Original article

Efficacy and safety of noninvasive positive pressure ventilation in the treatment of acute respiratory failure after cardiac surgery

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Keywords: *noninvasive positive pressure ventilation; acute respiratory failure; cardiac surgery; intensive care medicine*

Background Although noninvasive positive pressure ventilation (NPPV) has been successfully used for various kinds of acute respiratory failure, the data are limited regarding its application in postoperative respiratory failure after cardiac surgery. Therefore, we conducted a prospective randomized control study in a university surgical intensive care unit to evaluate the efficacy and safety of NPPV in the treatment of acute respiratory failure after cardiac surgery, and explore the predicting factors of NPPV failure.

Methods From September 2011 to November 2012 patients with acute respiratory failure after cardiac surgery who had indication for the use of NPPV were randomly divided into a NPPV treatment group (NPPV group) and the conventional treatment group (control group). The between-group differences in the patients' baseline characteristics, re-intubation rate, tracheotomy rate, ventilator associated pneumonia (VAP) incidence, in-hospital mortality, mechanical ventilation time after enrollment (MV time), intensive care unit (ICU) and postoperative hospital stays were compared. The factors that predict NPPV failure were analyzed.

Results During the study period, a total of 139 patients who had acute respiratory failure after cardiac surgery were recorded, and 95 of them met the inclusion criteria, which included 59 males and 36 females with a mean age of (61.5±11.2) years. Forty-three patients underwent coronary artery bypass grafting (CABG), 23 underwent valve surgery, 13 underwent CABG+valve surgery, 13 underwent major vascular surgery, and three underwent other surgeries. The NPPV group had 48 patients and the control group had 47 patients. In the NPPV group, the re-intubation rate was 18.8%, tracheotomy rate was 12.5%, VAP incidence was 0, and the in-hospital mortality was 18.8%, significantly lower than in the control group 80.9%, 29.8%, 17.0% and 38.3% respectively, P <0.05 or P <0.01. The MV time and ICU stay (expressed as the median (P25, P75)) were 18.0 (9.2, 35.0) hours and 4.0 (2.0, 5.0) days, which were significantly shorter than in the control group, 96.0 (26.0, 240.0) hours and 6.0 (4.0, 9.0) days respectively, P <0.05 or P <0.01. The postoperative hospital stays of the two groups were similar. The univariate analysis showed that the NPPV success subgroup had more patients with acute lung injury (ALI) (17 vs. 0, P=0.038), fewer patients with pneumonia (2 vs. 7, P <0.001) and lower acute physiology and chronic health evaluation II (APACHE II) scores (16.1±2.8 vs. 21.8±3.2, P <0.001). Multivariate analysis showed that pneumonia (P=0.027) and a high APACHE II score >20 (P=0.002) were the independent risk factors of NPPV failure.

Conclusions We conclude that NPPV can be applied in selected patients with acute respiratory failure after cardiac surgery to reduce the need of re-intubation and improve clinical outcome as compared with conventional treatment. Pneumonia and a high APACHE II score >20 might be the independent risk factors of NPPV failure in this group of patients.

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Anesthesia, surgical techniques and sites, and postoperative pain can induce respiratory derangement; postoperative pulmonary complications such as alveolar atelectasis, acute lung injury/pulmonary edema, acute cardiogenic pulmonary edema (CPE), pulmonary embolism or infection. All of these can impair pulmonary function and even cause acute respiratory failure (ARF), especially in patients with respiratory co-morbidities like chronic obstructive pulmonary disease (COPD). Some patients need re-intubation and invasive ventilation, and some eventually need tracheotomy and long-term mechanical ventilation.[1-3] Use of artificial airway and invasive ventilation may cause loss of airway protecting mechanisms, more sedative use, and airway trauma, all of which may increase the risk of ventilator associated pneumonia (VAP),[4] increase the hospital length of stay, morbidity, and mortality.

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Noninvasive positive pressure ventilation (NPPV) is a mechanical ventilation modality that does not require any artificial airway and, compared to invasive ventilation, requires lower sedation, improves comfort and reduces the occurrence of VAP.[5] NPPV has primarily been applied in patients with acute exacerbations of COPD, CPE, and hypoxemic respiratoryfailure.[5-9] In recent years NPPV has been also used to prevent the occurrence of or to treat ARF after abdominal, thoracic, cardiac or bariatric surgery.[10-12]

Rationale for postoperative NPPV use is the same as postextubation NPPV use[13] plus the specificities due to the respiratory modifications induced by surgery and anesthesia as described above. In selected patients with ARF, postoperative NPPV can improve gas exchange, decrease the work of breathing, and reduce atelectasis, and therefore reduce the need of re-intubation and improve clinical outcome.[11]

However, there are only limited data regarding the application of NPPV to treat postoperative respiratory failure after cardiac surgery and randomized trials are lacking.[14,15] To further evaluate the efficacy and safety of NPPV in ARF after cardiac surgery, a prospective randomized clinical study was performed based on our previous successful application of NPPV in various types of respiratory failure.[16,17]

METHODS

Patient selection

From September 2011 to November 2012, this study was carried out in the Surgical Intensive Care Unit of Beijing Anzhen Hospital, Capital Medical University. Patients between 18 years to 80 years who underwent valve surgery, coronary artery bypass grafting (CABG), valve surgery + CABG, and aortic surgery, were transported to surgical intensive care unit for postoperative recovery. The study protocol was approved by the local ethics committee of our hospital (No. 2009006). Informed written consent was obtained in all cases from either the patients or their proxy. After considering the inclusion and exclusion criteria, patients were randomly allocated to the NPPV group or the control group thereby dictating the method utilized after extubation.

Inclusion criteria

Patients enrolled in this study fulfilled all of the following criteria: (1) onset of ARF after initial extubation (ARF was defined by arterial partial O_2 pressure (PaO_2) ≤60 mmHg after oxygen therapythough nasalprong or PaO_2/fraction of inspired O_2 (PaO_2/FiO_2) ≤200 mmHg after oxygen therapy though a Venturi mask with or without respiratory acidosis (pH <7.35 with arterial partial CO_2 pressure ($PaCO_2$) >45 mmHg), a respiratory rate >25 breaths/min, or clinical signs of increased respiratory workloador muscle fatigue); (2) the patient was awake (Glasgow score ≥13), with the ability to protect their airway; (3) bleeding from mediastinal and pleural drainage less than 100 ml/h; (4) no obvious fever (T >38ºC) or hypothermia (T <35ºC); (5) hemodynamic stability, without the need of high doses of vasopressors (epinephrine ≤0.05 $g \cdot kg^{-1} \cdot min^{-1}$, dopamine ≤5 $g \cdot kg^{-1} \cdot min^{-1}$), no severe arrhythmia, and no use of intra-aortic balloon pump; (6) urine output ≥0.5 $ml \cdot kg^{-1} \cdot h^{-1}$.

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Exclusion criteria

The paitents were excluded if they meet any of the following criteria: (1) cardiac or respiratory arrest; (2) lack of consciousness; (3) with high-risk of aspiration like abdominal distention or swallowing reflex abnormality; (4) severe other organ dysfunction like refractory hypotension, severe arrhythmia, gastrointestinal perforation/bleeding, severe neurologic disease; (5) undrained pneumothorax or pneumomediastinum; (6) recent facial, esophageal, or upper airway surgery, or a facial deformity; (7) refusal of NPPV or psychomotor agitation requiring sedation; (8) need of immediate endotracheal intubation (ETI) for excessive airway secretions.

Treatment

NPPV group

All patients received standard medical care as needed. NPPV therapy was administered using the bilevel positive airways pressure (BiPAP) S/T mode (Resmed, VPAP III, Australia) via a properly fitted face mask (ZS-MZ-A, Zhongshan Technique Development Co., Shanghai). The head of the bed was raised to 30°–45° in order to minimize the risk of aspiration. The initial inspiratory pressure (IPAP) was set at 12 cmH_2O (1 cmH_2O = 0.098 kPa), and the initial expiratory pressure (EPAP) was set at 5 cmH_2O. Back-up respiratory frequency was set at 12 breaths/min. According to clinical efficacy and patient tolerance, we raised the IPAP and (or) EPAP by 2–3 cmH_2O every 5 to 10 minutes, but the IPAP/EPAP did not exceed 25/10 cmH_2O. FiO_2 was adjusted to maintain a pulse oxygen saturation (SpO_2) of around 92%. All patients continued to receive NPPV except for coughing, eating and talking until their condition was improved. Then NPPV was administered intermittently and the IPAP/EPAP was decreased gradually. When the support pressure level (IPAP-EPAP) reached ≤5 cmH_2O, a weaning trial was begun. If there was no sign of dyspnea at rest, GCS=15, RR ≤25 breaths/min, pH ≥7.35, PaO_2 ≥60 mmHg, and SpO_2>90% at room air or FiO_2 ≤40% with Venturi mask during spontaneous breathing and this condition was sustained for 48 hours, NPPV was considered successful (success). If there was a failure to meet above success criteria, NPPV was resumed until meeting the criteria or need of ETI (see ETI criteria below). A nasogastric tube was placed in all patients for feeding and (or) gastric intestinal drainage if gastric distension occurred.

Control group

All patients received standard medical care and oxygen therapy as needed. Patients were intubated and mechanically ventilated if their condition deteriorated and met the criteria for ETI (see ETI criteria below).

ETI criteria

Re-intubation was performed if one major or two minor

criteria were present.[12] Major criteria were as following: (1) respiratory arrest; (2) loss of consciousness; (3) severe agitation; (4) hemodynamic instability; (5) cardiogenic shock. Minor criteria were as following: (1) respiratory rate more than 35 breath/min; (2) arterial pH less than 7.30 and lower than admission value; (3) PaO_2 less than 45mmHg despite oxygen supplementation; (4) neurologic deterioration; (5) weak cough reflex with secretion accumulation.

Measurements

Data were gathered on age, sex, body mass index, concomitant diseases, smoking history, type of surgery, causes of postoperative respiratory failure, and acute physiology and chronic health evaluation (APACHE II). Patient's vital signs (heart rate, respiratory rate, blood pressure, SpO_2) and arterial blood gas analysis measured values (pH, PaO_2, $PaCO_2$) were recorded before the treatment and 2–4 hours after treatment. The primary outcome variables were the need for endotracheal intubation, tracheotomy rate, VAP incidence, in-hospital mortality, mechanical ventilation time after enrolled (MV time), ICU stay, and postoperative hospital stay.

Statistical analysis

SPSS16.0 statistical software was used for statistical analysis. Qualitative variables were expressed as frequency and percentage; quantitative variables expressed as mean±standard deviation (SD) when the data were in a normal distribution or expressed as median (P25, P75) when there was skewed distribution (MV time, ICU stay, postoperative hospital stay). For normal distribution and equal variance quantitative data, a two-sample Student's *t* test and a paired Student's *t* test were used to determine differences between and within the groups respectively. The nonparametric Mann-Whitney test was used for variables that were not normally distributed. Qualitative variables were tested using χ^2 or Fisher's exact test. To identify risk factors for NPPV failure, univariate analysis was used to compare patients demographicand baseline characteristic data in the NPPV success and failure subgroup patients, then multivariate Logistic regression analysis was used to identify risk factors for NPPV failure. A *P* value <0.05 was considered statistically significant.

RESULTS

From September 2011 to November 2012, 139 consecutive post cardiac surgery patients presented with ARF after routine extubation. Of these, 44 patients met the exclusion criteria, including 36 patients who needed emergency intubation (23 with severe arrhythmia, seven with loss of consciousness, and six with hemodynamic instability), five with psychomotor agitation requiring sedation, two with excessive airway secretions, and one with nausea and vomit. Thus, 95 patients were eligible, 48 were allocated to the NPPV group and 47 to the control group based on a predetermined randomization protocol. All of these patients were includedin the analysis (Figure 1).

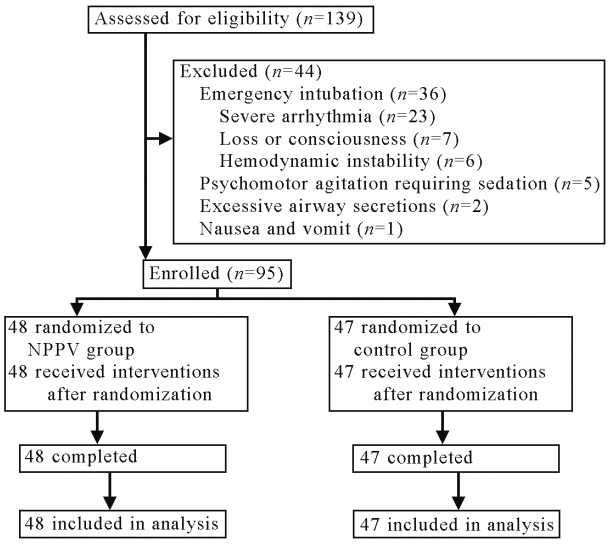

Figure 1. Flow diagram for the trial. NPPV: noninvasive positive pressure ventilation.

Patients' demographic and baseline characteristics

There were no significant differences between the NPPV group and the control group in patients' age, gender, concomitant diseases, smoking, type of surgery, causes of postoperative ARF, APACHE II scores (Table 1).

NPPV application

All of the patients in the NPPV group accepted NPPV through face mask and the S/T modes. For this group, NPPV was delivered for anaverage period of 31 hours

Table 1. Patient demographic and baseline characteristics in two groups

Characteristics	NPPV group (*n*=48)	Control group (*n*=47)	χ^2/t	*P* values
Age (years)	62.0±10.3	61.0±12.2	0.423	0.673
Sex (male)	32	27	0.858	0.354
Hypertension	23	31	3.151	0.076
diabetes	7	12	1.779	0.182
Smoking	25	16	3.151	0.076
BMI kg/m^2	25.3±4.6	24.4±3.5	1.000	0.320
Type of surgery				
Valve surgery	12	11	0.033	0.856
CABG	23	20	0.131	0.600
CABG+Valve surgery	8	5	0.731	0.393
Major vascular surgery	4	9	2.352	0.125
Others*	1	2	0.000	0.985
Causes of ARF				
Acute CPE	17	20	0.509	0.476
ALI	17	16	0.020	0.888
Lobar atelectasis	7	3	0.937	0.333
Pneumonia	9	10	0.095	0.758
COPD	3	1	0.240	0.625
RMF	2	5	0.663	0.415
APACHE II score	17.2±3.6	17.6±3.5	-0.501	0.618

NPPV: noninvasive positive pressure ventilation; BMI: body mass index; CABG: coronary artery bypass grafting; ARF: acute respiratory failure; CPE: cardiogenic pulmonary edema; ALI: acute lung injury; COPD: chronic obstructive pulmonary disease; RMF: respiratory muscle fatigue; APACHE II: acute physiology and chronic health evaluation II.*1 pericardiectomy surgery in NPPV group, 2 ventricular septal defect repair surgeries in the control group.

(range, 1–140 hours). The highest levels of IPAP and EPAP were (18.8±2.5) cmH_2O (range, 14–24) and (7.5±1.4) cmH_2O (range, 5–10) respectively.

Comparisons of re-intubation rate, tracheotomy rate, VAP incidence and mortality

As shown in Table 2, the re-intubation rate, tracheotomy rate, VAP incidence and in-hospital mortality in the NPPV group were 18.8% (9/48), 12.5% (6/48), 0, and 18.8% (9/48) respectively, which were significantly lower than in the Control group 80.9% (38/47), 29.8% (14/47), 17.0% (8/47) and 38.3% (18/47), P <0.05 or P <0.01. Nine patients in the NPPV group were re-intubated, four because of septic shock, two because of aspiration, two because of excessive airway secretions, and one because of cardiogenic shock. In the control group 38 patients were re-intubated because of their condition deteriorated after randomization and met the ETI criteria. Nine patients in the NPPV group died; six in the NPPV failure subgroup and three in the NPPV success subgroup (see below). Among them, six patients died due to septic shock, two due to multiple organ failure (MOF), and one because of acute hypoxic-ischemic encephalopathy. In the control group 18 patients died; eight due to MOF, six due to septic shock, two due to cardiogenic shock, and two due to acute hypoxic-ischemicencephalopathy.

Comparisons of MV time, ICU stay, and postoperative hospital stay

The MV time and ICU stay in the NPPV group were significantly (P <0.001 and P=0.002) shorter than in the control group, but the length of postoperative hospital stay of the two groups were not significantly different (Table 3).

Table 2. Comparisons of re-intubation rate, tracheotomy rate, VAP and in-hospital mortality in two groups (n (%))

Variables	NPPV group (n=48)	Control group (n=47)	χ^2	P values
Re-intubation rate	9 (18.8)	38 (80.9)	36.637	0.000
Tracheotomy rate	6 (12.5)	14 (29.8)	4.270	0.039
VAP	0 (0)	8 (17.0)	6.851	0.009
In-hospital mortality	9 (18.8)	18 (38.3)	4.461	0.035

VAP: ventilator associated pneumonia; NPPV: noninvasive positive pressure ventilation.

Comparisons of vital signs and arterial blood gas variables

As shown in Table 4, the basic systolic blood pressure, heart rate, SpO_2 and arterial blood gas variables (pH, PaO_2, $PaCO_2$) were similar in the two groups (P >0.05). The respiratory rate of the NPPV group was slightly higher than the control group (P <0.05). Two to four hours after treatment, the systolic blood pressure in both groups and pH of the control group remained stable at baseline level, but the heart rate, respiratory rate, SpO_2, $PaCO_2$ and PaO_2 of the two groups, and pH of the NPPV group were significantly improved compared with baseline (P <0.05 or P <0.01). The SpO_2 in the NPPV group improved more significantly, and the respiratory rate in the control group decreased more prominently; the latter might be associated with the use of sedatives for the intubated patients.

Complications

The VAP incidence in the two groups is shown in Table 2. Other NPPV associated complications occurred in 14 patients, including nine patients with gastric distensions which was controlled by negative pressure suction through a nasogastric tube, three patients with hypotension controlled by vasoactive drugs, and two patients with aspiration controlled by tracheal intubation.The latter two patients died of septic shock and MOF. Complications in the control group included two patients with pneumothorax controlled by chest drainage and one patient with a tracheoesophageal fistula which could not be managed and the patient died.

Analysis of the factors that affected the efficacy of NPPV

As indicted in Table 2, NPPV succeeded in 39 patients and failed in nine patients; six patients died although prompt ETI was performed for all of them, four patients died of septic shock and two of MOF. To explore the factors that affected the efficacy of NPPV in the NPPV success and NPPV failure subgroups, univariate analysis was used to compare patient demographic and baseline characteristic data; age, gender, body mass index, concomitant diseases, smoking, types of surgery, reasons of ARF, and APACHE

Table 3. Comparison of MV time, ICU stay and postoperative hospital stayin two groups (median (P25, P75))

Variables	NPPV group (n=48)	Control group (n=47)	Z	P values
MV time (hours)	18.0 (9.2, 35.0)	96.0 (26.0, 240.0)	−3.806	0.000
ICU stay (days)	4.0 (2.0, 5.0)	6.0 (4.0, 9.0)	−3.071	0.002
Postoperative hospital stays(days)	14.0 (11.0, 20.0)	8.0 (11.0, 32.0)	−1.584	0.113

MV: mechanical ventilation; ICU: intensive care unit; NPPV: noninvasive positive pressure ventilation.

Table 4. Vital signs and arterial blood gas variables in two groups (mean±SD)

Groups‖	Systolic pressure (mmHg)		Heart rate (/min)		Respiratory rate (/min)		SpO_2 (%)	
	Baseline	2–4 hours	Baseline	2–4 hours	Baseline	2–4 hours	Baseline	2–4 hours
NPPV group (n=47¶)	128.2±25.7	126.5±18.1	112.4±20.2	102.2±16.2†	28.3±8.6‡	20.3±4.7†‡	89.6±5.4	97.2±2.0†§
Control group (n=46)	124.7±21.9	123.1±19.8	111.3±23.4	100.2±19.6†	25.4±6.7	18.1±5.1†	88.8±4.9	95.2±4.1†

Groups‖	pH		$PaCO_2$ (mmHg)		PaO_2 (mmHg)	
	Baseline	2–4 hours	Baseline	2–4 hours	Baseline	2–4 hours
NPPV group (n=47¶)	7.43±0.76	7.45±0.05*	38.9±12.2	34.6±7.1†	69.4±16.8	97.4±32.3†
Control group (n=46)	7.42±0.09	7.44±0.07	38.3±11.3	35.0±7.8*	64.2±13.0	90.9±34.3†

NPPV: noninvasive positive pressure ventilation; SpO_2: pulseoxyhemoglobin saturation. *P <0.05, †P <0.01, vs. baseline within same groups; ‡P <0.05, §P <0.01, vs. control group at the same time. ‖Due to incomplete data records, NPPV group had 47 and control group had 46 cases when data were analyzed; ¶Due to 1 patient was intubated, NPPV group had 46 patients at 2–4 hours time point.

Table 5. Multivariate regression analyses foridentification of risk factors for NPPV failure

Variables regression coefficient	SE	*P* values	*OR*	95.0%	Confidence interval
APACHE II score >20	2.928	1.325	0.027	18.691	1.392–250.925
Pneumonia	3.975	1.296	0.002	53.227	4.198–674.785

II scores as shown in Table 1. The results show the NPPV success subgroup had more patients with ALI (17 vs. 0, *P*=0.038), fewer patients with pneumonia (2 vs. 7, *P* <0.001) and lower APACHE II scores (16.1±2.8 vs. 21.8±3.2, *P* <0.001). Further, multivariate logistic regression analysis showed pneumonia (*P*=0.027) and high APACHE II score (>20) (*P*=0.002) were the independent risk factors of NPPV failure (Table 5).

DISCUSSION

With the knowledge of severe complications associated with endotracheal intubation and tracheostomy invasive ventilation, the use of NPPV to treat ARF has become more common. ARF is one of the most severe complications after cardiac surgery, and artificial airway and invasive mechanical ventilation are needed in most of the patients.[2] Artificial airway poses a serious problem associated with longer ICU and hospital stays, including a higher VAP incidence and hospital expenditure, and the mortality may be as high as 25%–50%.[4,18] The results from this study showed that compared with the conventional treatment, NPPV can significantly reduce the re-intubation rate (18.8% vs. 80.9%), tracheostomy rate (12.5% vs. 29.8%), the incidence of VAP (0 vs. 17.0%) and mortality (18.8% vs. 38.3%) of ARF after cardiac surgery, and shorten the MV time and ICU stay. To our knowledge, this is the relatively early prospective randomized control clinical study to show that NPPV has significant advantages over conventional therapy to treat selected post cardiac surgery patients with acute respiratory failure after extubation.

NPPV is ordered routinely in ICUs, where it has demonstrated its effectiveness to treat ARF, especially in patients with COPD, acute heart failure, and immune suppression. It has been also used for respiratory failure after extubation in multiple surgical settings, such as abdominal surgery and pulmonary resection, achieving improvements in oxygenation and decreases in the re-intubation rate.[10,19] Currently, there is only limited experience regarding the use of NPPV to treat respiratory failure after cardiac surgery. De Santo et al[12] reported 43 cases of cardiac postoperative extubation failure with acute respiratory failure treated with NPPV. Results showed that 74.4% of the patients were successfully treated with NPPV, and the mortality was 14%. In the retrospective analysis by Boeken et al[20] extubation failure with hypoxic respiratory failure after cardiac surgery were treated with immediate endotracheal intubation, continuous positive airway pressure (CPAP) and BiPAP, results showed the re-intubation rate of CPAP and BiPAP were 25.8% and 22.2%. The mortality of the three groups was 8.8%, 4.2%, and 5.6% respectively. The researchers claim that NPPV (CPAP or BiPAP) can significantly reduce the re-intubation rate and improve patient outcome. Compared with the two studies above, the re-intubation rate of our study was lower, and mortality was higher. The different results may be related to case selection, different research methods, and severity of disease.

In this study, acute CPE, ALI, lobar atelectasis, pneumonia, COPD and respiratory muscle fatigue were the main postoperative pulmonary complications (PPCs) that caused ARF (Table 1). The main expected benefits from applying NPPV in PPCs are an increase in lung gas volume, an improvementin gas exchange, a reduction of atelectasis and work ofbreathing without the need for endotracheal intubation, thus avoiding the risks of invasive mechanical ventilation.[21,22] More importantly, NPPV induces lung volume and intrathoracic pressure changes, which can affect preload, afterload, heart rate, and myocardial contractility, result in improvement of cardiac function and resolution of acute CPE. Franco et al[23] studied 26 cases after cardiac surgery that were randomly divided into NPPV and the conventional treatment groups. The postoperative recovery of lung function of the patients who received NPPV was significantly improved compared with the conventional treatment group, and NPPV was safe for patients. After a long-term study, Zarbock et al[24] found that the prophylactic usage of NPPV in patients after cardiac surgery could effectively improve the oxygen saturation condition, reduce pulmonary complications such as CPE and pneumonia, and effectively reduce the re-intubation rate.

A careful search for any possible PPCs together with the individual characteristics of the patients is fundamental for increasing NPPV success. Our univariate analysis found that the NPPV success group had more patients with ALI (*P*=0.038), fewer patients with pneumonia (*P* <0.001), and lower APACHE II scores (*P* <0.001). Multivariate analysis showed that pneumonia (*P*=0.027) and high APACHE II score >20 (*P*=0.002) were the independent risk factors of NPPV failure,which is in accordance with other studies.[25-27] ALI after cardiac surgery is frequently related to cardiopulmonary bypass (CPB).[28,29] During CPB, inflammatory, coagulation, and fibrinolyticcascades are initiated, leading most often to postoperative interstitial pulmonary oedema and hypoxia. This kind of ALI might be easily treated by NPPV. In contrast to ALI, univariate and multivariate analyses consistently showed pneumonia and high APACHE II scores significantly associated with NPPV failure. Pneumonia has a relatively slow onset, and time is required for conventional medical therapy to show its effects. So, once oxygenation and ventilatory assistance are attained by NPPV, the major determinant of the outcome is the resolution of the underlying disease. Furthermore, airway secretion accumulation in the pneumonia lung may also affect the efficacy of NPPV in these post-surgical patients.[12,30] Our study revealed another important predictor of NPPV failure was the severity of the underlying illness defined by a high APACHE II >20 in post cardiac surgery

ARF, which is consistent with previous studies,[31,32] although some earlier studies have failed to demonstrate this observation.[33,34] Hence, it is important not only to select patients properly, but the duration of the NPPV trial also requires close observation with monitoring of clinical and blood gas parameters. Artificial airway and invasive ventilation should be instituted promptly to avoid the delay of treatment.

There is always a concern about the safety when using NPPV.[11] In our study, NPPV associated complications occurred in 14 patients (29.2%), including nine patients with gastric distension which was controlled by negative pressure suction through a nasogastric tube, three patients with hypotension controlled by vasoactive drugs, and two patients with aspiration controlled by ETI who died of septic shock and MOF afterward. So all patients treated with NPPV require close observation and any complications should be managed as necessary.

Finally, our study has limitations. The major limitations of our study include the relatively small number of patients. Thus many of the conclusions regarding risk factors in our study have limitations because of the small number of patients in each group, especially in the NPPV failure subgroup. The small data set does not allow for a valid assessment of whether some of these conditions in the study population may or may not be a contributing factor for success or failure of NPPV.

In summary, our study indicated that NPPV can be applied in selected patients with ARF after cardiac surgery to reduce the need of re-intubation and improve clinical outcome as compared with conventional treatment. Patient with pneumonia and a high APACHE II score >20 might be the independent risk factors of NPPV failure. A large sample and multicenter prospective randomized controlled trial to further determine the indication and efficacy of NPPV in the treatment of ARF after cardiac surgery is warranted.

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