International Journal of COPD

Dovepress
open access to scientific and medical research

Open Access Full Text Article

ORIGINAL RESEARCH

Can dead space fraction predict the length of mechanical ventilation in exacerbated COPD patients?

This article was published in the following Dove Press journal:
International Journal of COPD
24 November 2009
Number of times this article has been viewed

Raymond Farah[1]
Nicola Makhoul[2]

[1]Specialist in Internal Medicine and Nephrology, Department of Internal Medicine B, Ziv Medical Center, Safed-Israel; [2]Director of Respiratory Intensive Care Unit, Western Galilee Hospital, Nahariya, Israel

Background: Chronic obstructive pulmonary disease (COPD) is a condition in which there is limited airflow during expiration (exhaling, or breathing out) that is not fully reversible and usually worsens over time. The disease is estimated to kill more than 100,000 Americans each year, and costs related to care of patients with COPD are significant. Physiologically, COPD represents a disruption in ventilation and in the exchange of gases in the lungs. Laboratory tests indicate elevated CO_2 levels, gradual reduction of the levels of oxygen and pH in arterial blood, and a consequent rise in the dead space fraction (DSF) of the lungs.

Objective: Patients with COPD exacerbation represent a large portion of those artificially ventilated. In an attempt to develop a prognostic tool for length of treatment, we compared the proportion of DSF to the length of mechanical ventilation (MV).

Methods: This study included 73 patients admitted to the intensive care unit (ICU) where they received MV due to exacerbation of COPD. Each patient's arterial blood gases (ABG) were measured upon admission. $PeCO_2$ was tested using a Datex S/5 instrument. Subsequently, DSF was calculated using the Bohr equation. Statistical data was analyzed using SPSS software.

Results: Patients included in the study were ventilated from 6 to 160 hours (average 40 ± 47). In addition to ABG measurements, $PeCO_2$ (expired CO_2) levels were measured and DSF calculated for each patient. DSF values varied from 0.21 to 0.76 (average 0.119 ± 0.489). No correlation was found between DSF and length of artificial ventilation.

Conclusion: Evaluation of DSF does not provide a factor in estimating the length of treatment for patients with acute respiratory failure due to COPD exacerbation.

Keywords: dead space, weaning, mechanical ventilation, COPD

Introduction

Chronic obstructive pulmonary disease (COPD) is a leading cause of worldwide disability and mortality. An average of 5%–15% of adults in industrialized countries have COPD defined by clinical symptoms and spirometry.[1–3] In 1990, COPD was ranked twelfth worldwide as a cause of combined disability and mortality but is expected to rise to fifth by the year 2020. COPD has a chronic long-lasting course characterized by irreversible decline of forced expiratory volume in one second (FEV_1), increasing presence of dyspnea and other respiratory symptoms, and progressive deterioration of health status. After diagnosis the 10-year survival rate is approximately 50% with more than one-third of patients dying due to respiratory insufficiency.[2] The etiology of COPD is overwhelmingly dominated by smoking although many other factors can play a role. Particular genetic variants are likely to increase the susceptibility to environmental factors although little is known about which are the relevant genes.

Correspondence: Raymond Farah
Herzel St. 122/7 Nahariya 22448,
Department Head of Internal Medicine B,
Ziv Medical Center,
PO Box 1008, Safed 13110, Israel
Tel +972 4 682 8946
Fax +972 4 682 8116
Email raymond.f@ziv.health.gov.il

Although there is accumulating evidence that oxygen therapy, pharmacological treatment and rehabilitation may improve the course of COPD, abstaining from smoking continues to be the most relevant measure, not only in preventing COPD, but also in arresting its development.[4–6]

The admission of COPD exacerbation patients to an intensive care unit (ICU) is common, as 26%–74% of them need mechanical ventilation (MV). Few studies have been conducted to assess the value of physiological factors as a weaning predictor. The recording of dead space will give information on how much total ventilation reaches both ventilated and perfused alveoli and thus allows gas exchange between alveoli and pulmonary blood. CO_2 retention can be a result not only of low total ventilation but also of increased dead space. Correct measurement and calculation of the dead space will give valuable information on the ventilatory support of the critically ill patient and can also be a valuable diagnostic tool. It should therefore not be forgotten in the intensive care setting. The aim of this study was to assess whether the length of MV in patients with COPD exacerbation can be predicted by the measurement of dead space fraction (DSF).

Patients and methods

This study was conducted in the respiratory ICU of Nahariya Hospital during an eight-month period (from September 2007–May 2008). Seventy-three patients (52 males 71%; 21 females, 29%) with a history and clinical findings of COPD who were admitted to the respiratory ICU with respiratory failure due to COPD exacerbation and needed MV were eligible for the study. All these patients had not responded to noninvasive ventilation and were intubated before their admission to the ICU. Data were collected in all patients requiring MV; criteria used were similar to the GOLD guidelines for intubations.[7] The following information was recorded: age, gender, smoking history, co-morbidity, pulmonary function tests. Age range was 40 to 96 years, with mean age 70 years (standard deviation [SD] ± 11).

The institutional committee in accordance with the Helsinki declaration approved an informed consent for blood sampling and signed informed consent by the patients. COPD exacerbation was clinically evaluated and diagnosed according to known criteria (exacerbation of cough, purulent sputum production, severe dyspnea and negative response to bronchodilators).[1,7] Radiological imaging showed no signs of pneumonia or congestive heart failure. Each patient's arterial blood gases (ABG) were measured upon admission and ECG was performed, as were arterial blood gas measurements. $PeCO_2$ was tested using a Datex S/5 instrument. Subsequently DSF was calculated for each patient using the Bohr equation: $DSF = (PaCO_2 – PeCO_2)/PaCO_2$ with normal value less than 0.3,[8,9] where $PeCO_2$ is the partial pressure of carbon dioxide in mixed expired gas and is equal to the mean expired carbon dioxide fraction multiplied by the difference between the atmospheric pressure and the water-vapor pressure. All patients were under cardiac and respiratory monitoring (heart rate, respiratory rate, O_2 saturation and $PeCO_2$). All patients received treatment with bronchodilators, corticosteroids and sedative therapy such as propofol.

Statistical analysis

Statistical analysis was performed using SPSS software (v. 11; SPSS Inc, Chicago, IL, USA).

Data are expressed as mean ± standard error of mean. Differences in mean values were tested by two-way analysis of variance (ANOVA) and by the Bonferroni Multiple comparison test, using Prism version 3.0 statistical software (GraphPad, San Diego, CA, USA). Correlations between different study parameters were performed alone using Pearson correlation coefficients. $P < 0.05$ was considered significant.

Results

The clinical and biochemical parameters of ventilated patients with COPD exacerbation on admission are depicted in Table 1, and the correlation of the data shown in Table 2.

The duration of MV was between 6 and 160 hours, mean 47 ± 40. Most of the patients were weaned from MV by 70 hours (82%); 33 of the patients (67.3%) were weaned from MV within 24 hours.

Table 1 Summary of all results

	Values	Results
Gender	Male	52 (71.4%)
	Female	29 (28.6%)
Age (Year)	Mean (Std)	70.6
pH	Mean (Std)	7.15 ± 0.08
PaO_2 mmHg	Mean (Std)	91.47 ± 60.25
$PaCO_2$ mmHg	Mean (Std)	90 ± 16
Bicarbonate mEq/l	Mean (Std)	30.8 ± 6.68
O_2 – Saturation %	Mean (Std)	86.2 ± 10.9
$PeCO_2$ mmHg	Mean (Std)	45.0 ± 11.29
Respiratory rate	Mean (Std)	18.18 ± 7.9
DSF	Mean (Std)	0.49 ± 0.12
Duration of MV (Hours)	Mean (Std)	47.39 ± 40.07

Notes: This table shows the mean of 73 patients' parameters on admission to intensive care unit (all of them on MV) and the duration of MV in hours.
Abbreviations: DSF, dead space fraction; MV, mechanical ventilation; O_2, oxygen saturation in arterial blood; PaO_2, partial pressure of oxygen in arterial blood; $PaCO_2$, partial pressure of carbon dioxide in arterial blood.

Table 2 The correlations between parameters

			pH	$PaCO_2$	DSF	Hours
Spearman's rho	pH	R	1.000	–0.405**	–0.387**	0.205
		P (1-tailed)	–	0.002	0.003	0.079
		N	73	73	73	73
	$PaCO_2$	R	–0.405**	1.000	0.367**	0.110
		P (1-tailed)	0.002	–	0.005	0.226
		N	73	73	73	73
	DSF	R	–0.387**	0.367**	1.000	–0.024
		P (1-tailed)	0.003	0.005	–	0.434
		N	73	73	73	73
	Hours	R	0.205	0.110	–0.024	1.000
		P (1-tailed)	0.079	0.226	0.434	–
		N	73	73	73	73

Notes: *Spearman correlation coefficient test. **Correlation is significant at the 0.01 level (one-tailed). There is correlation between DSF and $PaCO_2$ and pH but there is no correlation between DSF and duration of MV in COPD patients.
Abbreviations: COPD, chronic obstructive pulmonary disease; DSF, dead space fraction; MV, mechanical ventilation; $PaCO_2$, partial pressure of carbon dioxide in arterial blood.

pH

Value of blood pH from all patients varied between 6.98–7.28 (mean 7.15 ± 0.08). There was no correlation between pH value and the duration of MV, and statistically was not significant ($P = 0.179$). Patients with very low PH were weaned within 5–7 hours from MV and vice versa.

PaO_2

Arterial PO_2 was 33–395 mmHg (mean 91 ± 60). Patients were ventilated with a different O_2 concentration to maintain acceptable blood PaO_2 and O_2 saturation (86%).[10] During the initial period of admission O_2 saturation was 56%–99% (mean 86 ± 11).

$PaCO_2$

$PaCO_2$ was between 52–126 mmHg (mean 90 ± 16). There was no correlation between these values and the duration of mechanical ventilation.

$PeCO_2$

This tool gives us a picture of the ventilated lung; high values indicate poor lung ventilation that requires prolonging the mechanical ventilation period. $PeCO_2$ was measured in all patients in the study using a Datex S/5 instrument; the values in this study were 25–70 (mean 45 ± 11).

DSF

Using the Bohr equation the average DSF in our study varied from 0.22 to 0.74 (average 0.489 ± 0.119) while the normal values are usually less than 0.3. There is an inverse relationship between the changes in DSF compared to blood acidosis level, ($P = 0.004$) considered statistically significant. A low level of DSF means a higher PH level, but when the acidosis is near normal range the DSF level is also near normal. There was good correlation between DSF and $PaCO_2$, ($P = 0.009$) considered statistically significant.

Our results show that no correlation was found between DSF and length of artificial ventilation, these findings do not contribute to the evaluation of the patient's condition nor do they enable us to predict the length of mechanical ventilation ($P = 0.295$).

Discussion

Patients with COPD may require mechanical ventilation for the treatment of respiratory failure during acute exacerbations. Usually we try to treat these patients with noninvasive positive pressure ventilation that should always be considered when there is a need for ventilation assistance, as indicated by such symptoms as worsened dyspnea, acute respiratory acidosis and worsened oxygenation (eg, ratio of PaO_2 of the fraction of inspired oxygen of less than 200), are Those patients with respiratory arrest, any medical instability or hypotensive shock as our selected patients in the study are unlikely to benefit from non-invasive ventilation. The major physiologic defects in COPD are increased dead space, severe ventilation-perfusion misdistributions, marked airflow limitation, air trapping, and hyperinflation. Such defects frequently result in poor oxygenation and hypercapnia. From the initiation of MV the program of weaning must begin, as some patients can be successfully weaned from MV within hours and for others it may take longer, possibly days or weeks.

Prolonged MV, especially in COPD exacerbation patients, yields a poor chance for weaning.[11–13] Complications such as pneumonia are frequently encountered in these patients especially with prolonged MV.[14,15] Other important risk factors for prolonged MV are severity at admission, ventilator-associated pneumonia, sepsis and other microbacterial findings, barotraumas, acute respiratory distress syndrome, cardiovascular and other multiple-organ failure.[16]

Weaning from mechanical ventilation usually implies some closely related aspects of care, discontinuation of mechanical ventilation and removal of any artificial airway. The first problem that the clinician faces is how to determine when a patient is ready to resume ventilation on his or her own. Several studies have shown that a direct method of assessing readiness to maintain spontaneous breathing is simply to initiate a trial of unassisted breathing. Once a patient is able to sustain spontaneous breathing, the artificial airway can be removed. This decision is made on the basis of the patient's mental status, airway protective mechanisms, ability to cough and the amount and the character of secretions and other known criteria. A good number of patients with COPD need reintubation immediately or within a short time after extubation, studies show rates of approximately 13%–19% reintubation within the first 48 hours.[17]

Several studies evaluated the ability to predict the combined outcome of a successful trial of unassisted breathing followed by successful weaning in patients with COPD exacerbation, and predicted the optimal time for extubation and the eventual prognosis without the use of invasive procedures.[18] Few studies have demonstrated the usefulness of simple biochemical and clinical markers that need only some calculations of the $PeCO_2$ concentration and DSF using a simple equation as the Bohr used in our study.[8,9]

Physiologically in COPD there are abnormalities in ventilation and in gas exchange; the consequence would be an increase in physiologic dead space and an impaired ability to excrete carbon dioxide.[9] Lung and cardiovascular diseases can lead to elevation in the pulmonary dead space fraction and consequently to an increase in respiration work and fatigability. These can cause difficulty and failure in the weaning process due to abnormalities in the alveolar dead space more than the anatomical dead space and elevation in the physiologic dead space. Prediction of dead space can be used as an index to estimate successful weaning in ventilated patients; furthermore, it is an objective monitor of pulmonary disease progression.[8] Other studies demonstrated the utility of DSF measurement at the time of diagnosis in patients with acute respiratory distress syndrome (ARDS) and in patients with pulmonary embolism.[9,19] No other studies succeeded in utilizing the measurement of DSF in COPD exacerbation patients as a predictor for weaning from MV. In acute respiratory distress syndrome the DSF was a helpful tool for prognostic information.[1]

In this study the aim was to calculate the DSF and to demonstrate whether this parameter can be useful in determining the prognosis and the optimal time for weaning. We found a good and significant correlation between DSF and $PaCO_2$, an inverse relation between PH and DSF value, PH and $PaCO_2$, and no correlation between DSF and the length of artificial ventilation. These findings do not contribute to the evaluation of the patient's condition nor do they enable us to predict the length of artificial ventilation necessary for patients with acute respiratory failure due to COPD exacerbation. More research is necessary to explore the reasons for differing patient management and outcomes.

Disclosures

The authors report no conflicts of interest in this work.

References

1. Barnes PJ. Chronic obstructive pulmonary disease. *N Engl J Med*. 2000;343(4):269–280.
2. Anto JM, Vermeire P, Vestbo J, Sunyer J. Epidemiology of chronic obstructive pulmonary disease. *Eur Respir J*. 2001;17(5):982–994.
3. Pauwels RA, Buist AS, Calverley PM, Jenkins CR, Hurd SS; GOLD Scientific Committee. Global strategy for the diagnosis, management, and prevention of chronic obstructive pulmonary disease. NHLBI/WHO Global Initiative for Chronic Obstructive Lung Disease (GOLD) Workshop summary. *Am J Respir Crit Care Med*. 2001;163(5):1256–1276.
4. Varsano S, Jacoby I, Garenkin M. Proper use and the ability to teach the use of pressurized hand-held inhalers in patients with chronic airway obstruction. *Harefuah*. 1999;136(1):9–14, 96.
5. Finkelstein R, Fraser RS, Ghezzo H, Cosio MG. Alveolar inflammation and its relation to emphysema in smokers. *Am J Respir Crit Care Med*. 1995;152(5 Pt 1):1666–1672.
6. Saetta M, Di Stefano A, Turato G, et al. CD8 + T-lymphocytes in peripheral airways of smokers with chronic obstructive pulmonary disease. *Am J Respir Crit Care Med*. 1998;157(3 Pt 1):822–826.
7. Asia Pacific COPD Roundtable Group. Global Initiative for Chronic Obstructive Lung Disease strategy for the diagnosis, management and prevention of chronic obstructive pulmonary disease: an Asia-Pacific perspective. *Respirology*. 2005;10(1):9–17.
8. Hardman JG, Aitkenhead AR. Estimation of alveolar deadspace fraction using arterial and end-tidal CO_2: a factor analysis using a physiological simulation. *Anaesth Intensive Care*. 1999;27(5):452–458.
9. Nuckton TJ, Alonso JA, Kallet RH, et al. Pulmonary dead-space fraction as a risk factor for death in the acute respiratory distress syndrome. *N Engl J Med*. 2002;346(17):1281–1286.
10. Murohy R, Driscoll P, O'Driscoll R. Emergency oxygen therapy for the COPD patient. *Emerg Med J*. 2001;18:333–339.
11. Nevins ML, Epstein SK. Predictors of outcome for patients with COPD requiring invasive mechanical ventilation. *Chest*. 2001;119(6):1840–1849.
12. Pierson DJ. Indications for mechanical ventilation in adults with acute respiratory failure. *Respir Care*. 2002;47(3):249–262; discussion 262–265.

13. Vitacca M, Clini E, Porta R, Foglio K, Ambrosino N. Acute exacerbations in patients with COPD: predictors of need for mechanical ventilation. *Eur Respir J*. 1996;9(7):1487–1493.
14. Torres A, Aznar R, Gatell JM, et al. Incidence, risk, and prognosis factors of nosocomial pneumonia in mechanically ventilated patients. *Am Rev Respir Dis*. 1990;142(3):523–528.
15. Kollef MH. The prevention of ventilator-associated pneumonia. *N Engl J Med*. 1999;340(8):627–634.
16. Frutos-Vivar F, Esteban A, Anzueto A, et al; International Study Mechanical Ventilation Group. Prognosis for acute exacerbation of chronic obstructive pulmonary disease in mechanically ventilated patients. *Med Intensiva*. 2006;30(2):52–61.
17. Esteban A, Frutos-Vivar F, Ferguson ND, et al. Noninvasive positive-pressure ventilation for respiratory failure after extubation. *N Engl J Med*. 2004;350(24):2452–2460.
18. Makhoul N, Wilderman I, Phares N, Zveibel F. Gastric mucosal gas monitoring and survival in acute exacerbated chronic lung disease. *Clin Intens Care*. 2004;15(2/3):83–86.
19. Kline JA, Kubin AK, Patel MM, Easton EJ, Seupal RA. Alveolar dead space as a predictor of severity of pulmonary embolism. *Acad Emerg Med*. 2000;7(6):611–617.