Positive Pressure Ventilation, Cardiac Surgery, Acute Respiratory Failure, Nursing Improvement

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## 1. Introduction

Acute respiratory failure is one of the most common complications after cardiac surgery, and with the increasing number of elderly surgical patients, the incidence of respiratory system complications is also on the rise [1]. Clinical treatment for such patients typically involves non-invasive positive pressure ventilation (NPPV) therapy. NPPV refers to non-invasive ventilation achieved by establishing a pressure difference through oral and nasal connection. NPPV is widely used in clinical practice due to its advantages such as not requiring the establishment of an artificial airway, minimal adverse reactions, allowing normal diet, convenience of use, and low cost. However, the application of NPPV is greatly limited by drawbacks such as patient discomfort with the mask, skin damage and air leaks, and inadequate sputum drainage. This study focuses on the efficacy of sequential application of non-invasive ventilators in 86 postoperative heart failure patients with respiratory insufficiency after tracheal extubation, analyzes the influencing factors on its efficacy, makes targeted improvements in nursing care to reduce complications of NPPV, and lower the rate of secondary tracheal intubation.

## 2. Materials and Methods

1) From September 2018 to October 2019, some preoperatively assessed high-risk patients undergoing cardiovascular surgeries such as valve surgery, coronary artery bypass grafting (CABG), valve surgery + CABG, and major vascular surgeries were treated at the Department of Cardiothoracic Surgery, Changzheng Hospital, Naval Medical University. Patients aged 18 to 80 years, regardless of gender, were included.

2) Inclusion criteria: Patients who underwent cardiovascular surgery and were admitted to the Cardiac Intensive Care Unit (CICU) for recovery were included if they met the following conditions: a) Meet the criteria for tracheal extubation; b) Had an oxygenation index (OI) of  $150 \text{ mmHg} \leq \text{OI} \leq 200 \text{ mmHg}$  prior to extubation; c) No significant fever ( $T \leq 38^\circ\text{C}$ ) and no hypothermia ( $T \geq 35^\circ\text{C}$ ); d) Hemodynamic was stable, with no requirement for high doses of vasopressor drugs (epinephrine  $\leq 0.05 \mu\text{g/kg/min}$ , dopamine  $\leq 5 \mu\text{g/kg/min}$ ), and no significant arrhythmias; e) Urine output  $\geq 0.5 \text{ mL/kg/h}$ ; f) Hemoglobin (Hb)  $\geq 90 \text{ g/L}$  and serum albumin (Alb)  $\geq 25 \text{ g/L}$ ; g) No contraindications to NPPV application. After inclusion, patients were randomly assigned to either the non-invasive ventilation group or the conventional treatment group.

3) Exclusion criteria: Patients meeting any of the following conditions were excluded: a) Altered mental status, weak spontaneous breathing, or coma; b) High risk of aspiration, inability to clear oral or pharyngeal secretions, and poor airway protection (abdominal distension, significant abnormal swallowing reflex); c) Concomitant organ dysfunction (difficult-to-correct hypotension, severe arrhythmias, gastrointestinal perforation/heavy bleeding, and severe brain diseases); d) Unresolved pneumothorax or mediastinal emphysema; e) Facial or neck trauma, burns, deformities, upper airway bleeding, or obstruction; f) Restlessness, extreme

anxiety, or refusal to undergo NPPV; g) Severe infections. h) The sputum is thick or there are excessive airway secretions, making effective expectoration impossible.

4) Treatment in the non-invasive ventilation group: Alongside standard diuresis, antispasmodic, and mucolytic therapy, patients were placed in a semi-recumbent position and provided with the Philips V60 non-invasive ventilator using an oronasal mask in ST mode for assisted ventilation. The initial inspiratory positive airway pressure (IPAP) was set at 12 cmH<sub>2</sub>O, expiratory positive airway pressure (EPAP) at 6 cmH<sub>2</sub>O, backup respiratory rate at 12 breaths/min, and rise time at 2 s. IPAP and/or EPAP were gradually increased based on tidal volume, clinical efficacy, and patient tolerance (generally adjusted every 5 - 10 minutes by 2 - 3 cmH<sub>2</sub>O), but the IPAP/EPAP did not exceed 20/12 cmH<sub>2</sub>O. The fraction of inspired oxygen (FiO<sub>2</sub>) was adjusted to maintain pulse oximetry saturation (SpO<sub>2</sub>) above 92%. Apart from coughing, speaking, oral care, and eating, NPPV was continuously used in the initial phase. As the patient's condition improved, IPAP/EPAP and NPPV duration were gradually reduced until successful weaning. A gastric tube was routinely placed for gastrointestinal decompression. If respiratory failure symptoms did not improve after NPPV use, the cause needed to be identified, and if intubation criteria were met, timely transition to invasive ventilation was necessary.

5) Treatment in the conventional therapy group: After extubation, patients were provided with standard medications and oxygen therapy via nasal cannula. If symptoms did not improve and intubation criteria were met, endotracheal intubation and invasive ventilation were performed.

6. Criteria for discontinuation of NPPV: Support pressure levels IPAP ≤ 10 cmH<sub>2</sub>O, EPAP ≤ 5 cmH<sub>2</sub>O, FiO<sub>2</sub> ≤ 40%, and the patient's general condition and blood gas analysis parameters remain stable for ≥ 24 hours. Attempt to wean off NPPV when the following criteria are met and remain stable for ≥ 48 hours: a) Spontaneous respiratory rate (RR) < 30 breaths/min, no difficulty breathing; b) Nasal cannula oxygen therapy (FiO<sub>2</sub> ≤ 40%), PaO<sub>2</sub> > 60 mmHg, SpO<sub>2</sub> > 90%; c) Clear consciousness, good cough reflex.

7) Criteria for endotracheal intubation: If a patient meets one major criterion or two minor criteria from the following list, immediate intubation is necessary. Major criteria: a) Weak or absent breathing; b) Loss of consciousness; c) Severe agitation; d) Unstable blood circulation; e) Cardiogenic shock. Minor criteria: a) RR ≥ 35 breaths/min; b) pH < 7.30; c) PaO<sub>2</sub> < 45 mmHg, despite increased FiO<sub>2</sub>; d) Deterioration of consciousness; e) Weak cough, accumulation of airway secretions.

8) Improvements in non-invasive ventilation care: Patients in the experimental group received comprehensive care, including: a) Respiratory care. Due to the use of non-invasive ventilators to assist breathing, close attention was paid to the operation of the ventilator, recording and monitoring the patient's respiratory status, assisting the patient in adjusting positions appropriately to improve respiratory comfort. Chest percussion and sputum expectoration were performed every 2 hours or using an automatic sputum suction device for 10 minutes to assist with sputum expectoration; nasopharyngeal suction was performed when necessary,

and equipment cleaning and disinfection were carried out to ensure airway patency. b) Mask care. Throughout the treatment process, nursing staff assisted patients in correctly wearing auxiliary breathing masks and regularly checked for proper mask fitting. Any instances of looseness or tightness were adjusted immediately to prevent ineffective breathing or skin irritation. Additionally, moisturizing care on the mask contact area or using pressure-relief patches was applied to enhance patient comfort during treatment (**Figure 1**). c) Psychological care. Some patients may experience fear or poor cooperation with the mask, leading to discomfort such as fear, worry, anxiety, or depression during treatment. Nursing staff enhanced communication with patients and utilized music therapy to help distract patients and prevent the accumulation of negative emotions affecting patient cooperation. d) Condition care. Non-invasive ventilators have alarm functions to alert in case of abnormal patient conditions. Nursing staff regularly checked the ventilator's functionality to ensure the alarm system was operational and functioning normally. Vital signs and external physical manifestations of the patient were monitored, and any signs of pallor or cold limbs were immediately reported to the physician for prompt action. e) Respiratory exercise training. Patients were educated on the importance of oxygen therapy for improving their condition and taught lip pursing and abdominal breathing techniques. Patients were encouraged to actively expectorate sputum and, if the condition allowed, assisted with daily mobilization.



**Figure 1.** Improvement of mask care using decompression dressing.

9) Observation indicators: Collect patient's age, gender, comorbidities, smoking history, body mass index, surgical procedure name, cardiopulmonary bypass time, preoperative left ventricular ejection fraction (EF), Euroscore, BNP levels. Record patients' vital signs (heart rate, respiratory rate, blood pressure, SpO<sub>2</sub>) before treatment and 2 - 4 hours after treatment, arterial blood gas analysis values (pH, PaO<sub>2</sub>, PaCO<sub>2</sub>). Calculate the reintubation rate, tracheostomy rate, incidence of pneumonia, and mortality rate.

10) Statistical methods: SPSS 29.0 statistical software was used for analysis. For normally distributed continuous variables, mean  $\pm$  standard deviation was used

for representation, while for non-normally distributed continuous variables, the median was used. Shapiro-Wilk test was performed to test the normality of data before statistical tests were applied. Group comparisons of normally distributed continuous variables with homogeneity of variance were conducted using independent sample t-tests. For within-group comparisons before and after treatment, paired t-tests were used. Non-normally distributed or variables with inhomogeneous variance were analyzed using the Wilcoxon signed-rank test. Categorical data were analyzed using the chi-square test or Fisher's exact test. A significance level of  $P < 0.05$  was considered statistically significant.

### 3. Result

A total of 103 cases were initially included. According to the inclusion and exclusion criteria, 17 cases were excluded, including 12 cases of emergency intubation (3 cases of severe arrhythmia, 1 case of loss of consciousness, 8 cases of low cardiac output syndrome), 3 cases of restlessness and mental tension, 1 case of difficulty expectorating sputum, and 1 case of nausea and vomiting. Finally, 86 cases were included, with 42 cases in the non-invasive ventilation group and 44 cases in the conventional treatment group.

1) Preoperative baseline characteristics: There were no significant differences between the two groups in terms of patient age, gender, underlying diseases, smoking history, cardiac function, and EuroScore assessment. Additionally, there were no significant differences in the duration of cardiopulmonary bypass during surgery (**Table 1**).

**Table 1.** Comparison of basic conditions between two groups of patients.

	Non-invasive ventilation group (n = 42)	Conventional treatment group (n = 44)	P value
Age	60.7 ± 7.3	61.8 ± 7.6	0.71
Male	18	20	0.53
Hypertension	12	8	0.25
Diabetes	16	10	0.12
Smoking	14	16	0.77
COPD	3	2	0.61
BNP	2724 ± 1397	2216 ± 1440	0.99
EF	50 ± 6.48	51.55 ± 7.17	0.76
EuroScore	8.6 ± 1.3	7.8 ± 1.6	0.65
CPB time	83.8 ± 26.4	91.4 ± 24.3	0.38

2) Comparison of postoperative reintubation rate, tracheostomy rate, and mortality rate.

After grouping treatment, in the sequential non-invasive ventilation group,

there were 6 cases of re-intubation, including 4 cases of septic shock, 1 case of aspiration, and 1 case of cardiogenic shock. Subsequently, 4 patients underwent tracheostomy, and there were 5 in-hospital deaths. In the conventional treatment group, there were 23 cases of re-intubation, all due to worsening respiratory failure despite comprehensive treatment such as diuresis, nebulization, sputum expectoration, and oxygen therapy. Following this, 19 cases underwent tracheostomy, and there were 14 in-hospital deaths. All deceased cases experienced multiple organ failure due to recurrent septic shock. The re-intubation rate ( $P = 0.000$ ), tracheostomy rate ( $P = 0.001$ ), and mortality rate ( $P = 0.026$ ) in the non-invasive ventilation group were significantly lower than those in the conventional treatment group (Figure 2).

### 3) Comparison of vital signs changes between two groups of patients.

Compare the changes in respiratory rate, arterial blood gas  $\text{PaO}_2$  and  $\text{PaCO}_2$ , and changes in 24-hour fluid balance between two groups of patients receiving non-invasive ventilation or conventional oxygen therapy for 2 hours. The results showed that patients in the sequential non-invasive ventilation group had significantly lower respiratory rates than the conventional oxygen therapy group. Arterial blood gas  $\text{PaO}_2$  was also better in the non-invasive ventilation group compared to the conventional oxygen therapy group. There was no significant difference in  $\text{PaCO}_2$  between the two groups. In terms of maintaining satisfactory blood pressure,

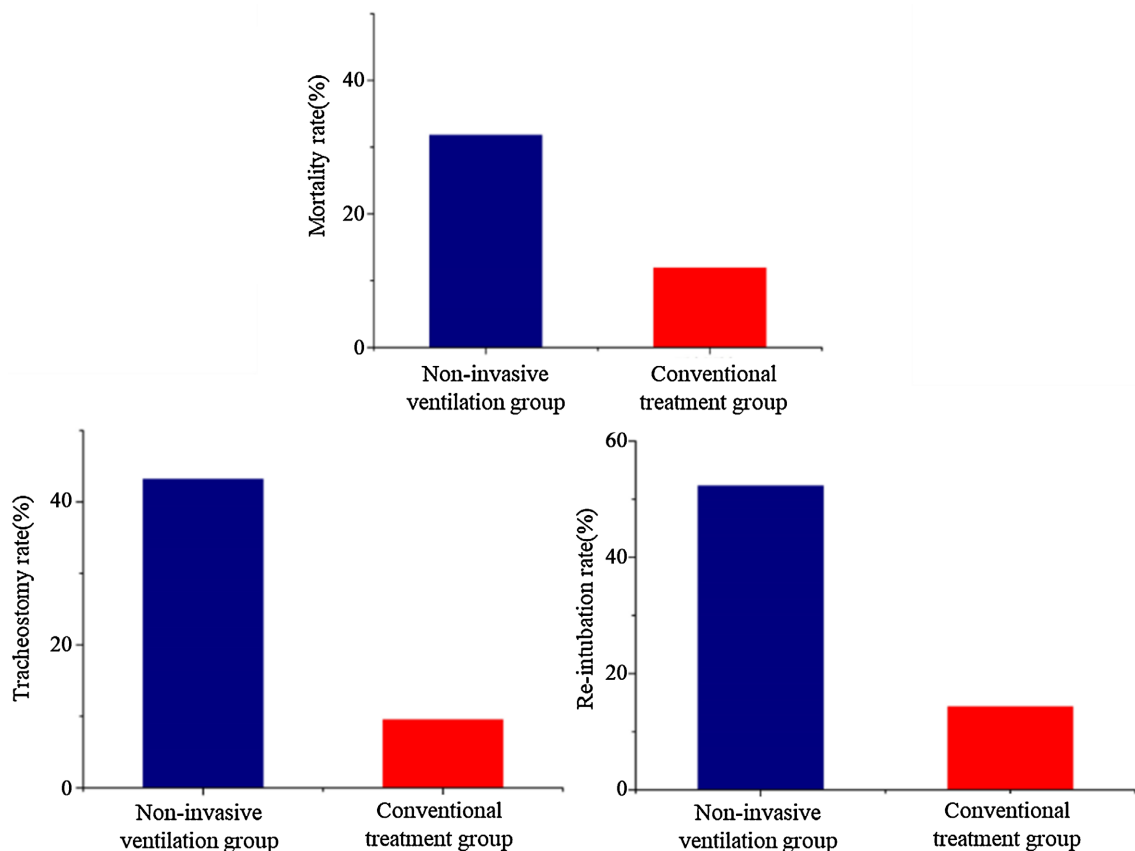


Figure 2. Comparison of tracheal intubation, tracheotomy, and mortality rates between two groups of patients.

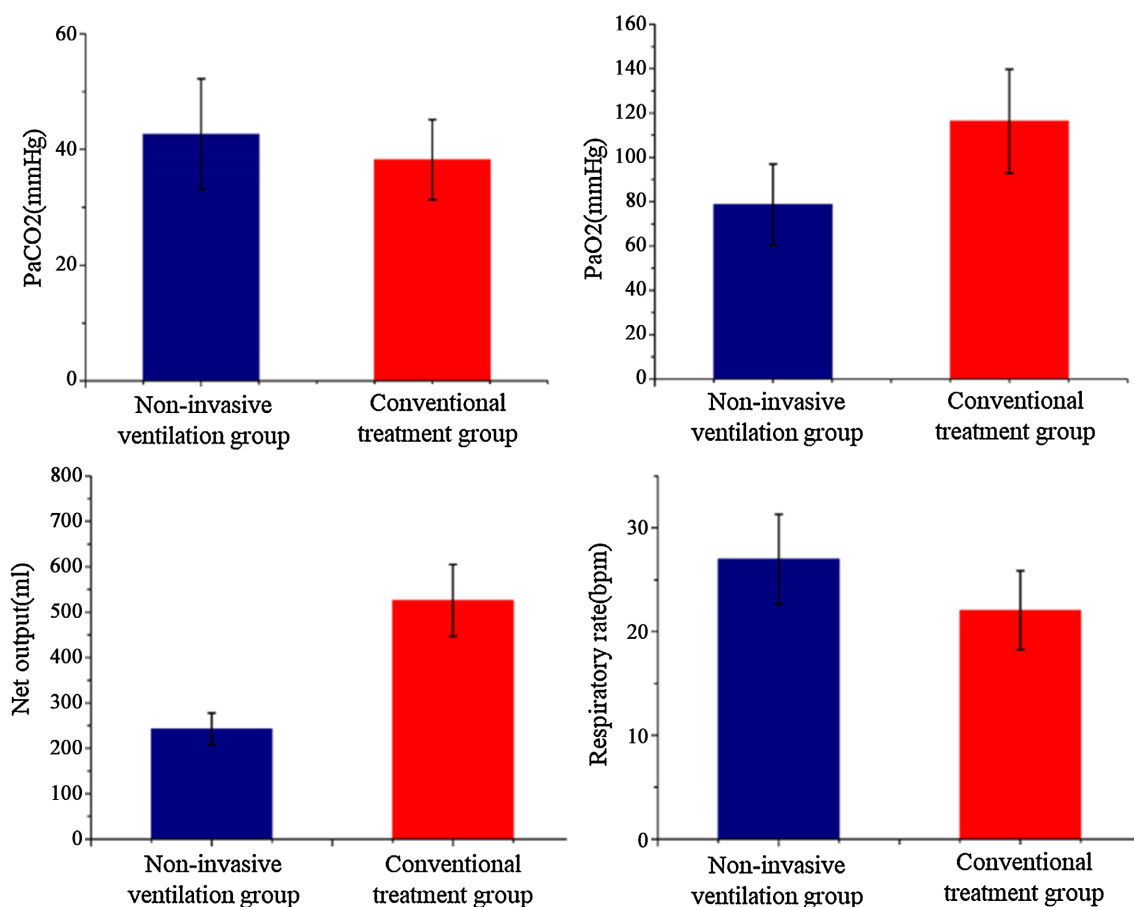
the net output (output minus input) in the 24-hour period was higher in the non-invasive ventilation group than the conventional oxygen therapy group (**Figure 3**).

4) The effects of Decompression dressing and other mask care improvements on patients' comfort and mask leakage rate in minutes.

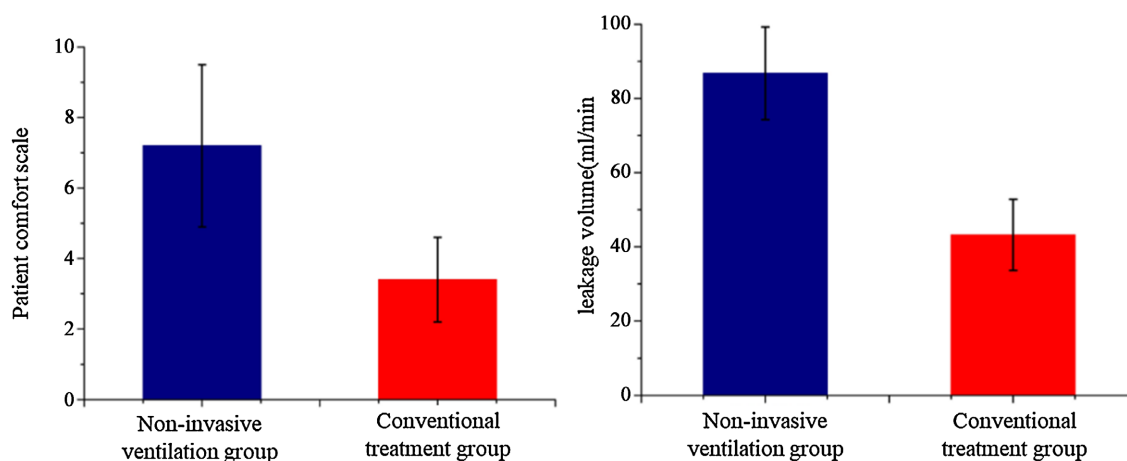
The 42 selected patients in the non-invasive ventilation group were randomly divided into two groups, with 21 people in each group. One group used a decompression dressing (**Figure 1**), while the other group did not use a decompression dressing. The results showed that the decompression dressing not only improved patient comfort but also reduced minute leakage volume. Patient comfort was evaluated using a 10-point scale, with 0 indicating no discomfort and 10 indicating extreme discomfort (**Figure 4**).

#### 4. Discussion

Acute respiratory failure is one of the most common complications after cardiac surgery, often requiring re-intubation and invasive mechanical ventilation once it occurs [2]. With the continuous accumulation and improvement of knowledge on the adverse reactions of invasive ventilation such as tracheal intubation and



**Figure 3.** Comparison of respiratory rate, oxygen partial pressure, carbon dioxide partial pressure, and 24-hour inflow and outflow between two groups of patients.



**Figure 4.** Comparison of discomfort and air leakage between two groups of patients.

tracheostomy, as well as the clinical application experience of non-invasive assisted ventilation techniques, the therapeutic effects of non-invasive mechanical ventilation on postoperative acute respiratory failure in cardiac surgery are increasingly valued. Non-invasive ventilatory support with a respiratory machine can rapidly correct postoperative hypoxemia, improve cardiac function, and reduce intubation time after surgery [3].

But previous studies have mostly focused on the application of non-invasive mechanical ventilation in patients with acute respiratory failure after cardiac surgery. There have been fewer studies on the sequential and preventive application of non-invasive mechanical ventilation in high-risk patients after endotracheal extubation. In this study, we selected patients with OI (oxygenation index) between 150 and 200 before endotracheal extubation after cardiac surgery for a clinical controlled study. These patients are prone to develop acute respiratory failure after extubation, and the main influencing factors include preoperative cardiac function, lung infections, and COPD. Compared to the conventional treatment group after extubation, patients treated with NPPV (non-invasive positive pressure ventilation) showed significant improvement in respiratory function ( $\text{PaO}_2$ ), stable blood pressure, slower heart rate and respiratory rate. There was a negative balance in the 24-hour fluid balance, reducing cardiac load, and a significant reduction in the rate of secondary intubation.

However, non-invasive mechanical ventilation still has some problems, especially due to the use of a mask for assistance. Many patients feel claustrophobic and uncooperative with the respiratory mask, resulting in resistance. They may exhibit skepticism, tension, anxiety, and fear, leading them to refuse treatment. Comprehensive nursing interventions can significantly improve patient treatment adherence, reduce the time to achieve patient-machine coordination, and enhance treatment effectiveness. It is the key to the success of non-invasive ventilation treatment [4] [5]. I adopt comprehensive nursing modes such as respiratory care, mask care, psychological care, and respiratory function exercise, effectively relieving the patient's sense of fear; Meanwhile, I strengthen mechanical sputum suction

and, under the premise of allowing the condition, assist the patient as much as possible in getting out of bed, sitting in a non-invasive ventilator-assisted training, assisting with the training of diaphragmatic breathing, and enhancing diaphragm muscle exercise, which significantly improves the treatment efficacy of non-invasive ventilators and reduces the rate of reintubation. In order to optimize mask care for patients, besides needing to understand the patient's actual mask usage experience and regularly check if the mask has fallen off, we also use Decompression dressing and other tools to help reduce the discomfort of wearing a mask and effectively reduce the amount of leakage caused by poor mask fit [6].

In summary, NPPV is selectively used in postoperative acute respiratory failure after cardiac surgery, which can significantly reduce the rate of reintubation, improve patient prognosis, and demonstrate better efficacy compared to conventional treatment mainly based on invasive ventilation. Whether proactive sequential application of non-invasive mechanical ventilation is needed for high-risk patients requires multicenter, large-sample, prospective randomized controlled trials to clarify its indications and factors affecting therapeutic effects.

### Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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