Use of non-invasive positive-pressure ventilation for acute respiratory failure: prospective study

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Objective. To study the effectiveness and safety of non-invasive positive-pressure ventilation in the management of acute respiratory failure.
Design. Prospective study.
Setting. Regional public hospital, Hong Kong.
Patients. One hundred and eighty-nine haemodynamically stable Chinese adults with acute respiratory failure (119 men and 70 women; mean age, 71.2 years [range, 18-92 years]) who were treated with non-invasive positive-pressure ventilation as the primary mode of ventilatory assistance from 1 January 1996 to 31 December 1998.
Main outcome measures. Arterial blood gas measurements, respiratory rate, airway pressures used, use of endotracheal intubation, and standardised mortality ratio.
Results. Fifty-two patients had hypoxaemic respiratory failure (group I); 97 had hypercapnic respiratory failure (group II); and 40 had either type with advanced co-morbidities and were not planned to receive endotracheal intubation (group III). For groups I and II, the overall mean duration of non-invasive positive-pressure ventilation was 56.2 hours. Improvements in gas exchange were seen in approximately 71% of these patients, endotracheal intubation was not needed for 82%, and the standardised mortality ratio was 0.86. The hospital survival rate was approximately 93% in non-intubated patients and 41% in intubated patients. Predictors of success were reduction in respiratory rate within 6 hours ($P<0.005$), and (for hypercapnic respiratory failure) increased pH and reduced arterial carbon dioxide tension within 24 hours ($P<0.005$). Patients with pneumonia had significantly higher failure rates ($P<0.05$). Group III patients were older, had higher Acute Physiology and Chronic Health Evaluation II scores, and required longer ventilatory support, but their gas exchange response rate was 68%. The only complication of treatment was minor facial skin abrasions.
Conclusion. Non-invasive positive-pressure ventilation is effective in treating haemodynamically stable patients with acute respiratory failure and causes few and minor complications.

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Key words: Intubation, intratracheal; Lung disease, obstructive; Positive-pressure respiration; Respiratory distress syndrome, adult; Treatment outcome

Introduction

Positive-pressure ventilation administered by endotracheal intubation or tracheostomy has been the standard mode of ventilatory support for acute respiratory failure (ARF) for several decades. Invasive placement, however, is required to create the artificial airway and is associated with increased risks of nosocomial pneumonia and barotrauma.[1] Non-invasive positive-pressure ventilation (NIPPV) through nasal or facial masks has recently been reported to be effective in ARF treatment in certain patient groups.[2-16] Randomised controlled studies have shown NIPPV to be effective in treating ARF and in avoiding endotracheal intubation secondary to chronic obstructive pulmonary disease (COPD)[2,3] and acute cardiogenic pulmonary oedema (APO).[6] Potential advantages of using NIPPV include preservation of the intact airway defence mechanism; preservation of speech and swallowing functions; avoidance of trauma to the larynx and trachea; and reduction in the level of patient discomfort. However, NIPPV is applicable only to conscious and cooperative patients, and it does not provide direct airway access to allow the removal of

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sputum. Furthermore, there is a potential danger of rapid deterioration in the clinical condition of a borderline patient, should the mask be dislodged.

Most published studies of NIPPV use in patients with various causes of ARF have yielded a favourable outcome.[2-16] On the other hand, conflicting results have been reported by some authors,[17,18] and few data exist on its application in the Chinese population.[19] We aimed to study the effectiveness of NIPPV in correcting gas-exchange abnormalities and avoiding endotracheal intubation in the management of ARF, and to identify predictors of response and treatment success in local Chinese adults with ARF.

Methods

Patient selection

All adult medical patients with ARF who were treated with NIPPV as the primary mode of ventilatory assistance from 1 January 1996 to 31 December 1998 in an eight-bed medical high-dependency unit of the Pamela Youde Nethersole Eastern Hospital were studied. The unit serves a 278-bed acute medical department and has a nurse to patient ratio of 1:2. Indications for NIPPV were increasing respiratory distress, as evidenced by moderate-to-severe dyspnoea, and abnormal arterial blood gas (ABG) measurements that met the following diagnostic criteria for ARF: ratio of arterial oxygen tension to fractional inspired oxygen (PaO_2/FiO_2) of <300 mm Hg (hypoxaemic ARF); or pH <7.35 and arterial carbon dioxide tension ($PaCO_2$) of >45 mm Hg (hypercapnic ARF).[20] Contra-indications to NIPPV, and thus exclusion from this study, were as follows: abnormal consciousness level; cardiac or haemodynamic instability (significant ventricular tachycardia, and/or systolic blood pressure of <90 mm Hg); cardiorespiratory arrest; and need for endotracheal intubation to protect the airway or manage secretions.

Non-invasive positive-pressure ventilation was delivered using a bilevel positive airway pressure (PAP) system (BiPAP; Respironics Inc., Murrysville [PA], United States), which is a pressure-limited device that delivers inspiratory and expiratory PAPs (iPAP and ePAP, respectively). The PAPs are adjustable to a maximum of 20 or 30 cm H_2O (setting BiPAP S/T-D or BiPAP S/T-D 30, respectively). The spontaneous-timed mode was used for all patients. In this mode, the ventilator activates inspiration either on sensing negative-pressure breathing effort or according to preset time elapsed since last inspiration in the absence of breathing effort. The iPAP level was adjusted by the initiating physician to achieve, with minimal patient discomfort, respiratory rates of less than 25 breaths per minute and exhaled tidal volumes of at least 7 mL/kg. The ePAP level was adjusted to achieve target oxygenation, with minimum carbon dioxide rebreathing. In accordance with the findings and recommendations of Ferguson and Gilmartin,[21] we used the standard exhalation device (Whisper-Swivel; Respironics Inc.) with ePAP levels of ≥8 cm, and the plateau exhalation device (Respironics Inc.) with levels of ≥4 cm. A back-up rate was set at 12 breaths per minute for all patients. Oxygen was connected to the mask and the FiO_2 was estimated from the patients' oxygen flow rate and minute volume.[22] A tight but comfortable mask fitting with minimal leakage was ensured. Nasal masks were fitted on all patients initially, whereas chin-straps were applied only to mouth-breathers. If a good seal still could not be achieved, facial masks were used instead.

The rationale, treatment procedures, and possible discomforts that may have been encountered were fully explained to patients before starting NIPPV. After ensuring that patients understood the procedure and would cooperate, and after obtaining consent, a physician positioned the nasal mask gently on patient's face and turned on low levels of positive pressure. The iPAP was set at 8 to 10 cm H_2O and the ePAP was set at 4 to 5 cm H_2O; mask positioning was then adjusted until there was no air leakage. The patient's comfort while breathing in full synchrony with the BiPAP system was confirmed before the application of the head-straps, after which the pressure was adjusted according to individual needs.

Following the protocol of Meduri et al,[20] we maintained patients on NIPPV continuously for at least 6 hours after initiation, unless they demanded temporary mask removal for sputum expectoration or rest. Thereafter, patients were allowed to remove the mask for short periods every few hours for meals, sputum clearance, conversation, or bronchodilator inhalation. During the first 1 to 2 days, patients were encouraged to use NIPPV as long as they could tolerate it; then they were gradually weaned off it in the daytime when their condition showed clinical improvement, which was defined as a reduction in the respiratory rate, decrease in oxygen requirement, and/or decrease in $PaCO_2$. Nocturnal weaning followed if a patient's condition became clinically stable. Standard therapies that were directed towards the causes of respiratory failure and all co-morbidities were simultaneously administered. Criteria for intubation after application of NIPPV were as follows: lack of clinical improvement with progressively increasing dyspnoea and desaturation;

haemodynamic instability; and electrocardiographic abnormalities that developed during NIPPV treatment. Patients were connected to mechanical ventilators after endotracheal intubation had been performed.

The following data were collected prospectively: age; gender; ARF type and precipitating conditions; Acute Physiology and Chronic Health Evaluation II (APACHE II) score and predicted mortality; NIPPV duration; iPAP and ePAP levels used; ABG measurements and best (slowest) respiratory rate at baseline (time, T_0), 2 to 6 hours (T_1), and 6 to 24 hours (T_2) post-NIPPV; and outcome in terms of intubation status, mortality, and NIPPV-related complications. The response variables studied were pH, $PaCO_2$, PaO_2/FiO_2, and respiratory rate. The ABG response was defined as an increase in the PaO_2/FiO_2 value by ≥50 mm Hg in the first 24 hours for patients with hypoxaemic ARF, and pH ≥7.35 or an increase in pH by ≥0.1 at least once during the same period for patients with hypercapnic ARF. Success was defined as the total avoidance of endotracheal intubation throughout the admission period. Measurements of mortality included observed hospital mortality, calculated risk of death from the APACHE II equation, and the standardised mortality ratio. To detect predictors of success (ie the avoidance of endotracheal intubation), we analysed (1) at T_0: age, conditions precipitating ARF, and APACHE II score; and (2) at T_0 and over time: respiratory rate, PaO_2/FiO_2, pH, $PaCO_2$, and iPAP and ePAP levels used.

Statistical analysis

The response variables at T_1 and T_2 were compared by performing an analysis of covariance (ANCOVA) after adjusting for T_0 values. In the analyses of difference between ABG responders and non-responders, and avoidance of endotracheal intubation, the Mann Whitney *U* test, Student's *t* test for independent samples, Chi squared test, and Fisher's exact test were used where appropriate. The cut-off level for statistical significance was taken as P=0.05.

Results

During the study period, NIPPV was used in 306 adult Chinese patients. One hundred and seventeen patients were excluded from the study because of intolerance to NIPPV (n=18), incomplete data (n=37), and NIPPV use outside the inclusion criteria of this study (n=62). Of the 189 patients recruited, 119 (63.0%) were men; the overall mean age was 71.2 years (range, 18-92 years) and the mean APACHE II score was 16.4 at T_0. Fifty-two (27.5%) of the patients had hypoxaemic ARF (group I); 97 (51.3%) had hypercapnic ARF (group II); and 40 (21.2%) had either type of ARF with complicating advanced co-morbidities, for whom endotracheal intubation was not planned because of their poor prognosis for survival (group III). Patients in group III had terminal stages of cardiopulmonary diseases (n=31), underlying malignant cancer (n=4), or other underlying diseases (n=5). Demographic and physiological characteristics for the three groups at T_0 are shown in Table 1. The ABG results were available at T_0 in all 189 patients, at T_1 post-NIPPV in 188, and at T_2 in 145.

The combined results of the 149 patients in groups I and II are shown in Table 2. The overall mean and median durations of NIPPV were 56.2 and 35.0 hours, respectively. An improvement in gas exchange was achieved in 105 (70.5%) of these patients, and endotracheal intubation was obviated in 122 (81.9%) of them. Endotracheal intubation was successfully avoided in 90.5% (95/105) of the patients who showed an improvement in gas exchange and in 61.4% (27/44) of those who showed no improvement. Predicted and actual hospital mortality rates were 19.5% and 16.8% respectively (standardised mortality ratio, 0.86). The hospital mortality rate was 7.4% (9/122) in non-intubated patients and 59.3% (16/27) in intubated patients (P<0.001, Chi squared test).

The overall mean (standard deviation [SD]) duration of stay in the medical high-dependency unit and hospital for all 189 patients was 4.7 (5.0) days and

Table 1. Baseline demographic and physiological characteristics

	Study group*			
	Group I (n=52)	Group II (n=97)	Group III (n=40)	Total (n=189)
Age (years)	70.1 (13.0)	70.3 (12.4)	75.0 (8.1)	71.2 ± 11.9
Male to female ratio	26:26	64:33	29:11	119:70
APACHE† II score	16.8 (6.5)	15.2 (5.5)	18.7 (5.1)	16.4 ± 5.8
Respiratory rate (breaths per minute)	30.3 (6.6)	27.2 (6.0)	28.1 (6.3)	28.2 ± 6.3
pH	7.38 (0.07)	7.25 (0.07)	7.29 (0.09)	7.30 ± 0.09
$PaCO_2$‡ (mm Hg)	37.9 (11.1)	73.3 (16.1)	66.0 (19.4)	62.0 ± 21.8
PaO_2/FiO_2§ (mm Hg)	183.4 (63.4)	251.2 (100.3)	260.0 (175.0)	234.4 ± 116.6

* Results are expressed as mean (standard deviation) where appropriate
† Acute Physiology and Chronic Health Evaluation
‡ $PaCO_2$ arterial carbon dioxide tension
§ PaO_2/FiO_2 arterial oxygen tension : fractional inspired oxygen

Table 2. Treatment outcomes for patients in groups I and II

	Study group		
	Group I (n=52)	Group II (n=97)	Total (n=149)
Duration of non-invasive positive-pressure ventilation (hours)			
Mean (SD)	33.3 (32.2)	68.5 (78.0)	56.2 (67.7)
Median	25.5	44.0	35.0
Arterial blood gas response (No. of patients [%])	37 (71.2)	68 (70.1)	105 (70.5)
Endotracheal intubation avoided (No. of patients [%])	37 (71.2)	85 (87.6)	122 (81.9)
No. of hospital mortalities (%)	17 (32.7)	8 (8.2)	25 (16.8)
Mean (SD) risk of death	0.23 (0.17)	0.18 (0.13)	0.20 (0.15)
Standardised mortality ratio	1.45	0.46	0.86
Mortality (intubated) [%]	12/15 (80.0)	4/12 (33.3)	16/27 (59.3)
Mortality (non-intubated) [%]	5/37 (13.5)	4/85 (4.7)	9/122 (7.4)

19.7 (17.5) days, respectively. The mean (SD) duration of stay in the high-dependency unit for the group not requiring endotracheal intubation was 4.3 (4.0) days, which was significantly shorter than that of the group who required intubation (9.1 [9.2] days; P<0.001, *t* test). The duration of hospitalisation between the two groups was not statistically significant. The iPAP and ePAP levels for COPD and APO—the two disease entities with level I evidence to support the utility of NIPPV[2,3,6]—were analysed. There were no significant differences in the iPAP and ePAP levels used when patients with and without COPD were compared. The ePAP level used in patients with APO was similar to that in patients without APO (5.88 [SD, 1.48] versus 5.29 [1.60]; P=0.07), but the iPAP level was significantly lower for patients with APO (10.2 [SD, 2.8] versus 11.4 [2.4]; P=0.02, *t* test).

Success (avoidance of endotracheal intubation) for patients in group I could be predicted by a lower APACHE II score, higher baseline PaO_2/FiO_2 value, and a reduction in respiratory rate within 6 hours of starting NIPPV (Table 3). Success for patients in group II could be predicted by a reduction in respiratory rate within 6 hours of starting NIPPV, and increases in pH and decrease in $PaCO_2$ within 24 hours (Table 4). Patients with pneumonia had significantly higher failure rates than patients who had other causes of ARF (32.6% versus 11.7%; P=0.035 [Table 5]). Patients who failed to respond to NIPPV (n=27) did so early in the study. Compared with the patients who did not require endotracheal intubation, NIPPV duration was significantly shorter in those who required intubation did, in both group I and II patients.

Compared with patients in groups I and II, those in group III were older (mean, 75 years), had higher APACHE II scores (mean, 18.7), and longer NIPPV use (mean, 120.8 hours; all variables, P<0.05). The ABG response was 68% and the overall survival rate was 48%. Complications during NIPPV were uncommonly encountered. There were no cases of gastric distention, and only one patient had nosocomial pneumonia, which was treated with antibiotics. Facial skin abrasions and/or minor necrosis were common (4/28; 14%) during the first year, but the frequency of these conditions in the subsequent 24 months of study decreased (to less than 3% [5/161]) owing to the introduction of the gel mask.

Discussion

In the past decade, NIPPV has been increasingly used worldwide to treat ARF. Prospective, randomised controlled trials have demonstrated that NIPPV can avert the need for endotracheal intubation, decrease mortality rates, and shorten the duration of hospital stay in patients with acute exacerbations of COPD.[2,3,14] Level I

Table 3. Treatment outcome for patients in group I according to intubation requirement

	Success*	Failure	P value
APACHE† II score	15.7 (5.7)	19.7 (7.5)	0.043
Duration of non-invasive positive-pressure ventilation (hours)	40.6 (34.1)	15.1 (16.6)	0.008
Baseline respiratory rate (breaths per minute)	30.2 (7.1)	30.7 (5.1)	ns
Respiratory rate at 2-6 hours (breaths per minute)	20.8 (4.8)	28.9 (9.0)	0.002§
Respiratory rate at 6-24 hours (breaths per minute)	18.2 (3.6)	27.9 (8.9)	0.003§
Baseline PaO_2/FiO_2‡ (mm Hg)	197.0 (62.3)	149.8 (54.4)	0.013

* As defined by the avoidance of endotracheal intubation; all results are expressed as mean (standard deviation)
† Acute Physiology and Chronic Health Evaluation
‡ PaO_2/FiO_2 arterial oxygen tension : fractional inspired oxygen
§ Analysis of covariance; other items were compared with the *t* test for independent samples
ns not significant

Table 4. Treatment outcome for patients in group II according to intubation requirement

	Success*	Failure	P value
Duration of non-invasive positive-pressure ventilation (hours)	75.9 (80.5)	16.6 (15.9)	<0.001
Baseline respiratory rate (breaths per minute)	27.4 (6.0)	25.6 (6.2)	ns
Respiratory rate at 2-6 hours (breaths per minute)	19.3 (4.9)	24.6 (6.8)	<0.001†
Respiratory rate at 6-24 hours (breaths per minute)	18.4 (3.9)	22.4 (4.8)	0.001†
pH (baseline)	7.25 (0.07)	7.24 (0.04)	ns
pH (2-6 hours)	7.32 (0.06)	7.26 (0.09)	ns†
pH (6-24 hours)	7.36 (0.06)	7.26 (0.05)	0.003†
$PaCO_2$‡ (baseline) (mm Hg)	73.6 (16.2)	71.7 (15.8)	ns
$PaCO_2$ (2-6 hours) (mm Hg)	63.1 (15.4)	71.9 (25.8)	ns†
$PaCO_2$ (6-24 hours) (mm Hg)	58.1 (12.9)	75.1 (21.8)	<0.001†

* As defined by the avoidance of endotracheal intubation; all results are expressed as mean (standard deviation)
† Analysis of covariance; other items were compared with the *t* test for independent samples
‡ $PaCO_2$ arterial carbon dioxide tension
ns not significant

Table 5. Endotracheal intubation status for different causes of respiratory failure for patients in groups I and II

	Success*	Failure
Pneumonia (n=46)	31	15†
Acute cardiogenic pulmonary oedema (n=24)	22	2
Chronic obstructive pulmonary disease (n=45)	38	7
Postextubation respiratory failure (n=16)	15	1
Others (n=18)	16	2

* As defined by the avoidance of endotracheal intubation
† P=0.035 when comparing failure rates for pneumonia and all other causes; Chi squared test

evidence also supports the effectiveness of NIPPV in the treatment of cardiogenic pulmonary oedema.[6,15] In a prospective randomised trial of patients with acute pulmonary oedema, however, Mehta et al[16] showed that the use of BiPAP was associated with a higher rate of myocardial infarction than when continuous PAP was used. The authors attributed the finding to a greater drop in cardiac output secondary to BiPAP-induced increases in intrathoracic pressure. Further studies are required to clarify the effect of BiPAP use on infarction rates and haemodynamics in patients with acute pulmonary oedema. Non-randomised cohort studies have also reported NIPPV to be effective in managing ARF secondary to status asthmaticus,[4] sleep apnoea,[5] community-acquired pneumonia,[9] opportunistic infection in acquired immunodeficiency syndrome,[8] postextubation respiratory failure,[11] weaning difficulty,[12] and ARF with advanced co-morbidities.[10]

Other studies have shown no substantial improvement or even an increase in hospital mortality rate after NIPPV use.[17,18] In a randomised controlled study of 24 COPD patients, Barbe et al[17] used fixed NIPPV treatment periods of 6 hours a day (3 hours each in the morning and afternoon) for the first 3 days of ARF management. Use of such a treatment schedule may, however, be insufficient to reduce diaphragmatic activity, increase tidal volume, or rest the inspiratory muscles. Wood et al[18] studied only 27 emergency department patients. Reasons for the negative effect of NIPPV in their study may include appreciable delays in applying endotracheal intubation and mechanical ventilation to patients who did not respond to NIPPV, and the non-standardisation of medical therapy.

When NIPPV was first used in the Pamela Youde Nethersole Eastern Hospital, only 67 patients with ARF were treated during the year of 1996. Because of the encouraging results achieved, NIPPV use was increased to an average of 120 cases per year in the subsequent 2 years. The choice of optimal mask interface in NIPPV remains controversial, because there are so far no studies that directly compare the efficacies of different models. We chose to initiate NIPPV using the nasal mask because of its smaller dead-space (105 mL versus 250 mL for the facial mask)[23] and its lower propensity to predispose to claustrophobia and aspiration. In addition, patients can freely cough to discharge their sputum. We did not encounter any major problems with this protocol, and less than 20% of the patients eventually required facial masks.

Another problem with NIPPV use is patient intolerance, which could be due to anxiety or claustrophobia. In our experience, patient tolerance can be improved by adequate preparation before instituting treatment, by clearly explaining to them about the rationale and procedures of treatment, as well as its possible discomforts. The physician should then position the nasal mask gently on the patient's face and administer low-level positive pressures to acclimatise the patient before applying the head-straps and adjusting pressures

according to individual needs. With these precautions implemented, less than 6% of the patients in this study could not tolerate NIPPV.

In contrast to most reported studies that have used conventional mechanical ventilators to generate positive pressure, we used the BiPAP, which is a much simpler and more economical device. The iPAP and ePAP levels are easily adjusted to achieve target respiratory rates, tidal volumes, and oxygenation, as well as to minimise carbon dioxide rebreathing. In this study, patient cooperation with and tolerance of such iPAP and ePAP levels was excellent. Because both the set-up and maintenance costs of BiPAP systems are low compared with invasive mechanical ventilation, NIPPV is now an effective and economical method of providing ventilatory assistance to appropriate patients in our department. Since an accurate oxygen blender or fixed-percentage oxygen cylinder was not available in the BiPAP system used, supplementary oxygen was applied through a direct connection to the mask. The FiO_2 was estimated from the oxygen flow rate and minute ventilation of the patient.[22] We recognise that this calculation may not be accurate in association with BiPAP use, because of the continuous airflow generated from iPAP and ePAP, which reduces the actual FiO_2 inside the mask. As such, the ABG response rate may be underestimated in hypoxaemic patients.

The overall ABG response (70.5%) and success (81.9%) rates in this study are similar to results obtained by Meduri et al[20] in 158 patients (ABG response rate, 76%; success rate, 65%). Kramer et al[3] also reported a similar success rate (69%) in 16 patients with ARF. In this study, the ABG response rate was similar in hypoxaemic (71.2%) and hypercapnic (70.1%) ARF patients within the first 24 hours. However, the hypoxaemic group had a lower success rate and higher mortality rate than the hypercapnic group: success rate, 71.2% versus 87.6% (P=0.01, Chi squared test); and mortality rate, 32.7% versus 8.2% (P<0.001, Chi squared test). In a study by Meduri et al,[20] the success rate was found to be 66% in both types of patient, but the mortality rate in the intensive care unit was similar to that in this study—that is, a higher mortality rate was found for hypoxaemic patients compared with hypercapnic patients (22% versus 7%). Of the 17 hypoxaemic patients in this study who died, seven initially presented with pneumonia but gradually progressed to acute respiratory distress syndrome, two patients died of intractable heart failure, four died of acute myocardial infarction, and the remaining four patients died of cytomegalovirus pneumonitis, fulminant pneumonia, phaeochromocytoma, and severe chronic obstructive airway disease.

When the BiPAP machine is used, a high ePAP is recommended to decrease rebreathing in COPD patients.[21] On the other hand, a positive end-expiratory pressure (PEEP) adjusted to <75% of the auto-PEEP is also recommended to overcome auto-PEEP in patients with COPD.[24] The minimal level of ePAP that is required to avoid excessive carbon dioxide rebreathing when a whisper valve is used is 8 cm H_2O.[21] This level is usually too high for COPD patients, because more air may be trapped by impedence to the expiratory flow. A plateau valve has thus been recommended for COPD patients to allow the use of lower ePAP (eg 4-5 cm H_2O) and at the same time minimise carbon dioxide rebreathing.[21] A higher ePAP level is expected for the APO patients to achieve better alveolar recruitment. However, there was no significant difference in the ePAP levels used in this study between the patients with and those without APO. This finding may be explained by the relatively small number of APO patients (n=26), so that the P value was of only borderline insignificance (P=0.07). The lower iPAP level used in APO patients may be explained by the fact that the opening of collapsed alveoli by ePAP is important in decreasing the work of breathing by alveolar recruitment. This sequence of events is supported by randomised studies that have shown that use of continuous PAP alone is very effective for the management of APO.[6,15]

Predictors of success used in this study were respiratory rate or ABG improvement within the first 6 hours of NIPPV, which are in line with reports in which these variables improved within the first 1 to 2 hours.[4,20] In this study, NIPPV was a very useful initial treatment for appropriate ARF patients, because it helped identify those who required endotracheal intubation very early in the course of treatment. The duration of NIPPV for intubated patients was thus much shorter than for those who were not intubated (mean, 16 hours versus 65 hours; P<0.005, *t* test).

Randomised controlled studies have shown that NIPPV is effective in treating ARF and avoiding endotracheal intubation secondary to COPD (74%-91%)[2,3] and cardiogenic pulmonary oedema (100%).[6] In this study, success rates for these two conditions were comparable, at approximately 84% and 92%, respectively.

Wysocki et al[25] found that the success rate was low in seven patients in whom pneumonia was the underlying cause of ARF. Reasons may include their inability to handle secretions; high levels of ventilatory

requirement; and reduced lung compliance with high iPAP requirements, which may not be adequately delivered by non-invasive means. In agreement with their findings, this study also found higher intubation rates in patients with pneumonia than in those without. Hence, NIPPV should be applied with caution in patients with ARF due to pneumonia, when there are copious secretions.

In ARF patients who had underlying advanced co-morbidities, NIPPV use for a mean of 120.8 hours resulted in a hospital survival rate of 48%. This figure is similar to that reported by Meduri et al,[10] who found a hospital survival rate of 45.5% for a mean NIPPV duration of 44 hours. Hence, NIPPV is a viable treatment option and merits a trial in such patients, as it could improve survival even for very sick patients with ARF.

There were no major complications in this study; minor facial skin abrasion/necrosis was the most frequently encountered complication. New developments in mask interfacing, especially the introduction of the gel mask, have further decreased the extent of this problem.

Conclusion

Non-invasive positive-pressure ventilation is effective in treating haemodynamically stable Chinese adults with types I or II ARF, as well as patients with advanced co-morbidities who fulfil the diagnostic criteria. Its use causes few and minor complications.

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