Bilevel positive airway pressure nasal mask ventilation in patients with acute hypercapnic respiratory failure

CK Chan, KS Lau, HC Fan, CW Lam

The efficacy and complications of bilevel positive airway pressure nasal mask ventilation for 22 patients with acute hypercapnic respiratory failure were reviewed retrospectively. The median patient age was 73 years (range, 57-92 years). The most common primary diagnosis (77%) was chronic obstructive pulmonary disease. The median duration of ventilation was 72.0 hours (range, 0.9 hours to 35 days). Within a median of 12 hours (range, 1-24 hours) after the initiation of therapy, there were significant improvements in the arterial oxygen and carbon dioxide tensions, oxygenation ratio, and arterial-alveolar ratio. Fourteen patients (64%) were treated successfully. Success with therapy was associated with a lower Acute Physiology and Chronic Health Evaluation score, a higher arterial oxygen tension, higher oxygenation and arterial-alveolar ratios, and lower respiratory and pulse rates. Complications were uncommon. We conclude that bilevel positive airway pressure nasal mask ventilation can be useful for patients with acute hypercapnic respiratory failure but who are otherwise clinically stable.

HKMJ 1998;4:125-31

Key words: Lung diseases, obstructive/ventilation; Masks; Positive-pressure respiration; Respiratory insufficiency/ therapy

Introduction

Intubation and mechanical ventilation are commonly employed to support patients with acute respiratory failure. It is well known, however, that endotracheal intubation and mechanical ventilation may predispose the patient to complications such as tracheal injury, nosocomial infection, and barotrauma. As a consequence, there has been growing interest in non-invasive ventilatory support because of its promising role in avoiding intubation and associated complications.[1]

A non-invasive bilevel positive airway pressure (BiPAP) system administered via a nasal mask has been developed recently (Respironics Inc., Murrysville, Pennsylvania, USA).[2] It is a pressure-support ventilatory system which maintains pressure at two different levels—namely, the inspiratory positive airway pressure (IPAP) and the expiratory positive airway pressure (EPAP)—through a pressure controlling valve.[3] The IPAP is equivalent to the pressure support of conventional methods of mechanical ventilation, whereas the EPAP is equivalent to the external positive end-expiratory pressure. The BiPAP unit can be cycled in spontaneous, timed, or spontaneous/timed modes. Bilevel positive airway pressure nasal mask ventilation, if tolerated, may prove useful for selected patients with acute respiratory failure but who are otherwise clinically stable.[4-5] We report our initial experience with the use of BiPAP nasal mask ventilation in patients with acute hypercapnic respiratory failure who were admitted to the Respiratory Medical Unit of the Ruttonjee Hospital between April and July 1996.

Department of Respiratory Medicine, Ruttonjee Hospital, 266 Queen's Road East, Wanchai, Hong Kong
CK Chan, MRCP, FHKAM (Medicine)
KS Lau, MRCP, FHKAM (Medicine)
HC Fan, MB, BS, MRCP
CW Lam, FRCP (Glas), FHKAM (Medicine)

Correspondence to: Dr CK Chan

Subjects and methods

Patient selection

We retrospectively reviewed the case records of all patients who were admitted to the Respiratory Medical Unit of the Ruttonjee Hospital with acute hypercapnic respiratory failure and who received BiPAP nasal mask ventilation from April 1996 to July 1996. All 22 patients had received non-invasive ventilation because of persistent hypoxaemia (arterial oxygen tension [PaO_2] <60 mm Hg) and/or hypercapnia (arterial carbon dioxide tension [$PaCO_2$] >50 mm Hg) and/or an arterial pH <7.35, despite maximal medical treatment (eg use of bronchodilators, steroids, or oxygen therapy). Six patients (patients 2, 8, 10, 16, 21, and 22) were

considered for intubation and mechanical ventilation; however, because of their very poor premorbid state, they were not intubated and were instead given a trial of non-invasive ventilation. The BiPAP nasal mask ventilation was initiated in the high dependency unit for 12 (55%) of the patients, and in a respiratory medical ward for the remainder.

The following data were extracted from the case records: the patient's age, sex, underlying medical condition, and Acute Physiology and Chronic Health Evaluation (APACHE) score[6] yielded by the worst parameters within the past 24 hours of initiation of non-invasive ventilation. Clinical and laboratory data included respiratory rate, mean arterial pressure, pulse rate, arterial pH, PaO_2, $PaCO_2$, bicarbonate level, and arterial oxygen percent saturation (SAO_2) before and within a median of 12 hours (range, 1-24 hours) after initiation of BiPAP nasal mask ventilation. Using arterial blood gas results, the oxygenation ratio (PaO_2 to fractional inspired oxygen [FiO_2]) and the arterial-alveolar ratio (PaO_2 to alveolar oxygen tension [PAO_2]) before and after initiation of therapy were calculated using standard formulae.[7]

The need for endotracheal intubation was noted. Bilevel positive airway pressure nasal mask ventilation was considered successful if a stable and satisfactory blood gas equilibrium was obtained and if there were an improvement in the patient's clinical condition, as judged by the attending physician. Failure of therapy was defined as the need for endotracheal intubation according to the judgement of the attending physician, or death during non-invasive mechanical ventilation.

Data analysis

Results are expressed as medians and ranges. Comparison of clinical and laboratory data before and after

Table 1. Baseline characteristics and outcomes of patients with acute hypercapnic respiratory failure who received bilevel

Patient	Sex/age (y)	Underlying medical condition	Respiratory rate (breaths per min)	Pulse rate (beats per min)	Mean arterial pressure (mm Hg)
1	F/84	Bronchiectasis, chest infection	28	115	104
2	F/76	COPD††, IHD‡‡	20	101	80
3	F/73	Bronchiectasis, COPD	25	98	79
4	F/82	COPD	20	110	90
5	F/82	COPD	22	129	87
6	F/74	COPD, old tuberculosis	28	110	110
7	F/88	COPD	24	96	103
8	M/65	COPD, IHD	24	109	95
9	M/80	COPD	24	103	102
10	M/70	COPD, chest infection	22	79	72
11	F/57	Fibrosis, old tuberculosis	24	103	67
12	M/65	COPD, lung carcinoma	16	105	80
13	M/60	COPD, old tuberculosis	22	95	68
14	M/72	COPD, chest infection	20	77	102
15	M/65	COPD	22	128	115
16	F/73	Bronchiectasis, chest infection	28	115	87
17	M/83	COPD, chest infection	28	104	104
18	F/73	Bronchiectasis, COPD	28	124	86
19	M/82	AMI¶¶, COPD, gastrointestinal bleed	26	122	79
20	M/62	COPD, old tuberculosis	43	148	105
21	M/72	COPD, chest infection	24	117	82
22	F/92	COPD, chest infection	28	136	100

*APACHE Acute Physiology and Chronic Health Evaluation
†PaO_2 arterial oxygen tension
‡$PaCO_2$ arterial carbon dioxide tension
§SAO_2 arterial oxygen percent saturation
‖FiO_2 fractional inspired oxygen
¶PAO_2 alveolar oxygen tension
**SS successful support
††COPD chronic obstructive pulmonary disease
‡‡IHD ischaemic heart disease
§§FV failure to ventilate
‖‖FA failure to accommodate
¶¶AMI acute myocardial infarction

initiation of BiPAP nasal mask ventilation were performed using the Wilcoxon signed rank sum test; results where $P<0.05$ were considered significant. A comparison was also made between the clinical and laboratory data in successfully ventilated patients and in those who failed, by using the Mann-Whitney *U* test. The aim was to identify factors that might predict the success or failure of BiPAP nasal mask ventilation. A logistic regression analysis was performed to assess which of the factors best predicted the result of treatment.

Results

Twenty-two patients who received BiPAP nasal mask ventilation for acute hypercapnic respiratory failure were reviewed. The median patient age was 73 years (range, 57-92 years). There were 11 men and 11 women. The most common primary diagnosis was chronic obstructive pulmonary disease (17 [77%] of 22 patients). The median peak flow rate was 120 L/min (range, 50-180 L/min). Four patients had bronchiectasis as the primary diagnosis and one had lung fibrosis. The median baseline APACHE score was 17 (range, 12-31). Measurement of baseline arterial blood gases while the patients were receiving oxygen showed a median PaO_2 of 53.6 mm Hg (range, 28.5-72.3 mm Hg) and a median $PaCO_2$ of 67.7 mm Hg (range, 42.5-89.1 mm Hg). The bicarbonate level was raised, with a median of 36.3 mmol/L (range, 25.1-48.1; normal range, 22-26 mmol/L), showing that most of our patients had underlying chronic respiratory diseases. All patients had either a normal pH (compensated respiratory acidosis) or were only mildly acidotic (median pH 7.36, range 7.24-7.47), except patient 22. The baseline characteristics of the patients are summarised in Table 1.

All patients received continuous non-invasive ventilation until a stable and satisfactory blood gas

positive airway pressure nasal mask ventilation

APACHE* score	Arterial pH	PaO_2† (mm Hg)	$PaCO_2$‡ (mm Hg)	Bicarbonate (mmol/L)	SAO_2§ (%)	PaO_2/FiO_2‖	PaO_2/PAO_2¶	Outcome
20	7.36	47.0	64.0	35.2	79.9	195.8	0.52	SS**
15	7.34	51.1	68.7	36.3	82.8	146.0	0.29	SS
18	7.41	65.7	67.7	42.8	92.3	219.0	0.51	SS
19	7.41	38.9	71.1	45.1	71.3	138.9	0.35	SS
15	7.41	63.3	63.6	39.2	91.7	263.8	0.69	SS
16	7.27	67.2	84.0	32.1	89.9	240.0	0.71	SS
18	7.40	59.7	60.4	36.6	90.2	248.7	0.63	SS
15	7.27	65.0	59.6	27.4	89.5	270.0	0.67	SS
19	7.36	46.4	72.2	41.1	78.8	165.7	0.42	SS
17	7.33	53.6	86.2	44.1	83.4	191.4	0.58	SS
12	7.33	72.3	77.3	40.9	92.7	278.0	0.81	SS
13	7.30	63.8	89.1	43.8	88.7	265.8	0.80	SS
16	7.36	46.1	63.7	35.8	78.8	200.4	0.54	SS
17	7.28	57.9	61.6	28.2	85.9	241.3	0.62	SS
21	7.36	44.0	70.8	40.2	76.1	157.0	0.36	FV§§
17	7.43	37.1	49.5	32.7	71.3	103.1	0.19	FV
24	7.24	44.4	59.3	25.1	71.2	185.0	0.46	FV
16	7.39	29.3	80.2	48.1	51.0	104.6	0.29	FA‖‖
19	7.42	58.6	51.2	34.7	90.4	209.0	0.43	FV
15	7.47	56.5	42.5	31.0	90.9	141.3	0.24	FV
24	7.24	28.5	73.2	31.2	42.0	101.8	0.26	FV
31	7.08	45.7	61.3	17.7	64.0	190.7	0.48	FV

equilibrium was achieved. The median duration of therapy was 72 hours (range, 0.9 hour to 35 days). After discontinuation of therapy, four patients felt fatigued at the end of the day, and thus BiPAP nasal mask ventilation was continued during the night for a median of a further 8.5 days. The median initial IPAP chosen was 8 cm H_2O (range, 6-10 cm H_2O), and the median initial EPAP was 3 cm H_2O (range, 2-5 cm H_2O). The IPAP was increased by 2 cm H_2O per step to achieve a PaO_2 of at least 60 mm Hg and/or an improvement in hypercapnia of more than 10%, while keeping the EPAP constant. The median maximum IPAP was 10 cm H_2O (range, 6-16 cm H_2O). All patients received the spontaneous/timed mode of ventilation at an initial rate of 12 to 14 breaths per minute. An inspiratory/expiratory ratio of 30% was chosen. Oxygen was supplemented at a median rate of 2 L/min (range, 1-5 L/min) to maintain an SAO_2 of >90% after non-invasive ventilation had been stabilised.

Clinical and laboratory data before and after BiPAP nasal mask ventilation are shown in Table 2. Results of pretreatment and during treatment arterial blood gas analyses were available for all patients except patient 22. Within a median of 12 hours (range, 1-24 hours) after the initiation of therapy, the PaO_2 improved significantly from a median of 53.6 mm Hg to 69.7 mm Hg (P<0.001). There were also significant improvements in calculated oxygenation indices such as the oxygenation ratio (195.8 compared with 255.4; P<0.001) and the arterial-alveolar ratio (0.51 compared with 0.64, P=0.008). The $PaCO_2$ also improved significantly, from a median of 67.7 mm Hg to 58.7 mm Hg (P=0.007). No significant change in arterial pH was detected. The respiratory rate and the mean arterial pressure also did not change significantly; there was significant improvement in pulse rate, however.

The clinical outcomes of the patients with acute hypercapnic respiratory failure who were given BiPAP nasal mask ventilation are summarised in the Figure. Of the 22 patients with acute hypercapnic respiratory failure, 14 (64%) were successfully treated with BiPAP nasal mask ventilation. In seven (32%) patients, treatment failed; four of these patients (two of whom survived) were intubated. The remaining three patients were not intubated because of their very poor morbid state; eventually, these patients died.

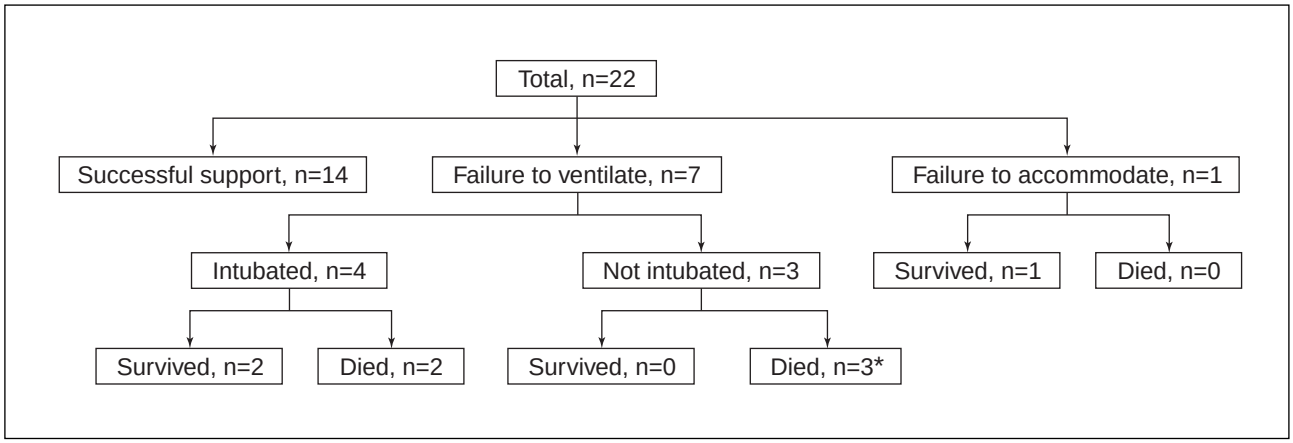
Comparison between successfully ventilated patients and those in whom ventilation failed showed that the former had a significantly lower APACHE score, a higher PaO_2, a higher oxygenation ratio and arterial-alveolar ratio, and lower respiratory and pulse rates (Table 3). Logistic regression analysis showed that when these variables were tested together, only the baseline APACHE score and the arterial-alveolar ratio were significant independent predictors of the eventual success of BiPAP nasal mask ventilation. The baseline APACHE score, when combined with the arterial-alveolar ratio, had a sensitivity of 87.3%, a specificity of 92.9%, and an overall predictability of 90.9%.

There were few complications. The most common

Table 2. Clinical and laboratory data before and within a median of 12 hours (range, 1-24 hours) after initiation of therapy (n=22)*

Patient data	Pretreatment	During treatment	P value
Arterial pH	7.36 (7.24-7.47)	7.37 (7.18-7.48)	ns
PaO_2† (mm Hg)	53.8 (28.5-72.3)	69.7 (51.2-98.9)	<0.001
$PaCO_2$‡ (mm Hg)	67.7 (42.5-89.1)	58.7 (42.3-96.6)	0.007
Bicarbonate (mmol/L)	36.3 (25.1-48.1)	35.6 (21.5-46.8)	ns
SAO_2§ (%)	85.9 (42.0-92.7)	92.8 (83.6-97.2)	<0.001
PaO_2/FiO_2‖	195.8 (101.8-278.0)	255.4 (158.8-353.2)	<0.001
PaO_2/PAO_2¶	0.51 (0.19-0.81)	0.64 (0.27-0.82)	0.008
Respiratory rate (breaths per min)	24 (16-43)	24 (18-43)	ns
Pulse rate (beats per min)	109 (77-148)	101 (77-140)	0.03
Mean arterial pressure (mm Hg)	87 (67-115)	81 (69-115)	ns

* Data expressed in terms of median and range; data before and after initiation of therapy were compared using the Wilcoxon signed rank sum test; differences were considered significant if P<0.05
† PaO_2 arterial oxygen tension
‡ $PaCO_2$ arterial carbon dioxide tension
§ SAO_2 arterial oxygen percent saturation
‖ FiO_2 fractional inspired oxygen
¶ PAO_2 alveolar oxygen tension
ns not significant



* One patient died from myocardial ischaemia

Fig. Clinical outcome of patients with acute hypercapnic respiratory failure who received bilevel positive airway pressure nasal mask ventilation

complication was the development of pressure sores over the nasal bridge. Four patients could not adapt to the nasal mask at the beginning of treatment, but only one of them discontinued treatment. The other three patients received BiPAP nasal mask ventilation for an average of 3 days. By that time, the condition of all three patients had improved.

Discussion

Non-invasive mechanical ventilation has been the focus of attention by respiratory physicians in recent years. Originally designed for domiciliary ventilatory support for patients with chest wall and neuromuscular diseases, non-invasive ventilatory techniques have now also been employed for the management of acute respiratory failure due to chronic obstructive pulmonary disease. There are conflicting results, however.[8-12] It has been reported that non-invasive ventilation can reduce the need for intubation in patients with an acute exacerbation of chronic obstructive pulmonary disease, thereby reducing associated complications, mortality, and length of

Table 3. Comparison between patients successfully ventilated with bilevel positive airway pressure nasal mask ventilation and those in whom it failed (n=22)*

Patient data	Successful support	Failure	P value
No. of patients	14 (64%)	8 (36%)	
Age (y)	74 (57-88)	73 (62-92)	ns
Arterial pH	7.35 (7.27-7.41)	7.37 (7.08-7.47)	ns
PaO_2† (mm Hg)	58.8 (38.9-72.3)	44.2 (28.5-58.6)	0.006
$PaCO_2$‡ (mm Hg)	68.2 (59.6-89.1)	60.3 (42.5-80.2)	ns
Bicarbonate (mmol/L)	37.9 (27.4-45.1)	31.9 (17.7-48.1)	ns
SAO_2§ (%)	89.1 (71.5-92.7)	71.2 (42.0-90.9)	0.02
PaO_2/FiO_2‖	229.5 (138.9-278.0)	149.1 (101.5-209.0)	0.005
PaO_2/PAO_2¶	0.60 (0.29-0.81)	0.32 (0.19-0.48)	0.002
Respiratory rate (breaths per min)	23 (16-28)	28 (22-43)	0.01
Pulse rate (beats per min)	103 (77-129)	123 (104-148)	0.002
Mean arterial pressure (mm Hg)	89 (67-110)	94 (79-115)	ns
APACHE** score	17 (12-20)	20 (15-31)	0.02

* Data expressed in terms of median and range; data were compared using the Mann-Whitney U test; differences were considered significant if P<0.05
† PaO_2 arterial oxygen tension
‡ $PaCO_2$ arterial carbon dioxide tension
§ SAO_2 arterial oxygen percent saturation
‖ FiO_2 fractional inspired oxygen
¶ PAO_2 alveolar oxygen tension
** APACHE Acute Physiology and Chronic Health Evaluation
ns not significant

hospitalisation.[11] Non-invasive ventilation may also be useful for patients in whom intubation is not appropriate because of poor premorbid states or concomitant medical illnesses.

There is no need for sedation when using non-invasive ventilation. Moreover, speech, swallowing function, and airway defence mechanisms are preserved. The technique can be used in a high dependency unit and, with adequate medical and nursing supervision, also in a respiratory medical ward. Consequently, there may be a reduced requirement for intensive care. Nevertheless, there are several potential limitations: the cooperation of the patient is needed and there is no control of the airway during non-invasive pressure support ventilation; hence, patients with excessive secretions may pose a problem. Close attention must also be paid to the choice of nasal mask, because a poor fit may result in patient discomfort, air leakage, and pressure necrosis on the bridge of the nose.

This study, although limited by its retrospective nature, showed that, in selected patients with acute hypercapnic respiratory failure, BiPAP nasal mask ventilation can be used successfully. There was a significant improvement in arterial oxygen tension. Calculated estimates of oxygenation deficits such as the oxygenation ratio (PaO_2:FiO_2) and the arterial-alveolar ratio (PaO_2:PAO_2) improved with BiPAP nasal mask ventilation. We did not use the arterial-alveolar oxygen partial pressure gradient, because the normal value tends to increase as the FiO_2 is increased, thus limiting its usefulness in assessing gas exchange in conditions in which FiO_2 varies. The oxygenation ratio and the arterial-alveolar ratio, on the other hand, are less affected by the FiO_2.

The $PaCO_2$ level also improved significantly with BiPAP nasal mask ventilation. The median $PaCO_2$ level was still elevated 24 hours after the initiation of therapy in our patients. Normalisation of the $PaCO_2$ levels, however, is probably unnecessary and may be harmful because it may induce inappropriate respiratory alkalosis. Quite unexpectedly, no significant change in arterial pH was detected in this study. This is probably because most of the patients had respiratory acidosis that was reasonably well compensated—in our opinion, this is the time when non-invasive ventilation should be started.

Of the 22 patients with acute hypercapnic respiratory failure, 14 (64%) were successfully treated with BiPAP nasal mask ventilation. The success rate is similar to that reported previously by other authors using mask ventilation in patients with respiratory failure.[13-15] Comparison between successful versus failed cases in this study shows that the former had a lower baseline APACHE score, a higher baseline PaO_2 and calculated oxygenation indices, and lower respiratory and pulse rates. The differences suggest that BiPAP nasal mask ventilation should be used early in the progression of respiratory failure—before severe decompensation takes place—to produce maximum efficacy. Logistic regression showed that a low APACHE score and a high arterial-alveolar ratio best predicted the successful treatment outcome.

Nearly all the patients in this study had underlying chronic respiratory diseases, as reflected by the raised bicarbonate levels. Studies investigating the non-invasive ventilatory treatment of acute respiratory failure due to purely acute disease processes[4,16] show that diseases other than chronic obstructive pulmonary disease (COPD) seem to have a poorer outcome (although these studies lacked controls). We found no statistically significant difference in the treatment outcome between patients who had acute respiratory failure not due to COPD (patients 1, 3, 11, 16, and 18) and the remaining patients who had underlying chronic respiratory failure due to COPD ($P>0.05$, two-tailed Fisher's exact test). However, the number in each group was probably too small for any real difference in the treatment outcome between the two groups to be detected. Further studies, perhaps with a larger sample size, will be required to determine whether BiPAP nasal mask ventilation is useful in the treatment of acute respiratory failure not due to COPD.

Six patients were considered for intubation and mechanical ventilation, but they were not intubated and instead were given a trial of non-invasive ventilation owing to a poor premorbid state (patients 2, 8, 10, 16, 21, and 22). We had expected that their conditions would become worse than that of the other patients. Our results showed that there was indeed a higher proportion with treatment failure in this group (three of six patients) compared with the remainder (five of 16 patients). This difference, however, was not statistically significant ($P>0.05$, Fisher's exact test).

There were no reports of potential complications such as aspiration, gastric distension, or inability to clear sputum. The only common complication was pressure sores over the nasal bridge. One patient could not tolerate the mask despite encouragement and eventually discontinued treatment. Complications could be under estimated, however, due to the retrospective nature of this study.

We emphasise that the patients in this study represent a carefully selected group who were conscious, cooperative, and without haemodynamic upset. In view of the potential limitations of BiPAP nasal mask ventilation, including the lack of direct access to the airway for suction and the need for patient cooperation, patients with a poor conscious level or those who are haemodynamically unstable are best treated using intubation and mechanical ventilation. Great care must be exercised in selecting appropriate patients for BiPAP nasal mask ventilation: if this form of ventilation is to be offered, the patient's respiratory and haemodynamic states should be closely monitored during the course of treatment. Adequate medical and nursing supervision is a prerequisite if non-invasive ventilation is to be used successfully.

In summary, BiPAP nasal mask ventilation is useful in carefully selected patients presenting with acute hypercapnic respiratory failure, who are otherwise clinically stable and who do not need immediate intubation. It may also be useful for patients for whom intubation may be inappropriate. Additional studies will be necessary to define the role of BiPAP nasal mask ventilation for patients with other forms of respiratory failure and to clarify the associated complications and effect of ventilation on mortality rate and costs when compared with conventional therapy.

Acknowledgement

We would like to thank Dr FH Ng for his help with the statistical analyses.

References

1. Hill NS. Non-invasive ventilation. Does it work, for whom, and how? Am Rev Respir Dis 1993;147:1050-5.
2. Strumpf DA, Carlisle CC, Millman RP, Smith KW, Hill NS. An evaluation of the Respironics BiPAP bi-level CPAP device for delivery of assisted ventilation. Respir Care 1990; 35:415-22.
3. Braghiroli A, Donner CF. Bilevel positive airway pressure. Eur Respir Rev 1992;2:398-9.
4. Meduri GU, Turner RE, Abou-Shala N, Wunderick R, Tolley E. Noninvasive positive pressure ventilation via face mask. First-line intervention in patients with acute hypercapnic and hypoxemic respiratory failure. Chest 1996;109:179-93.
5. Kramer N, Meyer TJ, Meharg J, Cere RD, Hill NS. Randomized, prospective trial of noninvasive positive pressure ventilation in acute respiratory failure. Am J Respir Crit Care Med 1995;151:1799-806.
6. Knaus WA, Draper EA, Wagner DP, Zimmerman JE. APACHE II: a severity of disease classification system. Crit Care Med 1985;13:818-29.
7. Covelli HD, Nessan VJ, Tuttle WK 3d. Oxygen derived variables in acute respiratory failure. Crit Care Med 1983;11: 646-9.
8. Brochard L, Isabey D, Piquet J, et al. Reversal of acute exacerbations of chronic obstructive lung disease by inspiratory assistance with a face mask. N Engl J Med 1990;323:1523-9.
9. Wysocki M, Tric L, Wolff MA, Gertner J, Millet H, Herman B. Noninvasive pressure support ventilation in patients with acute respiratory failure. Chest 1993;103:907-13.
10. Elliot MW, Steven MH, Phillips GD, Branthwaite MA. Non-invasive mechanical ventilation for acute respiratory failure. BMJ 1990;300:358-60.
11. Brochard L, Mancebo J, Wysocki M, et al. Noninvasive ventilation for acute exacerbations of chronic obstructive pulmonary disease. N Engl J Med 1995;333:817-22.
12. Barbe F, Togores B, Rubi M, Pons S, Maimo A, Agusti AG. Noninvasive ventilatory support does not facilitate recovery from acute respiratory failure in chronic obstructive pulmonary disease. Eur Respir J 1996;9:1240-5.
13. Meduri GU, Conoscenti CC, Menashe P, Nair S. Noninvasive face mask ventilation in patients with acute respiratory failure. Chest 1989;95:865-70.
14. Pennock BE, Kaplan PD, Carlin BW, Sabangan JS, Magovern JA. Pressure support ventilation with a simplified ventilatory support system administered with a nasal mask in patients with respiratory failure. Chest 1991;100:1371-6.
15. Ambrosino N, Foglio K, Rubini F, Clini E, Nava S, Vitacca M. Non-invasive mechanical ventilation in acute respiratory failure due to chronic obstructive pulmonary disease: correlates for success. Thorax 1995;50:755-7.
16. Wysocki M, Tric L, Wolff MA, Millet H, Herman B. Non-invasive pressure support ventilation in patients with acute respiratory failure. A randomized comparison with conventional therapy. Chest 1995;107:761-8.