# Is there a role for mask continuous positive airway pressure in acute respiratory failure due to COPD? Lessons from a retrospective audit of 3 different cohorts

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**Abstract:** Exacerbations of COPD that result in acute respiratory failure requiring intubation and mechanical ventilation have high morbidity and mortality. This study is a retrospective observational study that compared the outcomes of 237 patients with COPD and acute respiratory failure requiring intensive care unit (ICU) admission according to modality of initial therapy: mask continuous positive airway pressure (CPAP), medical therapy, or intubation. Of the patients treated with CPAP initially, only 16% failed and required intubation compared with 62% of those treated medically (p=0.001). The median length of ICU stay was 5 days in those treated with CPAP, compared with 7 days for those medically treated, and 8.5 days for intubated patients (p=0.001). When compared with mask CPAP, and after adjusting for potentially confounding differences, mortality was significantly higher if patients were initially intubated (adjusted odds ratios [OR] 15.7; 95% confidence interval [CI] 4.2, 59) or given medical therapy (OR 5.1; CI 1.2, 20.8). In COPD patients with acute respiratory failure, initial treatment with mask CPAP was associated with significantly better outcomes than other treatment modalities, even after adjusting for potentially confounding differences in disease severity.

**Keywords:** respiratory failure, mechanical ventilation, non-invasive ventilation, CPAP, COPD

## Introduction

Severe COPD exacerbations that result in acute respiratory failure requiring intubation and mechanical ventilation are associated with mortality of 35% in the intensive care unit, and total in-hospital mortality of 50% (Anon et al 1999). During these acute exacerbations, patients with COPD develop significant intrinsic positive end expiratory pressure (PEEP) (Murciano 1982; Fleury et al 1985). This results in increased inspiratory elastic work, which can represent the majority of the total inspiratory workload in these patients (Fleury et al 1985; Appendini et al 1996). The application of external PEEP has been shown to decrease the work of breathing in patients with COPD exacerbations by counterbalancing the effects of intrinsic PEEP (Tobin and Lodato 1989; Petrof et al 1990; Ranieri et al 1993; Goldberg et al 1995; Aerts et al 1997). However, mask CPAP has only been evaluated clinically in two case series: one with seven patients with COPD (Miro et al 1993), and the other for only 4 hours in 15 patients (de Lucas et al 1993).

In 1989, based upon physiologic studies conducted elsewhere (Smith and Marinii 1988; Appendini et al 1996), and at this institution (Petrof et al 1990), non-invasive mask CPAP was introduced into clinical use for treatment of acute respiratory failure in COPD patients admitted to our intensive care unit (ICU). By the late 1990s, mask

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CPAP was the most common initial treatment modality (and the only non-invasive respiratory assistance) used for these patients. However, after the publication of four randomized trials demonstrating benefits of non-invasive bilevel ventilation as treatment for acute respiratory failure in COPD patients (Bott et al 1993; Brochard et al 1995; Kramer et al 1995; Plant et al 2000), this modality increasingly replaced mask CPAP after 1995.

The present study examined outcomes of intubation, mortality, and length of stay among COPD patients with acute respiratory failure managed with mask CPAP between 1991 and 1995. Outcomes in these patients were compared with outcomes of similar patients who were treated with medical therapy alone or who were immediately intubated in our ICU and to similar patients admitted to the ICU of another hospital.

# Methods

## Study population

Patients were considered to have COPD if they had a history of cigarette smoking and after treatment with a bronchodilator, their best recorded $FEV_1$ was less than 70% predicted, and their ratio of $FEV_1$ to FVC was less than 0.7. In the absence of lung function measurements, a clinical diagnosis of COPD in a smoker or ex-smoker was also accepted (ATS guidelines 1995). Acute hypercapneic respiratory failure was defined as the acute onset of severe shortness of breath, with a pH less than 7.36 and $PCO_2$ greater than 45 on arterial blood gas. Patients were excluded if they had documented advance directives refusing intubation, were admitted to the ICU following a cardio-respiratory arrest, or were unconscious on presentation.

## Design

Three cohorts of COPD patients with acute hypercapneic respiratory failure admitted to two ICUs were reviewed. The primary analysis compared patients treated initially with CPAP with those intubated immediately and with patients treated initially with medical therapy only.

In one cohort all COPD patients admitted to a respiratory ICU in a tertiary care chest hospital between January 1st, 1991, and December 31st, 1995, were reviewed. No other forms of non-invasive ventilation were used in this ICU at that time.

Because of evidence that initial treatment modality was confounded with severity of illness in the first cohort, patients treated with CPAP were also compared with all patients in two other cohorts who did not have access to mask CPAP. The first comparison cohort was constructed to provide a contemporary comparison to minimize differences in outcomes due to improvements in medical care over the years reviewed. This cohort consisted of all COPD patients with acute respiratory failure admitted during the same years to a general medical ICU in a general, tertiary care hospital. No form of non-invasive respiratory assistance (including CPAP) was used in this other ICU during those five years.

The second comparison cohort consisted of all COPD patients with acute hypercapneic respiratory failure admitted to the same respiratory ICU of the same hospital between January 1st, 1985, and December 31st, 1988, prior to any clinical use of mask CPAP. This cohort was constructed to minimize bias due to inter-institutional differences in clinical practice, referral patterns, and selection of patient populations. Patients in the two comparison cohorts were categorized by the initial treatment modality: medical only, or intubation.

## Data collection

Using standardized data collection forms, baseline (pre-ICU admission) information collected included age, gender, $FEV_1$, and use of home oxygen. Etiology of exacerbation was defined as: (1) pneumonia – if clinically diagnosed and with a new infiltrate on chest radiograph, a temperature greater than 38.5°C, or elevated white blood cell count; (2) pulmonary edema – if clinically diagnosed and with supportive chest radiograph findings; or (3) acute bronchitic exacerbation if no other specific cause of acute respiratory failure could be identified. Data gathered at the time of ICU admission included whether the patient was transferred from inpatient wards or the emergency department, arterial blood gas values, vital signs, and initial modality of therapy – defined as use for at least the first full hour after ICU admission. Data gathered subsequent to the ICU admission included CPAP pressure used; medications; arterial blood gases after 1, 6, 12, and 24 hours; intubation; length of ICU stay; and all cause in-hospital mortality.

## CPAP system

The CPAP system used consisted of a tightly applied full face mask with an inflatable rim that was connected to a continuous high-flow system (approximately 100 L/min using a Downs Flow Generator nr 9250,Vital Signs Inc, Totowa, NJ, USA). The desired pressure was achieved by attaching a spring-loaded threshold valve to the respiratory circuit. Patients were usually started at a CPAP pressure of 5 cm $H_2O$ and increased in increments of 2.5 cm to the minimum level at which the patient experienced relief of dyspnea. No patient received pressures higher than 12.5 cm $H_2O$. There was no formal protocol for CPAP initiation or discontinuation. CPAP was discontinued when patients were able to tolerate prolonged periods off CPAP of 4 hours or more, or they required intubation according to the judgment of the treating physician.

## Data analysis

Baseline and ICU admission characteristics, as well as outcomes of patients, were compared according to initial treatment modality. Differences were tested for statistical significance with analysis of variance or Student's *t*-tests for continuous variables, and Chi-squared tests for categorical variables. Multivariate logistic regression was used to estimate the association of secondary intubation and death with initial mode of therapy after adjustment for potentially confounding differences in patient characteristics. Ninety-five percent confidence intervals (CI) were estimated for the adjusted odds ratios (OR) as suggested by Kleinbaum and Kupper (2002).

## Results

Between January 1st, 1991, and December 31st, 1995, 88 patients with COPD were admitted to the respiratory ICU with acute respiratory failure. Of these, 17 patients initially received medical treatment only, 22 were intubated immediately, and 49 received mask CPAP, which was very well tolerated by 44 (90%) of them. In 5 patients the mask was removed within 3 hours because of poor tolerance. None of the patients treated with CPAP suffered a pneumothorax, or any other complication, such as aspiration. As shown in Table 1, the three groups of patients were similar with respect to age, gender, and prior use of home oxygen, but intubated patients had higher average pre-morbid $FEV_1$ values. On the other hand, there appeared to be a gradient of severity of acute respiratory failure between the three groups. Based

**Table 1** Baseline and ICU admission characteristics as well as outcomes of patients with COPD and acute respiratory failure admitted to the respiratory ICU in 1991–1995, when CPAP was commonly used as a primary treatment modality

| Variables | Medical | | CPAP | | Intubated | | p-value |
|---|---|---|---|---|---|---|---|
| Number of patients | | 17 | | 49 | | 22 | |
| *Baseline characteristics* | | | | | | | |
| Age (mean, sd) | 64.1 | sd 9.0 | 67.6 | sd 8.9 | 70.3 | sd 9.8 | ns |
| Male (N, %) | 8 | (47%) | 26 | (53%) | 11 | 50%) | ns |
| Baseline $FEV_1$ (mean, sd) | 0.72 | sd 0.2 | 0.68 | sd 0.2 | 0.87 | sd 0.4 | 0.05 |
| Home $O_2$ (N, %) | 5 | (29%) | 14 | (28%) | 6 | (27%) | ns |
| *ICU admission characteristics* | | | | | | | |
| Cause of exacerbation | | | | | | | |
| Bronchitis (N, %) | 10 | (59%) | 32 | (65%) | 12 | (54%) | |
| Pulmonary edema | 2 | (12%) | 5 | (10%) | 5 | (23%) | |
| Pneumonia (N, %) | 5 | (29%) | 12 | (24%) | 5 | (23%) | ns |
| Transfer from | | | | | | | |
| Ward (N, %) | 3 | (18%) | 29 | (59%) | 8 | (36%) | |
| Emergency department | 14 | (82%) | 20 | (41%) | 14 | (64%) | 0.02 |
| Arterial blood gases | | | | | | | |
| pH (mean, sd) | 7.31 | sd 0.05 | 7.27 | sd 0.07 | 7.16 | sd 0.1 | <0.0001 |
| $PCO_2$ (mean, sd) | 69 | sd 14.6 | 74 | sd 19.5 | 92 | sd 24.9 | 0.0008 |
| Respiratory rate (mean, sd) | 31 | sd 9.4 | 33 | sd 8 | 36 | sd 7.0 | ns |
| Heart rate (mean, sd) | 103 | sd 18 | 113 | sd 23 | 125 | sd 20 | 0.01 |
| *Outcomes* | | | | | | | |
| $2^0$ intubation (N, %) | 3 | (17%) | 8 | (16%) | Not applicable | | ns |
| Death (N, %) | 1 | (5%) | 3 | (6%) | 6 | (27%) | 0.03 |
| ICU length of stay (mean, sd) | 8.5 | sd 5.6 | 5.7 | sd 3.4 | 11.4 | sd 6.3 | <0.0001 |

NOTE: $2^0$ intubation is defined as intubated in the ICU after failing medical therapy or CPAP.
**Abbreviations Tables 1–5:** CPAP, continuous positive airway pressure; $FEV_1$, forced expiratory volume in one second; ICU, intensive care unit; ns, not significant.

**Table 2** Baseline and ICU admission characteristics as well as outcomes of patients with COPD and acute respiratory failure admitted to the general medical ICU in another hospital in 1991–1995, compared with patients receiving CPAP in 1991–1995 in the respiratory ICU in the chest hospital

| **Variables** | **CPAP Respiratory ICU (1991–1995)** | | **Medical General medical ICU (1991–1995)** | | **Intubated General medical ICU (1991–1995)** | |
|---|---|---|---|---|---|---|
| Number of patients | | 49 | | 26 | | 65 |
| *Baseline characteristics* | | | | | | |
| Age (mean, sd) | 67.1 | sd 8.9 | 71.4 | sd 8.7 | 69.4 | sd 8.5 |
| Male (N %) | 26 | (53%) | 9 | (35%) | 31 | (48%) |
| Baseline $FEV_1$ (mean, sd) | 0.68 | sd 0.2 | 0.86 | sd 0.34** | 0.81 | sd 0.5* |
| Home $O_2$ (N %) | 14 | (28%) | 2 | (8%) | 14 | (21%) |
| *ICU admission characteristics* | | | | | | |
| Cause of exacerbation | | | | | | |
| Bronchitis (N %) | 32 | (65%) | 20 | (77%) | 51 | (80%) |
| Pulmonary edema (N %) | 5 | (10%) | 3 | (11%) | 2 | (3%) |
| Pneumonia (N %) | 12 | (25%) | 3 | (11%) | 11 | (17%) |
| Transfer from | | | | | | |
| Ward (N %) | 29 | (59%) | 12 | (46%) | 21 | (32%) |
| Emergency department | 20 | (41%) | 14 | (54%)* | 44 | (68%)*** |
| Admission blood gases | | | | | | |
| pH (mean, sd) | 7.27 | sd 0.07 | 7.31 | sd 0.09 | 7.24 | sd 0.1 |
| $PCO_2$ (mean, sd) | 74.6 | sd 19.5 | 66.6 | sd 23 | 78.8 | sd 27 |
| Respiratory rate (mean, sd) | 33 | sd 8 | 33 | sd 10 | 33 | sd 10 |
| Heart rate (mean, sd) | 114 | sd 23 | 112 | sd 20 | 116 | sd 23 |
| *Outcomes* | | | | | | |
| $2^0$ intubation (N %) | 8 | (16%) | 14 | (52%)*** | Not applicable | |
| Deaths (N %) | 3 | (6%) | 5 | (18%)* | 23 | (35%)*** |
| ICU days (mean, sd) | 5 | (3) | 7 | (6) | 7 | (3)* |

NOTE: $2^0$ intubation: defined as intubated in the ICU after failing medical therapy or CPAP. P-value for test of significance of differences between medical or intubated patients vs CPAP treated group: *p=0.05–0.09 **p<0.01 ***p<0.001.

on vital signs and arterial blood gases at the time of ICU admission, the CPAP-treated group appeared to be more severely ill than the medically treated patients, but had similar mortality and secondary intubation rates, and shorter length of stay. Patients who were intubated were most severely ill, had higher mortality, and longer lengths of stay.

Patients treated with CPAP in the respiratory ICU had somewhat worse baseline status than the 91 COPD patients admitted with acute respiratory failure to the general medical ICU, where neither CPAP nor other forms of non-invasive ventilation were being used between 1991 and 1995 (Table 2). Despite this, and despite having somewhat better ICU admission blood gases and vital signs, the 26 medically treated patients in the general ICU were more likely to require intubation, to die, and to stay longer in the ICU than the CPAP-treated patients in the respiratory ICU.

Between January 1st, 1985, and December 31st, 1988, 58 patients with COPD were admitted to the respiratory ICU with acute respiratory failure. The 27 patients treated medically, and the 31 initially intubated, had remarkably similar baseline and ICU admission characteristics as the patients treated with CPAP in the same ICU in 1991–1995 (Table 3). However, secondary intubation for those treated medically, as well as mortality and length of stay for all patients in 1985–1988, were significantly worse than for the CPAP-treated patients.

As shown in Table 4, after adjusting for baseline and ICU admission characteristics using multivariate analysis, initial intubation and medical therapy were associated with significantly increased risk of death compared with CPAP therapy. Other factors significantly associated with mortality were older age, lower $FEV_1$, and transfer from an inpatient unit, rather than the emergency department. In multivariate analysis, failure of initial therapy requiring intubation was associated with initial medical therapy (rather than CPAP therapy) and transfer from an inpatient unit (after medical therapy).

**Table 3** Baseline and intensive care unit (ICU) admission characteristics as well as outcomes of patients with COPD and acute respiratory failure admitted to the respiratory ICU in 1985–1988, compared with patients receiving CPAP in 1991–1995 in the same ICU

| Variables | CPAP Respiratory ICU (1991–1995) | | Medical Respiratory ICU (1985–1988) | | Intubated Respiratory ICU (1985–1988) | |
|---|---|---|---|---|---|---|
| Number of patients | 49 | | 27 | | 31 | |
| *Baseline characteristics* | | | | | | |
| Age (mean, sd) | 67.1 | sd 8.9 | 68.3 | sd 7 | 70.6 | sd 8.3 |
| Male (N, %) | 26 | (53%) | 14 | (53%) | 17 | (56%) |
| Baseline $FEV_1$ (mean, sd) | 0.68 | sd 0.2 | 0.76 | sd 0.31 | 0.68 | sd 0.25 |
| Home $O_2$ (N, %) | 14 | (28%) | 11 | (41%) | 11 | (31%) |
| *ICU admission characteristics* | | | | | | |
| Cause of exacerbation | | | | | | |
| Bronchitis (N, %) | 32 | (65%) | 13 | (48%) | 20 | (65%) |
| Pulmonary edema (N, %) | 5 | (10%) | 7 | (26%) | 5 | (16%) |
| Pneumonia (N, %) | 12 | (25%) | 7 | (26%) | 6 | (19%) |
| Transfer from | | | | | | |
| Ward (N, %) | 29 | (59%) | 12 | (44%) | 21 | (68%) |
| Emergency department (N, %) | 20 | (41%) | 15 | (56%) | 10 | (32%) |
| Arterial blood gases | | | | | | |
| pH (mean, sd) | 7.27 | sd 0.07 | 7.29 | sd 0.08 | 7.25 | sd 0.07 |
| $PCO_2$ (mean, sd) | 74.6 | sd 19.5 | 75 | sd 19 | 83 | sd 20* |
| Respiratory rate (mean, sd) | 33 | sd 8 | 33 | sd 7 | 36 | sd 8 |
| Heart rate (mean, sd) | 114 | sd 23 | 113 | sd 22 | 118 | sd 15 |
| *Outcomes* | | | | | | |
| $2^0$ intubation (N, %) | 8 | (16%) | 20 | (77%)** | Not applicable | |
| Death (N, %) | 3 | (6%) | 6 | (23%)* | 14 | (37%)*** |
| ICU length of stay (mean, sd) | 5 | (3) | 8 | (9) | 12 | (9)*** |

NOTE: $2^0$ intubation: defined as intubated in the ICU after failing medical therapy or CPAP. P-value for test of significance of differences between medical or intubated patients vs CPAP treated group: *p=0.06 **p<0.01 ***p<0.001.

**Table 4** Adjusted odds of death or secondary intubation from multivariate logistic regression

| Variable (comparison) | Death OR | Death (95% CI) | Secondary intubation OR | Secondary intubation (95% CI) |
|---|---|---|---|---|
| Number of patients | | (237)[a] | | (119)[a] |
| Older age (per increase of 5 years) | 1.2 | (1.0, 1.5) | 1.1 | (0.8, 1.5) |
| Gender (male vs female) | 2.5 | (1.2, 5.0) | 1.0 | (0.4, 2.7) |
| Baseline $FEV_1$ (increase of 200 mL) | 0.7 | (0.5, 0.9) | 1.3 | ( 0.9, 1.9) |
| On home oxygen therapy (vs not) | 0.7 | (0.3, 1.5) | 0.6 | (0.2, 1.8) |
| Transfer to ICU from ward (vs from ER) | 2.8 | (1.4, 5.5) | 3.1 | (1.1, 8.8) |
| Initial therapy (medical vs CPAP) | 4.8 | (1.2, 20.2) | 5.6 | (1.8, 17) |
| (intubated vs CPAP) | 14.5 | (3.7, 57) | – | – |
| Lower admission pH (per decrease of 0.05) | 1.0 | (0.8, 1.2) | 1.1 | (0.8, 1.4) |
| ICU (respiratory vs general medical) | 0.9 | (0.4, 1.8) | 0.2 | (0.1, 0.8) |

[a] All patients included in analysis of factors associated with mortality, but only patients initially treated with CPAP or medical therapy included in analysis of factors associated with secondary intubation (ie, failure of primary therapy).
**Abbreviations:** CI, confidence interval; ER, emergency room; OR, odds ratio.

Eight patients failed CPAP and were intubated: 4 after 1–2 hours, and the remainder after 12–24 hours. CPAP failure was associated with pneumonia, less improvement in tachycardia and arterial blood gas abnormalities after one hour of CPAP (Table 5), and poor tolerance. Three of the 5 (60%) who could not tolerate CPAP required intubation,

**Table 5** Baseline and ICU admission characteristics as well as course in ICU among patients treated with CPAP: comparing those who required intubation (failed CPAP) with those who did not (success)

| Variables | Failed CPAP | | CPAP success | | p-value |
|---|---|---|---|---|---|
| Number of patients | | 8 | | 41 | |
| *Baseline characteristics* | | | | | |
| Age | 65.1 | sd 8 | 68.1 | sd 9 | ns |
| Male | 6 | (75%) | 20 | (49%) | ns |
| Baseline $FEV_1$ | 0.75 | sd 0.26 | 0.67 | sd 0.22 | ns |
| Home oxygen therapy | 2 | (25%) | 12 | (29%) | ns |
| *ICU admission characteristics* | | | | | |
| Cause of respiratory failure | 3 | (37%) | 29 | (70%) | |
| Bronchitis | 0 | | 5 | (13%) | |
| Pulmonary edema | 5 | (62%) | 7 | (17%) | 0.02 |
| Pneumonia | | | | | |
| Transfer to ICU from | | | | | |
| Ward | 6 | (75%) | 21 | (51%) | |
| Emergency department | 2 | (25%) | 18 | (44%) | ns |
| Arterial blood gases | | | | | |
| pH | 7.3 | sd 0.04 | 7.27 | sd 0.07 | ns |
| $PCO_2$ | 73 | sd 22 | 74 | sd 19 | ns |
| Respiratory rate | | | | | |
| Heart rate | 34 | sd 7 | 33 | sd 8 | ns |
| | 119 | sd 17 | 111 | d 23 | ns |
| *Course in ICU and outcomes* | | | | | |
| Did not tolerate CPAP | 3 | (37%) | 2 | (5%) | 0.025 |
| Change after 1 hour in: | | | | | |
| Arterial pH | –0.02 | sd 0.04 | 0.06 | sd 0.01 | 0.004 |
| Arterial $PCO_2$ | +5 | sd 8.8 | –11.2 | sd 10.7 | 0.005 |
| Respiratory rate | –3 | sd 9 | –5 | sd 6 | ns |
| Heart rate | +2 | sd 7 | –4 | sd 17 | ns |
| Deaths | 2 | (25%) | 1 | (2.5%) | 0.001 |

compared with 5 of the 44 who did tolerate it (11%). Two of the CPAP failures (25%) died, compared with only one of the 41 (2.5%) who did not require intubation.

## Discussion

As a result of several randomized controlled trials demonstrating reduced need for intubation and lower mortality (Bott et al 1993; Brochard et al 1995; Kramer et al 1995; Angus et al 1996; Plant et al 2000), non-invasive bilevel positive pressure ventilation (BIPAP) is now considered standard therapy for acute respiratory failure in COPD patients. In our experience, mask CPAP was safe, well tolerated, and had similar outcomes and effectiveness (relative to medical therapy) as the bilevel non-invasive ventilation interventions in randomized trials. As well, mortality was much lower among CPAP-treated patients than intubated patients, after adjustment for potentially confounding clinical differences.

Although limited by its retrospective observational design, strengths of the study include the examination of all patients with COPD and acute respiratory failure treated over several years at two hospitals. A large number of potential confounders were measured and adjusted for in multivariate analysis, findings were consistent in all patient groups, and our results are similar to other published results (Brochard et al 1995). Inclusion of COPD patients with all causes of acute respiratory failure should enhance generalizability (Benson and Hartz 2000). Differences in premorbid and acute illness disease severity can be controlled by randomly assigning modality, as in published randomized trials, or, if measured, can be controlled in the analysis, with multivariate techniques. There were significant differences in patients' characteristics, particularly in the cohort with access to mask CPAP, reflecting selection of modality according to disease severity. Multivariate analysis was therefore used to estimate the effect of CPAP after controlling for other variables associated with mortality, such as age (Heuser et al 1992), baseline $FEV_1$ (Menzies et al 1989), severity of presentation (Portier 1992), and location prior to ICU admission (Seneff et al 1995). Even with this adjustment, outcomes were consistently better among the patients treated with non-invasive CPAP ventilation compared with patients in all 3 cohorts who were initially treated with medical therapy or were intubated.

The CPAP-treated patients in this study had very similar baseline and ICU admission characteristics as the patients randomized to non-invasive ventilation in the largest previously published trials (Brochard et al 1995; Plant et al 2000). In these same studies, mortality and secondary intubation rates in the intervention groups were 9% and 26% (Brochard et al 1995), and 10% and 15%, respectively (Plant et al 2000), which are very similar to the rates of mortality and intubation among the CPAP-treated patients. From a meta-analysis, non-invasive bilevel ventilation was associated with significantly lower rates of intubation (OR 0.12; 95% CI 0.05–0.29) (Keenan 2000) and lower mortality (meta-analysis – OR 0.22; CI 0.09–0.54) (Keenan et al 1997), compared with medical therapy alone. These improvements in outcomes relative to medically treated patients are also similar to the adjusted odds ratios in CPAP treated patients in this study.

Nevertheless, these findings must be interpreted with caution because of several important limitations. These include the retrospective design, the time period of study, potential selection bias, and differences in outcomes due to temporal or inter-institutional differences in patients and/or their care. The retrospective design meant that certain factors may have been associated with outcomes because they influenced outcomes and were not truly independent predictors. For example, the association of CPAP failure with worse arterial pH after one hour may have reflected the direct influence these blood gas results had on the physicians' decision to intubate.

In the respiratory ICU between 1991 and 1995, the decision to use CPAP was not made randomly, but rather patients were carefully selected. This is evident from the differences in ICU admission blood gases and vital signs. This was why CPAP-treated patients were also compared with patients treated in the same years at another ICU in a different hospital where CPAP was not available. Although such a comparison might be hampered by systematic differences in the patient populations, the clinical characteristics of the two groups of patients were very similar. However, other inter-institutional differences, such as the threshold for intubation, or experience in the care of COPD patients, were not measured and may have also influenced outcomes. This problem was addressed by use of a historical comparison population, ie, patients admitted to the same respiratory ICU in earlier years. This approach also has limitations because mortality from acute respiratory failure in COPD patients decreased over the ten years spanned by this study (Weiss and Hudson 1994). Therefore, some of the apparent benefit of CPAP could have been due to other changes in treatment between 1985–1988 and 1991–1995, such as decreased use of theophylline and increased use of gastric protection.

In the previously published studies of non-invasive ventilation (Bott et al 1993; Brochard et al 1995; Kramer et al 1995; Angus et al 1996; Plant et al 2000), patients who were intubated were excluded and their outcomes were not reported. The finding that mask CPAP had substantially lower mortality than intubated patients, after adjustment for markers of severity of acute illness, is of considerable interest. This suggests intubation may confer an added risk for worse outcomes in this population.

CPAP alone is effective for acute pulmonary edema (Bersten et al 1991) and was effective in this study for the few patients with COPD who also had pulmonary edema. In one study of patients with acute hypoxemic respiratory failure, CPAP did not appear to improve outcomes compared with oxygen only (Delclaux et al 2000). In another randomized controlled trial among 101 patients with various causes of acute respiratory failure, outcomes with CPAP or BIPAP were similar (Cross et al 2003). Also in two randomized controlled trials in patients with pulmonary edema there was no benefit of BIPAP over CPAP (Brochard et al 1995; Kramer et al 1995; Mehta et al 1997; Bellone et al 2005). A randomized trial comparing mask CPAP with other forms of non-invasive ventilation in COPD would be of great interest. This could clarify the mode of non-invasive respiratory assistance that is best tolerated, simplest, and most cost-effective for COPD patients with acute respiratory failure.

Given the evidence of safety, tolerability, and effectiveness of other forms of non-invasive ventilation (Meduri et al 1996; Keenan et al 1997, 2000; Sinuff et al 2000), what might be the potential advantages of CPAP? Mask CPAP is simple to administer, requires no synchronization of machine to patient, and the equipment is inexpensive. In our setting, the equipment for mask CPAP costs less than Can$1000, compared with $10 000–$20 000 for BIPAP equipment such as the BIPAP Vision (Respironics, CA, USA). It is important to point out that the CPAP system used in this study differed from the CPAP systems used for patients with obstructive sleep apnea.

In summary, CPAP applied non-invasively was tolerated in 90% of patients and had no major complications. After adjustment for potential confounders, this approach was associated with significantly reduced rates of intubation and mortality in COPD patients with acute respiratory failure. In these patients, mask CPAP may be a useful alternative mode of non-invasive respiratory assistance.

## Acknowledgments

The authors thank Dr Yoanna Skrobik for facilitating access to the medical records of patients in the general medical ICU; Kim Danovitch and Naomi Kerner for assistance in data gathering; and Catherine Michaud for secretarial assistance.

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