

# Spirometric Correlates of Dyspnea Improvement Among Emergency Department Patients With Chronic Obstructive Pulmonary Disease Exacerbation

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**OBJECTIVE:** To examine whether change in slow vital capacity (SVC) correlates to dyspnea improvement during emergency department (ED) treatment of chronic obstructive pulmonary disease (COPD) exacerbation. **METHODS:** We performed a prospective cohort study and enrolled consecutive patients during a 3-week period. ED patients  $\geq 55$  years old with COPD exacerbation were asked to perform bedside spirometry shortly after ED arrival and again at discharge. SVC was measured first, then forced expiratory volume in the first second ( $FEV_1$ ), peak expiratory flow (PEF), and forced vital capacity (FVC). Concurrent with spirometry, patients rated their dyspnea on a 10-cm visual analogue scale. **RESULTS:** Thirty-six patients were enrolled. The median ED stay was 271 min (interquartile range 219–370 min). Seventy-one percent of the patients reported dyspnea improvement during their ED stay. Change in SVC was significantly higher among the patients whose dyspnea improved than among those whose did not (median increase of 0.15 L vs median decrease of 0.25 L, respectively,  $p < 0.01$ ). By contrast, the change in spirometry values were similar for  $FEV_1$ , PEF, and FVC (all  $p > 0.30$ ). Spearman correlation supported these findings: SVC  $r = 0.45$  ( $p = 0.02$ ) versus nonsignificant correlation with  $FEV_1$  ( $r = 0.33$ ), PEF ( $r = -0.22$ ), and FVC ( $r = 0.35$ ). **CONCLUSIONS:** Increase in SVC significantly correlated with dyspnea improvement among ED patients with moderate-to-severe COPD exacerbation. Change in SVC merits consideration when evaluating therapeutic response during COPD exacerbation. *Key words:* chronic obstructive pulmonary disease, COPD, dyspnea, emergency department, exacerbation, slow vital capacity, spirometry. [Respir Care 2008;53(7):892–896. © 2008 Daedalus Enterprises]

## Introduction

Exacerbations of chronic obstructive pulmonary disease (COPD) account for approximately 1.5 million emergency department (ED) visits in the United States each year.<sup>1</sup>

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Patients who have frequent exacerbations have worse quality of life and a more rapid decline in health status,<sup>2</sup> and dyspnea contributes substantially to their perceived poor health status. Indeed, dyspnea is the most distressing symptom during a COPD exacerbation.<sup>2,3</sup>

Despite its importance in COPD exacerbations, we are not aware of any prior study that examined the relationship between dyspnea and lung mechanics in the ED setting.

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By definition,<sup>4</sup> a patient who presents to the ED with a COPD exacerbation has at least a moderate exacerbation; many exacerbations are considered severe because more than half of those ED patients are admitted to hospital.<sup>5</sup> Previous studies have focused on exertional dyspnea in patients with stable COPD,<sup>6-9</sup> or patients with mild-to-moderate exacerbation.<sup>10,11</sup> Those studies showed that COPD exacerbations are associated with worsening expiratory flow, which can compromise lung-emptying during tidal expiration. Consequently, end-expiratory lung volume is dynamically increased above baseline (ie, acute lung hyperinflation). There is growing evidence that lung hyperinflation is a mechanistic link between expiratory flow limitation and a patient's perception of dyspnea during COPD exacerbation.<sup>10-14</sup>

Assuming that acute lung hyperinflation is an important contributor to dyspnea during COPD exacerbation, we hypothesized that acute changes in dyspnea severity would be associated with reduced lung hyperinflation, as reflected by change in volume-related spirometric measurements such as slow vital capacity (SVC). The purpose of this study was to examine whether change in SVC reflects dyspnea improvement among patients who present to the ED with COPD exacerbation.

## Methods

### Study Design

This prospective cohort study was performed as part of the Multicenter Airway Research Collaboration, which is a division of the Emergency Medicine Network (<http://www.emnet-usa.org>). The details of the study design and data collection are described elsewhere.<sup>15</sup> Institutional review board approval was obtained and informed consent was obtained from all participants.

### Study Setting and Population

We enrolled consecutive patients at Massachusetts General Hospital for a 3-week period. Repeat visits by individual subjects were excluded. All patients were managed at the discretion of the treating physician. The inclusion criteria were: physician diagnosis of COPD; presentation to the ED for treatment of COPD exacerbation, as defined by increasing shortness of breath, worsening cough, or change in sputum production;<sup>16</sup> age  $\geq 55$  y; and ability to give informed consent.

### Study Protocol and Measurements

Trained research personnel performed the ED interview and assessed the patients' demographic characteristics, COPD history, and details of their current COPD exacer-

bation. Data on ED management and disposition were obtained from chart review.

Bedside spirometry was performed shortly after ED arrival and again at ED discharge. All study personnel who administered spirometry were trained and certified for a concurrent phase IIb asthma trial.<sup>17</sup> Patients were encouraged to perform spirometry to accepted standards,<sup>18</sup> but this was not always possible, given their acute illness. The spirometry was performed with a PB100 spirometer (Puritan Bennett, Lenexa, Kansas), and each subject performed the spirometry maneuvers at least 2 times (ideally, 3 times), and the best values were recorded. SVC was measured first. Then the subject performed a forced exhalation, which yielded the forced expiratory volume in the first second (FEV<sub>1</sub>), peak expiratory flow (PEF), and forced vital capacity (FVC) values. Concurrent with spirometry, patients rated the intensity of their dyspnea on a 10-cm visual analog scale. This instrument has been validated and its results are reproducible and responsive.<sup>19,20</sup> The minimum clinically important difference on the visual analog scale is believed to be 1 increment on the scale,<sup>21</sup> so subjects who had a  $\geq 1$ -point increase in their visual-analog-scale score over the course of the ED visit composed the group of patients judged to have improved dyspnea.

### Statistical Analysis

All analyses were performed with statistics software (Stata 9.0, StataCorp, College Station, Texas). All results are reported as proportions (with 95% confidence intervals) or medians (with interquartile ranges). Associations between the spirometry values and dyspnea scores were examined with nonparametric statistics: Mann-Whitney test and Spearman correlation. All p values are 2-tailed, and  $p < 0.05$  was considered statistically significant.

## Results

Of 50 eligible patients, 36 entered the study. Fourteen patients were excluded because they were too ill and/or unwilling to perform spirometry. Among the 36 subjects, all had COPD, according to the treating physician and a subsequent validation study.<sup>22</sup>

The subjects' median age was 70 years (interquartile range 64–78 y), 58% were male, and 83% were white. Median ED stay was 271 min (interquartile range 219–370 min). Over the course of the ED visit, 83% of the subjects received inhaled albuterol, 67% received inhaled ipratropium, 67% received systemic corticosteroids, and 50% received antibiotics. Seventy-one percent reported dyspnea improvement during their ED stay, although 69% were ultimately admitted to the hospital.

The bedside spirometry protocol, although quite simple, was difficult for most of the patients to complete, even though they had volunteered for the study. At ED discharge, 27 patients (75%) were able to conduct the SVC maneuver, and

## SPIROMETRIC CORRELATES OF DYSPNEA IN COPD EXACERBATION

Table 1. Dyspnea and Lung Function Measurements at Study Entry and at Discharge in Emergency Department Patients With Exacerbation of Chronic Obstructive Pulmonary Disease

Measurement	On Arrival	At Discharge	p
Dyspnea score (median and IQR visual-analog-scale score)	3.75 (1.0–5.0)	6.0 (4.5–8.0)	< 0.001*
No. patients with complete data	36	27	NA
SVC (median and IQR L)	1.5 (1.1–2.0)	1.69 (1.19–2.13)	0.58
No. patients with complete data	36	22	NA
FEV <sub>1</sub> (median and IQR L)	0.72 (0.46–1.02)	0.76 (0.57–1.29)	0.60
PEF (median and IQR L/s)	2.03 (1.30–3.03)	2.29 (1.60–4.14)	0.76
FVC (median and IQR L)	1.40 (1.02–2.01)	1.44 (1.19–1.95)	0.82
FEV <sub>1</sub> /FVC (median and IQR)	0.50 (0.43–0.72)	0.53 (0.44–0.69)	0.77

\*Improvement significant via Wilcoxon signed-rank test.

IQR = interquartile range

NA = not applicable

SVC = slow vital capacity

FEV<sub>1</sub> = forced expiratory volume in the first second

PEF = peak expiratory flow

FVC = forced vital capacity

Table 2. Change in Spirometry Values Relative to Improvement in Dyspnea in Emergency Department Patients With Exacerbation of Chronic Obstructive Pulmonary Disease

Measurement	Dyspnea Improved*	Dyspnea Did Not Improve	p
SVC (median and IQR L)†	0.15 (0 to 0.32) (n = 20)	–0.25 (–0.1 to 0.43) (n = 7)	0.007
FEV <sub>1</sub> (median and IQR L)	–0.03 (–0.01 to 0.08) (n = 17)	–0.04 (–0.08 to 0) (n = 5)	0.43
PEF (median and IQR L/min)	0.08 (–0.98 to 0.35) (n = 17)	0.31 (–0.21 to 0.39) (n = 5)	0.31
FVC (median and IQR L)	–0.03 (–0.08 to 0.13) (n = 17)	–0.07 (–0.21 to 0.04) (n = 5)	0.42

\*Among the subjects whose dyspnea improved during their emergency-department stay, 20 subjects conducted the slow vital capacity (SVC) maneuver, but only 17 conducted the forced exhalation maneuver for forced expiratory volume in the first second (FEV<sub>1</sub>), peak expiratory flow (PEF), and forced vital capacity (FVC). Among the subjects whose dyspnea did not improve during their emergency-department stay, 7 subjects conducted the SVC maneuver, but only 5 conducted the forced exhalation maneuver for FEV<sub>1</sub>, PEF, and FVC.

†Restricting the data set to the 22 subjects who had complete data yielded median SVC-change values of 0.12 L among those whose dyspnea improved, versus –0.17 L among those whose dyspnea did not improve (p = 0.059).

22 patients (61%) completed the forced exhalation maneuver for FEV<sub>1</sub>, PEF, and FVC. Table 1 shows the changes in dyspnea and spirometry values. None of the spirometric measurements were sensitive enough to detect change in dyspnea over the course of the ED visit. Patients unable to complete the pre-discharge spirometry protocol may have been sicker at baseline (eg, FEV<sub>1</sub> 0.45 L vs 0.74 L, p = 0.05). Most patients were able to tolerate the SVC measurements, whereas many patients (or their attendant family members) objected to the forced exhalation maneuver.

Table 2 shows patient-reported dyspnea improvement compared to change in spirometry values. Only change in SVC was significantly associated with dyspnea improvement. The correlation between change in dyspnea and spirometric measurements support this finding. Change in SVC had the highest correlation with change in dyspnea (r = 0.45, p = 0.02) (Fig. 1). By contrast, changes in the traditional spirometry values were not significantly correlated with change in dyspnea: FEV<sub>1</sub> r = 0.33 (p = 0.13), PEF r = –0.22 (p = 0.32), and FVC r = 0.35 (p = 0.12).

## Discussion

To our knowledge this is the first study of the spirometric correlates of dyspnea improvement in patients with moderate-to-severe COPD exacerbation in the ED. SVC (an indirect measure of acute lung hyperinflation) correlated better with dyspnea improvement than did FEV<sub>1</sub>, PEF, or FVC.

Our findings are consistent with, and extend, those from prior investigations of exertional dyspnea in patients with stable COPD.<sup>6–8,23</sup> In patients with stable COPD, acute lung hyperinflation (measured indirectly via inspiratory capacity) during exercise is the best predictor (among all spirometric measurements) of dyspnea improvement after treatment with bronchodilator.<sup>8</sup> This study also extends the dyspnea/spirometry link in patients with mild-to-moderate COPD exacerbations<sup>10,11</sup> to a previously unstudied ED population. Two recent studies of patients with mild-to-moderate exacerbations, investigators found significant changes in both SVC (or inspiratory capacity) and dyspnea over “weeks.”<sup>10,11</sup> Given the short ED stay in our study, change in SVC was not sensitive enough to detect dyspnea

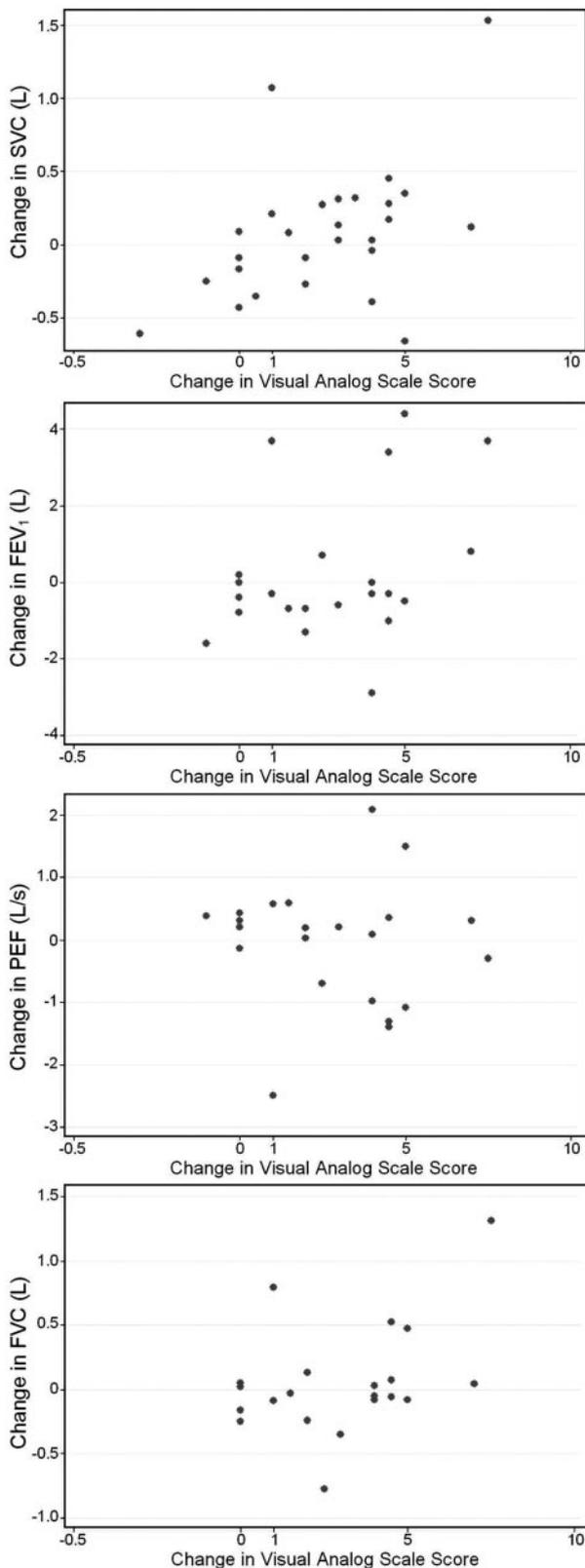


Fig. 1. Change in visual-analog-scale dyspnea score versus change in slow vital capacity (SVC), forced expiratory volume in the first second ( $FEV_1$ ), peak expiratory flow (PEF), and forced vital capacity (FVC). Subjects who had a  $\geq 1$ -point increase in visual-analog-

improvement in COPD exacerbations. Change in SVC, however, did demonstrate superior discriminant validity among all changes in spirometry values in distinguishing patients with and without improvement in dyspnea. Moreover, the change in SVC among patients with improvement in dyspnea could, roughly, serve as the minimum clinically important difference of SVC (0.15 L). Establishing the precise minimum clinically important difference of SVC is an iterative process and requires future studies.

Accumulating data support a spirometric link between acute lung hyperinflation and dyspnea during COPD exacerbation.<sup>6-8,10,11,23</sup> The degree of lung hyperinflation is directly reflected by the end-expiratory lung volume; however, this is impractical to measure during an exacerbation.<sup>12</sup> As a result, change in end-expiratory lung volume is often indirectly measured by change in inspiratory capacity, because total lung capacity remains unchanged during a COPD exacerbation.<sup>10,11</sup> SVC is another indirect measure of hyperinflation, which adds a dynamic component of effective reserve volume to inspiratory capacity.<sup>12</sup> SVC also more accurately reflects vital capacity than does FVC during an exacerbation,<sup>24</sup> which might help explain why FVC, as a volume-related spirometric measurement, did not correlate with dyspnea improvement in our study.

With regard to the flow-related spirometric measurements, a lack of correlation between change in  $FEV_1$  and change in dyspnea has been reported in studies of patients with stable COPD.<sup>25,26</sup>  $FEV_1$  gives no information about the shape of the expiratory flow-volume curve over the tidal-volume operating range, or the extent of lung hyperinflation required to maximize tidal expiratory flow.<sup>12</sup> Likewise, PEF is not closely related to symptom changes during a COPD exacerbation.<sup>27</sup> One study found a correlation between PEF and  $FEV_1$  among ED patients with COPD exacerbations.<sup>28</sup> However, because  $FEV_1$  is a poor predictor of symptom changes during exacerbation, the clinical implications of PEF also are unclear in this setting.

### Limitations

One limitation of the present study is that the superior correlation between change in SVC and improvement in dyspnea may be due, in part, to our having more complete data for SVC than for the other spirometric measurements. When we restricted the data set to the 22 subjects from whom we obtained all the spirometric measurements, the association between SVC and dyspnea was of borderline significance ( $p = 0.059$ ).

The second limitation is that bronchodilator treatment was not standardized in our study, and this might have contributed

scale score during their emergency department visit composed the group of patients whose dyspnea was deemed to have improved.

to the nonresponsiveness of all spirometric measurements. To determine the responsiveness of spirometric measurements in exacerbations of COPD will require further study with a standardized treatment protocol and larger sample size. In fact, after taking into account the pre-ED treatment (bronchodilator use at home or en route to the hospital) and the immediate treatment after ED arrival, the initial spirometry was *after* treatment in 89% of the subjects. Despite this, we still found positive results, which suggests that the strength of association might have been stronger if we could have conducted spirometry before treatment in all the subjects.

The third limitation is that our small sample size limited us in exploring other potential roles of SVC as a marker or outcome measure in COPD exacerbation. However, given its pathophysiologic link with dyspnea in COPD exacerbation, we believe SVC could provide complementary information (as a secondary outcome measure) in clinical trials designed to evaluate the efficacy of COPD treatments in the ED.

### Conclusions

Increase in SVC correlated significantly with dyspnea improvement in patients who presented to the ED with moderate-to-severe COPD exacerbation. Reduced lung hyperinflation, as indirectly reflected by increased SVC, is a likely mechanism for the observed improvements in dyspnea. In addition to the pathophysiologic implications, these data suggest that SVC merits consideration when evaluating therapeutic response during COPD exacerbations.

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