Ultrasonographic Assessment of Diaphragmatic Excursion and its Correlation with Spirometry in Chronic Obstructive Pulmonary Disease Patients

Abstract

Introduction: Chronic obstructive pulmonary disease (COPD) is a common disease. Spirometry is a standard method of assessment of severity of COPD. We evaluate utility of diaphragmatic excursion using ultrasonography in COPD patients and compare this technique with spirometry. **Methods:** Twenty-six COPD patients and 18 self-reported healthy controls were included in this study. After taking the sociodemographic data, measurement of diaphragm excursion was done using M-mode and B-mode ultrasound. Lung function was assessed by spirometry. **Results:** In the COPD group, diaphragmatic excursion was found to be reduced, and it correlates with forced expiratory volume in 1 s (FEV1)/forced vital capacity, whereas it did not correlate with FEV1. **Conclusion:** Ultrasound assessment of diaphragmatic excursion is an easy, noninvasive, and readily available diagnostic tool and correlates with spirometry in estimation of severity of COPD.

Keywords: *Diaphragmatic excursion, lung function, spirometry, ultrasonography*

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Introduction

Chronic obstructive pulmonary disease (COPD) is a common preventable and treatable disease as per the Global Initiative for Chronic Obstructive Lung Disease (GOLD) and is characterized by persistent respiratory symptoms and airflow limitation that is due to airway and/or alveolar abnormalities usually caused by significant exposure to noxious particles or gases.[1]

According to the GOLD report, COPD is projected to be the third leading cause of death by 2020, and currently, it is the fourth.[2,3] The Global Burden of Disease Study done in 2013 attributed COPD as the cause of death for >3 million people that constitutes 6% of all deaths globally.[2] A review of the published reports revealed 384 million cases of COPD in 2010 which is 11.7% globally.[4] This makes COPD a leading cause of morbidity and mortality, thus causing huge economic and social burden on the society.[3,5] As per the WHO estimates, 90% of COPD-related deaths occur in developing countries. India and China alone account for 66% of global COPD mortality which is approximately 33% of the total human population.[6,7]

COPD impairs the function of diaphragm muscle which is the primary muscle of inspiration. Diaphragm provides 75% of the increase in lung volume during quiet inspiration.[8] Movement of diaphragm during breathing is called diaphragm mobility. Movement of diaphragm from end-expiration to full inspiration is known as diaphragm excursion.

Diaphragmatic mobility has been found to be lower in patients with COPD than in healthy elderly individuals due to hyperinflated chest.[9] COPD patients with thoracic hyperkyphosis have lower diaphragm mobility than those without it. An increase in kyphosis angle decreases the diaphragmatic mobility.[10]

Ultrasonography is a cost-effective, radiation-free, widely available, and real-time investigation.[11] Many studies have proposed the possible use of ultrasonography to measure the diaphragmatic excursion.[11-14] Although, the literature is limited. Spirometry is a noninvasive, easy, and valid tool for COPD assessment. There are established criteria based on spirometry, according to which COPD can be classified as mild,

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moderate, severe, and very severe.[1,9] Our study evaluates the diaphragmatic excursion on the basis of preestablished protocols and compares the outcome with the spirometry results. This study explores a new opportunity of using standard ultrasonography as a tool to establish the diagnosis of COPD and assess the severity of the same.

Materials and Methods

The study was conducted between January and April 2020 at a tertiary care hospital. Forty-four study participants were recruited from chest OPD of our hospital after their due informed consent. Out of these, 26 were COPD patients who were labeled as study group and 18 were non-COPD patients who were labeled as control group. For the COPD group, only those patients who did not require oxygen supplementation and were clinically stable were recruited. Both smokers and nonsmokers were recruited in both the groups.

The exclusion criteria included any patient with recent COPD exacerbation in the last 3 months, patients with comorbidities such as cardiac disease, pulmonary fibrosis, or ankylosing spondylitis, or patients who were unable to understand and perform the test.

All these patients underwent spirometry and ultrasonographic assessment of diaphragmatic excursion on the same day as per the below-mentioned protocol. These patients and controls were randomized so that the spirometry observer and radiologist were blinded for the cases and controls.

Spirometry

All participants underwent a detailed postbronchodilator spirometry examination using a calibrated Spirolab III MIR Spirometer in sitting position. Spirometry was performed thrice by experienced technicians at our pulmonary function laboratory. Patients were asked to take a maximal inspiration and then to forcefully expel air for as long and as quickly as possible. Results were recorded and saved for statistical analyses.[15]

Ultrasonography

Ultrasound assessment of diaphragmatic excursion was done by experienced ultrasonologists. Diaphragmatic excursion for patients was measured on GE make, Voluson S8 series ultrasound machine. The assessment was done in supine position using M-mode and B-mode techniques in quiet and deep breathing scenarios. For M-mode assessment, the transducer was placed in the subcostal region at the midclavicular line with probe tilted cranially, and for B-mode assessment, patients were scanned by placing the transducer in the subcostal region at the midclavicular line with probe tilted horizontally[12,13] [Figure 1]. Ultrasonologists were blinded about the spirometry results.

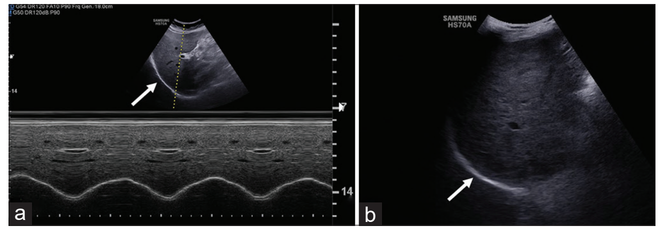

Figure 1: Ultrasound images on diaphragm (arrow). (a) M-Mode scan done at the midclavicular line to assess diaphragmatic motility. (b) B-Mode acquisition shown here as a still from cine-loop image obtained to measure diaphragmatic excursion

Sample size calculation

The sample size required for 40+ years of age group COPD in our district is 1,000,000 individuals which was calculated based on the assumption that the lowest prevalence of COPD in our district is about 4.75% with an absolute precision of 5%, CI of 80%, and design effect as 1.[6,15,16]

Sample size formula n = (DEFF * N*p*q]/[(d2/Z2 1-α/2* (N-1) +p*q].

Statistical analysis

Data was analyzed using IBM SPSS statistical package for Linux version 16.0. Bangalore, India. Demographic data were analyzed using independent samples *t*-test. Diaphragmatic excursion and lung function were analyzed by an independent *t*-test. To analyze the relationship between lung function and diaphragmatic excursion, Karl Pearson's correlation coefficient test was used. The level of significance was <0.05 ($P < 0.05$).

Results

Forty-eight participants were included in the study. Out of those, 30 were COPD and 18 were non-COPD. Four COPD patients were dropouts. Therefore, their data were not included in this study. Nineteen were male COPD and 11 were healthy male. The rest of them are females. Table 1 shows the mean and standard deviation of different variables in both the groups.

Independent *t*-test between the groups revealed that diaphragmatic mobility and lung function are reduced in COPD patients than healthy controls with level of significance <0.01 ($P < 0.01$).

Pearson's correlations between diaphragmatic excursion and lung measurements showed a positive strong correlation between forced expiratory volume in 1 s/forced vital capacity (FEV1/FVC) with M-mode (r = 0.75) [Table 2 and Figure 2] and B-mode (r = 0.85) in the study group [Table 3 and Figure 3], but this relationship was not found in control controls. There is a weak correlation between FEV1 and M-mode in the study group. There is a strong correlation between M-mode and FEV1 ($r = -0.50$) in the control group.

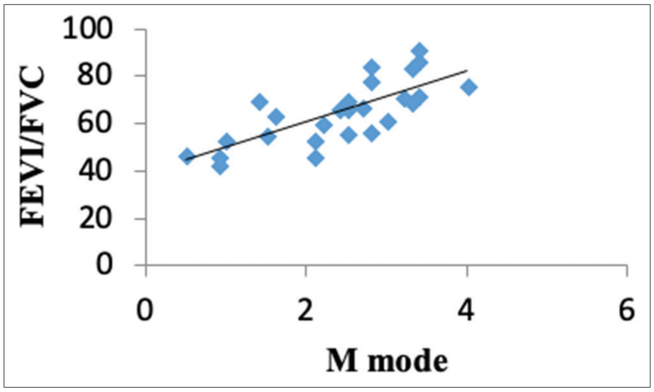

Figure 2: Correlation between forced expiratory volume in 1 s/forced vital capacity and M-mode in study group

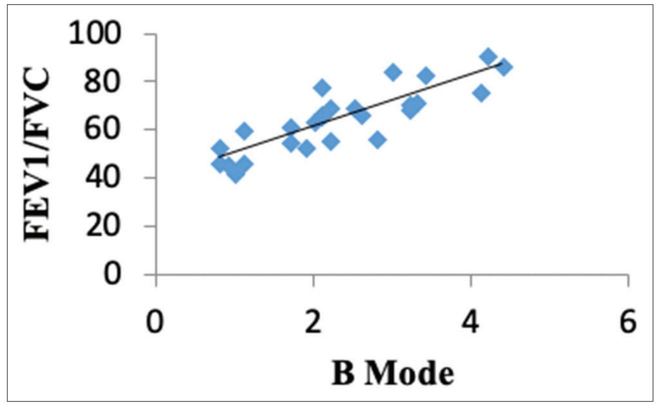

Figure 3: Correlation between forced expiratory volume in 1 s/forced vital capacity and B-mode in experimental group

Table 1: Mean and standard deviation data of study and control groups

Variables	Study group	Control group	*P*
Age	62.69±7.53	55.50±9.62	0.01
DE, M-mode	2.39±0.92	4.18±0.58	0.00
DE, B-mode	2.32±1.06	4.01±0.75	0.00
FEV_1/FVC	65.04±13.32	79.96±13.32	0.00
FEV_1	1.01±0.34	1.96±0.34	0.00
FVC	1.57±0.45	2.44±0.45	0.00

FEV_1: Forced expiratory volume in 1 s; FVC: Forced vital capacity, DE: Diaphragmatic excursion

Table 2: Relationship between diaphragmatic excursion (M-mode) and variables in study group

Variable	Mean±SD	*r*
FEV_1/FVC	65.04±3.31	0.75
FEV_1	1.01±0.34	0.25

FEV_1: Forced expiratory volume in 1 s; FVC: Forced vital capacity, SD: Standard deviation

Table 3: Relationship between diaphragmatic excursion (B-mode) and variables in study group

Variable	Mean±SD	*r*
FEV_1/FVC	65.04±3.31	0.85
FEV_1	1.01±.34	0.14

FEV_1: Forced expiratory volume in 1 s; FVC: Forced vital capacity, SD: Standard deviation

Finally, we observed that diaphragmatic excursion was significantly reduced in the study group than controls ($P < 0.05$). Spirometry measurements showed a significant difference between the groups. FEV1/FVC is significantly reduced in COPD [Table 1].

Discussion

The study establishes that COPD affects diaphragmatic excursion and lung function. We found that diaphragmatic excursion was reduced in COPD than controls. Decreased diaphragmatic excursion shows that contractile ability of diaphragm is reduced in COPD.

The reason of reduced contractility lies in the pathophysiology of the disease. COPD includes bronchitis and emphysema which cause airway obstruction and air trapping in the lungs. Normally, diaphragm moves caudally during inspiration and cranially during expiration. COPD can cause hyperinflation of the lungs, and therefore, diaphragm shifts caudally. This causes mechanical disadvantage of the diaphragm muscle.[1] Previous studies revealed that reduced diaphragmatic mobility is associated with increased perception of dyspnea. Structural changes cause flattening of the diaphragm which reduces their ability to move cranially and caudally.[9,10,12]

Another important outcome of this study is the correlation between sonographic assessment of diaphragmatic excursion and spirometry results. In the present study, we found that diaphragmatic excursion strongly correlates with FEV1/FVC and weakly correlates with FEV1 in the study group. These findings corroborate those of Rocha *et al*., who found that diaphragmatic mobility is related to pulmonary parameters (FEV1, FEV1/FVC, FVC, IC, and MVV).[9] Progression of the disease causes shortening of diaphragm fibers and decreases resting diaphragm muscle length. This causes a decrease in their ventilator capacity and lung function.

COPD causes inflammation and obstruction of the airways that lead to air trapping in the alveoli. As the severity of the disease increases, lung function decreases. COPD can cause hyperkyphosis in later stage which reduces the expansion of the chest wall. A study proved that diaphragmatic mobility is correlated with kyphotic angle.[10] Hence we can say COPD affects diaphragmatic mobility and lung function.

The limitation of the present study is that only two Stage 4 COPD patients were involved because most of them came to chest OPD with acute exacerbation. Another limitation is that only right hemidiaphragm was assessed on ultrasonography.

Further studies with larger number of patients, especially with severe COPD (Stage 4), would be required covering wider geographical areas for standardized guidelines on assessment of diaphragmatic excursion in COPD patients.

Conclusion

This study describes the use of ultrasonography for assessing the diaphragmatic excursion. Sonographically determined diaphragmatic excursion strongly correlates with FEV1/FVC. Both the B-mode and M-mode approaches can be used to measure the diaphragmatic excursion, and these correlate well with the severity of COPD.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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