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Original research article

A study of difference between slow vital capacity and forced vital capacity in COPD patients and its association with exercise tolerance

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Abstract

Background: COPD is a preventable and treatable disease with some significant extra pulmonary effects that may contribute to its severity in individual patients. COPD is a significant cause of worldwide morbidity and mortality(1). Exercise tolerance is an important factor which affects quality of life in COPD patients. The 6MWT simple powerful tool in the evaluation of the global and integrated responses of all the systems involved during exercise, including the pulmonary and cardiovascular systems. Recently, several publications have established the value of the 6MWT in predicting morbidity and mortality from heart and lung disease. Spirometry is indicated primarily to detect abnormal lung function, to quantify the severity of disease and assess a patient's treatment response. In this study we assessed the increased difference between slow vital capacity (SVC) and forced vital capacity (FVC) and its association with exercise tolerance 6MWT) in COPD patients.

Methods: This is a hospital based observational cross-sectional study which included 100 patients who were all diagnosed and confirmed COPD patients attending the Department of Pulmonary Medicine, Gandhi hospital/Medical College.

Results: In the present study, a total of 100 stable COPD patients were included. Out of 100 COPD patients in the study, patients with mild obstruction were 38%, moderate obstruction were 62%. Mean of SVC before 6 MWT in these patients is 2.08L and after 6 MWT is 1.96L. It indicates that SVC decreases after 6 MWT in these patients. Mean of FVC in mild obstruction before 6 MWT is 2.19L and after 6 MWT is 1.90L. It indicates that FVC also decreases after 6MWT. But the fall in FVC is 0.39 L which is more compared to fall in SVC that is 0.10L and the p value of both is statistically significant. In patients with mild obstruction the difference between SVC and FVC (SVC-FVC) after 6 MWT is 0.40 which is more than the difference before 6 MWT (0.21L). In moderate obstruction the difference in SVC and FVC before and after 6 MWT IS 0.21L and 0.25L respectively, both of which are statistically significant. The mean distance covered in mild obstruction patients was 408 ±15m and in moderate obstruction patients was 355.6 ±57m.

Conclusion: We routinely use FEV1/FVC to diagnose COPD. This usually under diagnoses the patients of COPD especially in mild disease. Use of SVC to FVC difference may help in early identification of such patients and help in improved treatment outcomes. The difference between SVC and FVC can be used as a predictor of exercise tolerance and pulmonary rehabilitation can be planned accordingly. The degree of air trapping can also be identified but this warrants further investigation.

Keywords: Slow Vital Capacity (SVC), Forced Vital Capacity (FVC), Exercise Tolerance, 6 Minute Walk Test (6MWT), Chronic Obstructive Pulmonary disease (COPD), Spirometry

Introduction

Background

COPD is a preventable and treatable disease with some significant extra pulmonary effects that may contribute to its severity in individual patients. Its pulmonary component is characterized by airflow

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limitation that is not fully reversible. The airflow limitation is usually progressive and associated with the abnormal pulmonary inflammatory response to noxious particles or gases [1, 2].

COPD is characterized by increased numbers of macrophages in peripheral airways, lung parenchyma and pulmonary vessels, together with increased activated neutrophils and increased lymphocytes. These inflammatory cells, together with epithelial cells and other structural cells release multiple inflammatory mediators [1, 2]which attract inflammatory cells from the circulation (chemotactic factors), amplify the inflammatory process (via proinflammatory cytokines), and induce structural changes (via growth factors)[1, 2].Lung inflammation can persist after smoking cessation through as yet unclear mechanisms [1, 2].Systemic inflammation may also be present and could play a role in the comorbid conditions frequently found in patients with COPD. The nature of the inflammatory response in non-smoking related COPD is much less well characterized.

Airflow obstruction is usually measured by spirometry as this is the most widely available and reproducible test [3] of lung function. In COPD, airflow obstruction is caused by a mixture of small airways disease (which increases airway resistance) and parenchymal destruction (emphysema, that reduces the normal elastic recoil of the lung parenchyma), the relative contributions of which vary from person to person[1, 2].Chronic inflammation causes structural changes, narrowing of the small airways, luminal exudates in the small airways and destruction of the lung parenchyma that leads to the loss of alveolar attachments to the small airways and decreases lung elastic recoil. In turn, these changes diminish the ability of the airways to remain open during expiration. Collectively, all these changes limit emptying of the lungs during forced expiration, decrease FEV1 and the FEV1/FVC ratio, and contribute to gas trapping and lung hyperinflation[4].

The systemic co-morbidities seen with COPD include cardiovascular diseases, skeletal muscle wasting and dysfunction, nutritional abnormalities and weight loss, osteoporosis, metabolic abnormalities like diabetes and anemia. Most recent evidence highlights the need to address the physical limitations imposed by COPD comorbidities along with improving lung function and disease symptoms[1, 2].According to evidence-based guidelines pulmonary rehabilitation improves dyspnea, exercise capacity and quality of life and decreases health care utilization in COPD patients [5].

Spirometry is indicated primarily to detect abnormal lung function, to quantify the severity of disease and assess a patient's treatment response (volume displacement and flow sensing spirometers).

Forced vital capacity, or FVC is defined as the volume of air exhaled with maximal forced effort from a maximal inspiration. FVC is used to help determine both the presence and severity of lung disease. SVC is similar to the FVC, but the maneuver is not forced and it is performed in a relaxed manner, except near the end-inspiration and end-expiration.

Small airways, defined as those smaller than 2 mm in diameter, have no cartilaginous support and are subject to collapse when compressed[6].During a slow vital capacity (SVC) maneuver, less thoracic gas compression occurs, and greater air volume can be expired. In contrast, during an FVC maneuver, greater airway compression occurs, and a smaller volume is expired. However, in healthy people this tendency is partly opposed by the attachment of the alveolar septa to the airway walls. In those with COPD, the airways tend to collapse during a forced expiration due to the reduction of alveolar attachments and airway abnormalities. Therefore, finding that SVC is higher than FVC suggests small airway collapse and air trapping[7].

In healthy individuals, the difference between SVC and FVC (SVC-FVC) is practically zero; however, in the presence of airway obstruction, these differences can become apparent and are mostly related to the presence of lung hyperinflation [8].

Exercise tolerance is an important factor which effects quality of life in COPD patients. 6 MWT is one of the most widely used, practical modalities. It requires a100 ft hallway but no exercise equipment or advanced training for technicians[9].Although the 6MWT is limited in its inability to provide objective measures of functional capacity, such as oxygen uptake, the test provides very useful clinical information. In addition, it realistically represents the patient's functional capacity during physical effort that more closely reflects his or her daily activity.

Because of its simplicity, the 6MWT has become a powerful tool in the evaluation of the global and integrated responses of all the systems involved during exercise and prognosis of patients with a variety of functional impairments. The 6 MWT used as a onetime measure of functional status of patients with COPD, cystic fibrosis and peripheral vascular disease. Can also used a predictor of morbidity and mortality in cardiac (heart failure), respiratory (COPD) and vascular diseases (primary PAH)[9].

The patient is asked to rate baseline dyspnea and overall fatigue using the revised Borg scale (from 1 to 10). The patient walking at a comfortable pace completes 60-m laps on a walking course which is 30 m in length[10]. Cones are used to mark the turnaround points. The number of laps and a post walk Borg scale assessment[9]are recorded, as is the total distance walked over 6 minutes (6MWD).

Healthy subjects 6MWDs range from 400 to 700 meters. An improvement of more than 70 meters walked was clinically important to the patients. Pulmonary rehabilitation clearly improves 6MWT performance in patients with COPD. Results from the test have been shown to have an inverse relationship with mortality in severe COPD, walk distance and velocity.

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The difference between SVC and FVC has been described as a marker of air trapping, an early step in the development of obstruction[11, 12].This difference is also an independent predictor of diminished exercise tolerance and peak oxygen uptake in COPD patients[13].This study attempts to assess the early recognition of small airway obstruction which is not only an index of severity of airflow limitation but also predict the early decreased exercise tolerance in patients with COPD which helps to plan for early rehabilitation. In this study we have attempted to assess the increased difference between slow vital capacity and forced vital capacity and its association with exercise tolerance (6MWT) in COPD patients as it correlates well with the lung capacities.

Methods

This is a hospital based observational cross-sectional study included 100 patients who were all diagnosed and confirmed COPD patients attending the Department of Pulmonary Medicine, Gandhi hospital/ Medical College.

Inclusion criteria: Diagnosed COPD patients with mild or moderate obstruction as per GOLD guidelines.

Exclusion criteria

COPD patients with neuromuscular and peripheral vascular diseases.

COPD with associated chronic lung diseases like PTB, Bronchiectasis, Pulmonary HTN and Corpulmonale.

COPD in association with cardiovascular diseases.

After taking informed consent from patients, a proper history was taken, thoroughly examined and were subjected to investigations like CBP, RBS, RFT, Chest x-ray, Resting ECG and 2DECHO, ABG, Spirometry, 6 Minute Walk Test. With the help of spirometry SVC and FVC values were recorded.

With the spirometer hose and flow sensor in their hand, few quiet tidal breaths were taken by the patient and then the patient inspired fully and then slowly exhaled all the air in his lungs and then the patient exhaled fully and inspired slowly to a maximum and SVC is recorded.

Then the patient is instructed to forcefully exhale the air. The patient was encouraged for effective performing of the maneuver and to continue blowing until he/she experiences a feeling of emptiness and FVC was recorded. If the patient complained of light-headedness or dizziness or breathlessness, extra time was given between maneuvers.

At least three readings were taken and the best reading with maximum quality was considered for the final interpretation. Maximal effort was entertained, with no cough during the first second or leaks/obstruction of the mouthpiece. Tracking of a minimum of six seconds of exhalation was done. Three acceptable spirograms were obtained. The spirograms with the highest SVC and FVC were reported.

Table 1: Classification of Severity of Airflow Limitation in COPD (Based on Post Bronchodilator FEV1)-In patients with FEV1/FVC <70%)[2]

Stages	Severity of Symptoms	FEV1%
Gold 1	Mild	>80% Predicted
Gold 2	Moderate	50-80% Predicted
Gold 3	Severe	30-50% Predicted
Gold 4	Very Severe	<30% Predicated

After the above evaluation 6MWT was performed in a 30m long and ventilated indoor corridor according to ATS guidelines[9].All the patients underwent the 6MWT within 1 hour of spirometry. Each patient rested for at least 10 min prior to the 6MWT during which baseline vital signs are taken. Patients were given proper instructions. Encouraging phrases such as “keep up the good work”, “well done”, and “good” were used during the test.

The test was discontinued if patients experience severe chest pain, severe dyspnea, spasm of lower extremity muscles, or if the patient wanted to quit and then continue walking when they felt better. However, the resting time was included in the 6- minute time period[9].At the end of the test, blood pressure, heart rate, oxygen saturation by pulse oximeter and the distance walked for 6 minutes were recorded in meter. Both pre walk and post walk measurement slow vital capacity and forced vital capacity were recorded. The patients were asked to be observed for a 10-15 min period after the test, to assess any possible complications. Four groups emerged in the study population based on criteria on GOLD guidelines that is patients with Mild and Moderate obstruction and the one is based on age at presentation and one group is based on gender.

Statistical analysis

Statistical analysis was done using version 16 statistical software –SPSS. Inferential Statistics obtained

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included Chi Square Test and p Values. The 2 groups of patients with mild and moderate obstruction before and after 6MWT were compared by paired t test. The group of patients based on age and gender criteria were compared by Chi- square test.

Results

In the present study, a total of 100 stable COPD patients were included. Out of these patients, 81(81%) were males and 19 (19%) were females. The patients in age group 40-60 were 49 (49%) and patients above 60 were 51 (51%). Our study group was divided into patients with mild and moderate obstruction. Total number of patients with mild obstruction were 38 among that males were 34 (41.9%) and females were 4 (21.05%). Patients with moderate obstruction were 62 among that males were 47 (58.02%) and females were 15 (78.94%). Patients with mild obstruction presented at the mean age of 61.66 and with moderate obstruction presented at a mean age of 58.60. Total numbers of patients in age group of 40-60 years, with mild obstruction were 16 (32.65%) and with moderate obstruction 33 (67.34%). Total number of patients in age group above 60 years, with mild obstruction were 22 (43.13%) and with moderate obstruction are 29(56.86%). In the present study group, mean of SVC before 6 MWT in these patients is 2.08L and after 6 MWT is 1.96L. Mean of FVC before 6 MWT is 1.79L and after 6 MWT is 1.67L. It indicates that SVC and FVC decreases after 6 MWT in these patients.

Table 1: Trends Depicting Correlates of COPD With Clinical Variables in Study Population

	COPD (n=100) P value	**Mild obstruction(n=38) P value**	**Moderate obstruction(n=62) P value**
Age 40-60	0.50(n=49)	0.50(n=16)	0.50(n=33)
Age >60	0.50(n=51)	0.50(n=22)	0.50(n=29)
Male	0.167(n=81)	0.167(n=34)	0.167(n=47)
Female	0.167(n=19)	0.167(n=4)	0.167(n=15)

Table 2: Spirometricand Clinical Parameters in Each Group (*Before 6MWT,**After 6MWT,#SVC,##FVC)

	6MWT	**Total (N=100) Mean ±SD**	**Mild Obstruction (n=38) Mean ±SD**	**Moderate Obstruction (n=62) Mean ±SD**
SVC (L)	Before 6MWT	*2.08±0.62	*2.40±0.58	*1.90 ±0.57
	After 6MWT	**1.96+0.55	**2.30+0.59	**1.72 +0.41
FVC (L)	Before 6MWT	*1.79+0.60	*2.19 +0.64	*1.69+0.50
	After 6MWT	**1.67+0.55	**1.90+0.58	**1.47 +0.458

The mean distance covered in mild obstruction patients was 408 ±15m. both pre and post 6MWT PFT was performed to record SVC and FVC. Mean of SVC, before 6 MWT was 2.40L and after 6 MWT was 2.30L. Mean of FVC in mild obstruction before 6 MWT was 2.19L and after 6 MWT was 1.90L. It indicates that in mild COPD patients, both FVC and SVC decreased after 6 MWT. The fall in FVC is 0.39L which is more compared to fall in SVC that is 0.10L and the p value of fall in FVC is 0.04 (<0.05) which is statistically significant.

The difference between SVC and FVC (SVC-FVC) after 6 MWT is 0.40 which is more than the difference before 6 MWT (0.21L).

Table 3:SVC And FVC values Before and After 6 MWT in patients with mild obstruction

Spirometer	**Before 6 MWT**	**After 6 MWT**	**P Value**
SVC (L)	2.40	2.30	0.45
FVC(L)	2.19	1.90	0.04
P Value	0.13	0.003	

The mean distance covered in moderate obstruction patients was 355.6 ±57m. PFT was performed to record SVC and FVC pre and post 6MWT. Mean of SVC before 6 MWT in these patients is 1.90L and after 6 MWT is 1.72L. Mean of FVC in moderate obstruction before 6 MWT is 1.69L and after 6 MWT is 1.47L. It indicates that both SVC and FVC decreased after 6 MWT. Both fall in FVC and SVC are statistically significant.

The difference in SVC and FVC before and after 6 MWT IS 0.21L and 0.25L respectively, both of which are statistically significant.

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Table 4: Distribution of Patients with Moderate Obstruction and Their SVC and FVC

Spirometer	Before 6 MWT	After 6 MWT	P Value
SVC (L)	1.90	1.72	0.04
FVC(L)	1.69	1.47	0.01
P value	0.03	0.001	

Discussion

In the present study total of 100 stable COPD patients diagnosed and staged as per GOLD guidelines, with mild and moderate obstruction were included. Among the total 100 patients, 49 patients between the age of 40-60 group were 49(49%) and >60 were 51 (51%). COPD patients with mild obstruction presented at the mean age of 61.66 and with moderate obstruction presented at the mean age of 58.60. P value is 0.508 (>0.05) meaning the is no association between these variable and grading of COPD.

Among the total patients with mild obstruction were 38 among them, 34 were males and rest were females. Patients with moderate obstruction were 62, among them males were 47 and females were 15. (P value is 0.167 (P>0.05) it means that gender is not associated with the grading of severity in COPD patients.

In this study slow vital capacity and forced vital capacity of 100COPD patients was measured before and after 6-minute walk test and there was a significant difference between SVC and FVC before and after 6 MWT in all group of patients. In COPD patients, studies have shown that there is a considerable difference between SVC and FVC and this difference is a good marker for hyperinflation and air trapping [(14)]. Forced maneuver like FVC are effort dependent and provide more information than slow maneuvers. This is the reason for the predisposition to air trapping due to dynamic compression and causes fall in FVC. This does not happen with SVC as it is a slow maneuver. The difference between SVC and FVC is recognized as a marker for air trapping.

In this study we have seen that the difference between SVC and FVC before and after 6 MWT in mild and moderate COPD patients in all age groups is not statistically significant (P>0.05). It means that there is no association between age and grading of severity of COPD.

The difference between SVC and FVC (SVC-FVC) in mild obstruction before 6 MWT is 0.21L (with p value 0.13) and after 6 MWT is 0.40 L (with p value 0.003), showing difference is more after 6 MWT. The difference before 6 MWT is not statistically significant. This can be explained by the fact that in normal and people with mild obstruction there is only minor difference between SVC and FVC [(15)]. In mild COPD group both FVC &SVC decrease after 6MWT. The difference between SVC before and after 6 MWT (0.13) is more than the difference between FVC before and after 6 MWT (0.07). So, SVC is more decreased than FVC after 6 MWT in mild COPD. In mild COPD obstruction, the change in SVC before and after 6 MWT is statistically significant (the p value is 0.008). But the change after 6 MWT in FVC is statistically not significant (the p value 0.216). Study conducted by Hyatt *et al*. confirmed this observation, with an increased prevalence of obstructive lung disease from 26% with the use of FVC to 45% when applying FEV1/SVC criteria[16].

The difference between SVC and FVC (SVC-FVC) in moderate obstruction before 6 MWT is 0.21L (with p value 0.03) and after 6 MWT is 0.25 L (with p value 0.001), showing difference is more after 6 MWT, both of which are statistically significant. In patients with moderate COPD both FVC and SVC decreased after 6 MWT. The difference between SVC before and after 6MWT (0.11L) is less than the difference between FVC before and after 6MWT (0.15L). So FVC is more decreased than SVC after 6 MWT. In patients with moderate COPD obstruction, the change in SVC before and after 6 MWT is statistically significant (the p value is 0.003). But the change after 6 MWT in FVC is statistically not significant (the p value 0.008).

Seong Mi Moon *etal*.[17] in their study correlating the FVC and exercise capacity described decreased FVC was associated with decreased 6minute walk distance especially in moderate to severe COPD patients. In our study also it was seen that patients with mean FVC of 2.19L (in mild obstruction) could walk a mean distance of 408m and patients with mean FVC of 1.69L (in moderate obstruction) could walk a mean distance of 355m in 6 minutes.

Few studies have shown that there is a difference in SVC and FVC in COPD patients and this difference is related to air flow limitation and air trapping. This can cause lung hyperinflation. This hyperinflation is very much increased in activities which need increased ventilatory demand along with decreased expiratory time. This is called dynamic hyperinflation. This is usually evaluated by measuring inspiratory capacity. Static lung hyperinflation related to the loss of elastic recoil reduces inspiratory capacity and is commonly associated with further (dynamic) hyperinflation during exercise related to airflow limitation, causing exertional dyspnea and limiting exercise capacity[2]. This can happen even in patients with mild airflow obstruction[14, 18, 19].6 MWT can be used to detect hyperinflation. Larissa Martinez *et al*.[20],in their study tried to detect the difference between SVC and FVC before and after 6 MWT and to measure the dynamic hyperinflation. They concluded that there was only weak relation in development of dynamic hyperinflation during 6 MWT. In our study, we had a significant difference between SVC and FVC before and after 6 MWT especially in moderate obstruction.

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Studies indicate that usually SVC is more than FVC in obstructive airway disease, but in few cases FVC may be greater than SVC. Chances are more in normal patients and in patients with mild obstruction. Our study findings were consistent with the analysis done by Barros ARG, which showed that the differences between SVC and FVC (SVC-FVC) were greater in the presence of airway obstruction[21].The negative intrathoracic pressure causes more amount of air to be expelled from distal airways with greater force and stenting open the large airway so that more amount of air is pushed out. In case of very severe obstruction even the proximal airways are closed with increased intrathoracic pressure, chances of FVC being more are less. Study by Jonathan Jerlas Fernandez *et al*.[22].Took 200 ml as a significant value for SVC-FVC and evaluated the study group by dividing them as SVC>FVC and FVC>SVC. In our study we have the difference between SVC and FVC to be about 200 ml before 6MWT in both mild and moderate obstruction (there was not much difference in SVC-FVC between mild and moderate obstruction). This could be explained by the fact that patients were not divided as above study. According to Fortis *et al*.[23]FVC>SVC could be due to difference in inspiratory reserve volume changes occurring due to changes in BMI and increased BMI reduces FVC more than SVC. In our study BMI was not considered.

Another study similar to this is difference Between Slow and Forced Vital Capacity and Its relationship with Dynamic Hyperinflation in Patients with COPD by Larissa Martinez *et al*.[20]in 2018 &concluded that the SVC-FVC difference presented only weak correlation with the development of DH (dynamic hyperinflation) during the 6MWT in patients with COPD.

Another study by Chen Hong *et al*.[24]in 2012 & they concluded that the 6MWT correlated with spirometric parameters in severe and very severe COPD. In our study we evaluated the correlation of 6MWT with SVC and FVC before and after and concluded that 6MWT played a role to increase the dynamic compression of the airways and resulted in decreased FVC compared to SVC. Thus, this study enables us to assess the early recognition of small airway obstruction and also helps to predict the early decreased exercise tolerance which helps to plan for early rehabilitation, to reduce frequency of exacerbations and hospitalization rates in COPD patients.

Limitations: In our study we did not consider BMI which was a drawback.

Conclusion

We routinely use FEV1/FVC to diagnose COPD. This usually under diagnoses the patients of COPD especially in mild disease. Use of SVC to FVC difference may help in early identification of such patients and help in improved treatment outcomes. The difference between SVC and FVC can be used as a predictor of exercise tolerance and pulmonary rehabilitation can be planned accordingly. The degree of air trapping can also be identified but this warrants further investigation.

Authors contribution

Conceptualization: Prof and HOD- Dr. M. G. Krishna Murthy.
Design of study and supervision of study: Dr. G. Ramulu, Dr. P. Sunitha.
Collected data, conducted research and analysis: Dr. V. Veena, Dr. Shobha.
Interpretation of data, editing: Dr. G. Phani Bhushan.
Conflict of interest: None.

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