# Effects of Acute on Chronic Respiratory Failure on Hypercapnia and 3-Month Survival*

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***Background:*** **There is a lack of information on respiratory function and mechanics after COPD exacerbations.**
***Study objectives:*** **To find their role in short-term survival and occurrence of chronic hypercapnia after these events.**
***Patients and interventions:*** **Seventy-three COPD patients recovering from a recent severe exacerbation underwent evaluation of breathing pattern, breathing mechanics, lung function, and arterial blood gas levels at the time of discharge from a respiratory ICU (RICU).**
***Results:*** **The 3-month mortality rate after RICU discharge was 11%. The percent of ideal body weight (%IBW) [*R* = 6.04; p = 0.01] and occlusion pressure (*R* = 5.41; p = 0.02) provided significant distinction between deceased patients and survivors; the final discriminant equation showed that %IBW was able to predict patient death or survival with an accuracy of 90%. With decreasing order of power, the ratio of inspiratory time to total breathing cycle time (TI/TTOT) [*R* = 8.87; p = 0.003], pressure-time product of the inspiratory muscles (*R* = 7.12; p = 0.009), maximal esophageal pressure (*R* = 6.00; p = 0.01), esophageal pressure (*R* = 5.50; p = 0.02), $Pao_2$/fraction of inspired oxygen (*R* = 4.72; p = 0.03), and pressure time index (PTI) [*R* = 4.57; p = 0.03] provided a significant distinction between hypercapnia and normocapnia at discharge. The discriminant equation, including TI/TTOT and PTI, could correctly separate hypercapnic or normocapnic patients with an accuracy of 76%.**
***Conclusions:*** **In COPD patients who are recovering from a severe exacerbation, hypercapnia is strongly related to inspiratory muscle work, strength, and breathing pattern; and only body weight predicts short-term survival.** ***(CHEST 2005; 128:1209–1215)***

**Key words:** acute exacerbations of COPD; lung function; respiratory failure; respiratory muscles

**Abbreviations:** ECOPD = exacerbation of COPD; %IBW = ideal body weight percentage; NPPV = noninvasive positive-pressure ventilation; PEmax = maximal expiratory pressure; Pes = esophageal pressure; Pesmax = maximal esophageal pressure; PImax = maximal inspiratory pressure; PTI = pressure time index; PTPmin = pressure-time product minimum; RICU = respiratory ICU; TI = inspiratory time; TTOT = total breathing cycle time

The role of physiologic and clinical parameters, such as age,[1] respiratory function,[1–3] malnutrition,[4] activity of daily life,[4] or a recent multidimensional grading system, including body mass index, airflow obstruction, dyspnea, and exercise capacity,[5] has been evaluated to predict the natural history of COPD. It has also been shown[6] that the probability of developing chronic hypercapnia in severe, stable COPD increases with the severity of airway obstruction, obesity, and inspiratory muscle weakness. Malnutrition and the degree of airway obstruction were also associated with the failure of medical treatment and the related need for mechanical ventilation in severe exacerbations of COPD (ECOPDs).[7] ECOPDs are frequent complications of the disease that may lead to acute respiratory failure and an associated high prevalence of reversible hypercapnia.[8] Stable hypercapnia is often proposed as a negative prognostic factor for survival after discharge from an ICU, whereas "reversible" hypercapnia is associated with a similar prognosis to the prognosis of COPD patients undergoing nonhypercapnic acute

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Manuscript received December 7, 2004; revision accepted February 8, 2005.
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respiratory failure.[9] Critically ill patients with prolonged ICU stays may sometime present unplanned ICU readmission or even unexpected death.[10] For this reason, strict clinical surveillance and monitoring of respiratory muscle function is recommended[10] after patients are discharged from an ICU to the general ward. At the same time, after hospital discharge, the need for monitoring of hypercapnia, exacerbations with risks of death, or readmission to the ICU for COPD patients with therapeutic tools, such as comprehensive rehabilitation programs[11] and, eventually, with long-term domiciliary mask ventilation,[12] appears of great interest.

On the other hand, the role of respiratory muscles and mechanics in predicting the short-term survival and the presence of hypercapnia after a severe ECOPD needing a respiratory ICU (RICU) admission has been less studied. The aims of this study were as follows: (1) to measure breathing pattern, mechanics, lung function, and arterial blood gases in COPD patients recovering from a recent severe ECOPD; (2) to find an equation, if any, to discriminate chronic hypercapnic patients; and (3) to evaluate the predictive factors of 3-month survival immediately before RICU discharge.

## Materials and Methods

The investigative protocol was approved by the Institutional Ethics Committee of the Salvatore Maugeri Foundation and was conducted according to the Declaration of Helsinki. Informed consent was obtained from all of the patients before their enrollment into the study.

### *Patients*

This article reports on the results of a prospective, observational study that was carried out on patients known to be affected with COPD from January 1, 1995, to January 1, 1996. The diagnosis of COPD was according to the American Thoracic Society criteria[13] based on the clinical history, physical examination, chest radiograph, and previous pulmonary function tests. Consecutive COPD patients who were discharged from the RICU of the Salvatore Maugeri Foundation in Gussago, Italy, were studied. The RICU of the Salvatore Maugeri Foundation is an ICU located in a rehabilitation hospital, which is a referral rehabilitation and chronic care center for a large geographic area in northern Italy. Among others, difficult-to-wean tracheotomized patients are also admitted to this institution to undergo either a program of progressive discontinuation from mechanical ventilation or to be discharged to a home program of long-term ventilatory assistance, if weaning from the ventilator fails. In addition, patients undergoing episodes of acute on chronic respiratory failure are admitted for treatment by noninvasive positive-pressure ventilation (NPPV).

Among the 110 patients admitted to our RICU in the study period, 27 (cardiosurgical sequelae, 11 patients; neuromuscular disease, 7 patients; neurologic disease, 6; ARDS, 3 patients) were non-COPD patients. Four COPD patients were excluded from the study because of concomitant cancer, and six were excluded because they refused evaluations. A total of 73 COPD patients were studied. No patients asked for a do-not-resuscitate order to be implemented during their RICU or hospital stay or during the 3 months of follow-up.

At the time of evaluation (1 to 3 days before RICU discharge), all of the patients had recovered from their exacerbation for $\geq 8$ days (range, 8 to 21 days). They were in stable conditions as assessed by the following methods: (1) arterial pH $> 7.35$ during spontaneous breathing with an inspiratory oxygen fraction that was able to maintain arterial oxygen saturation $> 90\%$; (2) absence of severe dyspnea or signs of respiratory distress-like abdominal paradox, use of accessory muscles, ratio of respiratory frequency to tidal volume $< 95$; and (3) hemodynamic stability (systolic arterial BP $> 100$ and $< 150$ mm Hg, with no need for IV vasopressor drugs); and (4) no use of nocturnal mechanical ventilation on the night before the RICU discharge.

### *Causes of RICU Admission*

Twenty-four of 73 patients (33%) were difficult-to-wean tracheotomized patients. These 24 patients had been transferred to our RICU from the ICUs of other hospitals, because the caring physicians classified them as difficult-to-wean after some weaning attempts had failed and a tracheotomy had been performed. The causes of acute respiratory failure and consequent ICU admission were pneumonia in 10 patients, COPD exacerbation in 12 patients, and cardiogenic pulmonary edema in 2 patients. The time that elapsed from intubations to tracheotomy ranged from 6 to 10 days. The time from intubation to RICU admission ranged from 10 to 27 days. The weaning modalities were spontaneous breathing trial or decreasing levels of inspiratory pressure support, as described elsewhere.[14]

The other 49 patients (67%) had been treated in our RICU during an episode of acute respiratory failure. The causes of acute respiratory failure were pneumonia in 12 patients, ECOPD without pneumonia in 30 patients, cardiogenic pulmonary edema in 4 patients, and severe arrhythmia in 3 patients. Among these 49 patients, 4 were intubated in our RICU and successfully extubated, 23 patients were successfully treated with NPPV, and the other 22 patients were treated only with standard medical therapy.

In summary, 51 of 73 patients (70%) had been ventilated for a period of 4 to 15 days. Mechanical ventilation had been withdrawn 8 to 12 days before their enrollment into the study. Twenty patients (27%) were still tracheotomized, but they were breathing spontaneously at the time of the study.

The medical treatment of ECOPD had consisted of systemic steroids (76% of patients), inhaled bronchodilators (100%), and oxygen (100%). In their stable condition before the ECOPD, all of the patients were receiving treatment with inhaled bronchodilators but no with systemic or inhaled steroids. In their stable state before ECOPD, 69% of the patients were receiving long-term oxygen therapy, whereas 10.5% were receiving domiciliary long-term mechanical ventilation (90% with mask positive-pressure ventilation and the remaining through tracheotomy). Table 1 shows the RICU admission data for the patients in our study.

### *Measurements and Monitoring*

The following data were recorded: anthropometrics, nutritional status (percentage of ideal body weight [%IBW] and body mass index), percentage of patients needing mechanical ventilation (either invasive or noninvasive), ICU and hospital length of stay, and 3-month mortality rate.

One to 3 days before RICU discharge, all of the patients underwent the following measurements. For lung and respiratory

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