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The Relationship between Diaphragmatic Movements in Sonographic Assessment and Disease Severity in Patients with Stable Chronic Obstructive Pulmonary Disease (COPD)

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ABSTRACT

Introduction: Pulmonary hyperinflation in patients with chronic obstructive pulmonary disease (COPD) can increase the breathing rate and reduce diaphragmatic movements by pushing the diaphragms downward and limiting their movements; this, in fact, can affect the breathing process. The purpose of this study was to compare diaphragmatic movements in COPD patients and healthy ones and to evaluate the relation of diaphragmatic movements and COPD severity in patients.

Materials and Methods: This cross- sectional study was performed in Ghaem hospital, Mashhad Iran. Twenty-five COPD patients (case group) were selected, based on the inclusion and exclusion criteria. The patients' demographic and clinical characteristics along with factors related to pulmonary function were recorded. Patients were referred for sonography after pulmonary evaluation. The status of the left portal vein or one of its branches at the end of a deep expiration and a deep inspiration was considered as a marker. Twenty-five healthy non-smoker subjects, who were matched with the patients in terms of age and sex, were studied as the control group for the comparison of sonographic findings of the diaphragms.

Results: The current study included 25 healthy subjects and 25 COPD patients, with the mean age of 59.2±12 years; approximately 84% of the subjects were males. Evaluation of the rate of diaphragmatic movements by sonography showed the mean of 42.08±12.15mm and 73.28±15.19mm in the case and control groups, respectively, which showed a statistically significant difference between them (P=0.02). Statistical analysis indicated the relationship between the rate of diaphragmatic movements with factors related to airway obstruction. However, no relationship was observed between the rate of diaphragmatic movements and the factors associated with pulmonary hyperinflation or air retention.

Conclusion: The rate of diaphragmatic movements as a parameter for determining exercise capacity in COPD patients could help with a better understanding of activity limitations in these patients.

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Introduction

Chronic obstructive pulmonary disease (COPD) is predicted to be the third leading cause of death and the fifth most common cause of disability up to 2020 in the world (1). This disease is diagnosed by the progressive obstruction of the airways, which is partly irreversible (2). Today, COPD has been shown to influence the function of organs other than the lungs. Its effect is particularly manifested in the respiratory muscle dysfunction in COPD patients.

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Several pathophysiological mechanisms including airway obstruction, air retention, and pulmonary hyperinflation may contribute to respiratory muscle injury (3). Respiratory muscles are essential components of the respiratory pump. The contraction of these muscles during the respiratory cycle deforms the thorax and facilitates the air exit and entry into the lungs through displacing its components (4, 5). Reduced respiratory muscle capacity in COPD could lead to dyspnea, which is the most debilitating symptom of COPD patients.

Hypercapnic respiratory failure due to respiratory muscle weakness is associated with increased morbidity in these patients (6-8). Recently, the number of studies, examining the role of respiratory muscle failure in COPD patients, has increased. Most of these studies have focused on the diaphragm as the main muscle in the respiration process. Studies have shown that defects in the diaphragmatic movements may be associated with changes in pulmonary function parameters (9, 10). However, further research is required with regard to the relationship between pulmonary function defects and diaphragmatic movements.

Several methods have been used in different studies for measuring diaphragmatic movements including chest radiography (11), CT scan (12), and dynamic MRI (13). Radiologic evaluation of diaphragmatic movements is carried out using fluoroscopy; however, the patient's exposure to ionizing radiation is the basic defect of this method (14).

In some recent studies, sonography along with the measurement of the vertical displacement of the left branch of the portal vein has been used as a method to assess diaphragmatic movements. According to literature review, few studies have concentrated on the evaluation of the relationship between the rate of diaphragmatic movement and pulmonary functional capacity in COPD patients. Therefore, this study was performed with the aim to investigate the relationship between the rate of diaphragmatic movements, pulmonary function, and activity function in COPD patients, using diaphragmatic movements to evaluate the rate of these movements and compare between patients and healthy ones.

Materials and Methods

This study is a cross sectional study which has been done in Ghaem hospital, Mashhad, Iran. All COPD patients (case group), referring to the Lung Clinic of Ghaem Hospital from June 2012 to june 2013 were enrolled in the study, based on the inclusion and exclusion criteria. The exclusion criteria were as follows: 1) disease relapse, 2) previous history of chest or upper abdominal surgery, 3) previous history of neuro muscular disorders, and 4) pleural effusion.

At first, a checklist including information such as demographic characteristics and medical history was completed. Spirometry was performed in accordance with the standard method, and the factors related to pulmonary function were recorded. Finally, the 6-minute walk test (6MWT) was performed.

After pulmonary evaluation, the patients were referred for sonography. To evaluate the diaphragmatic movements by the ultrasound method, Medison V20 and GERTX200 imaging systems were used, and the patients were assessed with 3.5mhz Convex Probe in dorsal decobitus position.

The status of the left portal vein or one of its branches at the end of a deep expiration and a deep inspiration was considered as a marker; diaphragm mobility was measured based on its movement (in millimeters) between these two points. In addition, M-mode sonography was performed for all patients.

Twenty-five healthy non-smoker subjects, who were matched with COPD patients in terms of age and sex, were studied as the control group for the comparison of sonographic findings in patients and healthy ones.

Statistical Analysis

SPSS version 14 was used for data analysis. Distribution of quantitative variables in the subgroups of qualitative variables was analyzed using t-student test. For assessing the relation between quantitative variables, Scatter/Dot Chart and Pearson correlation test were used. Before performing the statistical analysis, the normal distribution of quantitative variables was assessed by Kolmogronov-Smirnov test, and in case the variable was not normally distributed, non-parametric tests were applied. P-value less than (or equal to) 0.05 was considered statistically significant

Results

In this study, 25 COPD patients and 25 healthy non-smokers were evaluated. Approximately 84% of the patients in the case group were male, and the mean age of the case group was 59.2 ±12 years (Table 1).The Patients in the case group were examined in terms of pulmonary and activity functions. The information related to spirometric parameters, 6MWT and arterial oxygen can be seen in Table 2. According to GOLD criteria, the patients in the case group were classified in terms of disease severity. Of patients in this group, 36%, 28%, 8%, and 24% were in severe, moderate, mild, and zero stages of the disease, respectively.

Table1. Differences between 2 groups: case group and control group

Variant		Minimum	Maximum	Average	Standard deviation	P-value
Year (age)	Case group	59.20	35	59.20	12.00	0.578
	Control group	58.25	37	58.25	11.25	
Height (cm)	Case group	164.04	143	164.04	9.053	0.387
	Control group	163.58	148	163.58	10.48	
Weight (kg)	Case group	67.36	45	67.36	8.69	0.485
	Control group	66.58	46	66.58	7.58	
BMI (Kg/m²)	Case group	25.1430	19.58	25.1430	3.70	0.255
	Control group	25.85	19.86	25.85	3.42	

BMI: Body mass index

Table 2. Spirometery factors in COPD patients

Variant	Min	Max	Average	Standard deviation
FEV1	0.58	3.86	1.74	0.93
FEV1%	24.00	107.00	60.72	24.78
FVC (lit)	1.03	5.36	2.80	0.99
FEV1/FVC%	32.98	94.31	59.46	14.76
RV/TLC	0.16	0.81	0.5494	0.17
RV (lit)	0.36	9.67	4.17	2.33
TLC (lit)	2.20	11.95	7.11	2.47
6MWT (m)	180.00	497.00	370.12	79.17
o2 before	66.00	99.00	92.52	7.10
o2 after	65.00	99.00	92.24	6.91
SVC	1.17	5.40	2.90	0.94

FEV1:Forced expiratory volume in one second
FVC: Forced vital capacity
RV1: Residual volume
TLC: Total lung capacity
SVC: Slow vital capacity

Table 3. Correlation between diaphragm movement and patient's factors

variant	r	P-value
FEV1	0.556	0.004
FVC	0.619	0.001
FEV1/FVC	0.332	0.105
RV/TLC	0.313	0.128
RV	0.160	0.445
TLC	0.099	0.637
6MWT	0.494	0.012
o2 before	0.441	0.028
o2 after	0.505	0.010

FEV1: Forced expiratory volume in one second
FVC: Forced vital capacity
RV1: Residual volume
TLC: Total lung capacity
SVC: Slow vital capacity

Table 4. Differences of diaphragm movement in different patient groups based on severity

variant		Diaphragm movement		P-value
		Average	Standard deviation	
Disease severity	Stage 0	47.50	7.58	0.024
	Mild	47.142	15.77	
	Moderate	37.23	10.33	
	Severe	35.25	10.25	
	Very Severe	…….	33.5000	

The evaluation of the differences in the rate of diaphragmatic movements showed significant difference between the two groups; the mean rate of movement was 42.08±12.15 mm in the case group and 73.28 ± 15.19 mm in the control group (P value 0.024).

The diaphragmatic movement in the case group was associated with forced expiratory volume in 1 second (FEV1), forced vital capacity (FVC), 6MWT, primary and secondary O2, and SVC. However, it was not associated with factors related to pulmonary hyperinflation [total lung capacity (TLC)] or air retention in the lungs [residual volume (RV) and RV/TLC] (Table 3) (Figure 1A-F).

The evaluation of the differences in the rate of diaphragmatic movements in different classified groups, according to disease severity (based on GOLD criteria), presented a significant difference. In fact, the patients in stage zero had a higher mean of diaphragmatic movement and the patients in severe and very severe stages had a lower mean of diaphragmatic movement (Table 4).

In order to obtain the sensitivity and specificity of the rate of diaphragmatic movement for the detection of disease severity and to use Receiver Operating Characteristic (ROC) curve, the classified groups according to disease severity (based on GOLD criteria) were divided into 2 groups. The patients in zero, mild, and moderate stages were allocated to one group, and patients in severe and very severe stages were considered as another group.

ROC curve was drawn with regard to the rate of diaphragmatic movements in these two groups; the curve was determined according to the plotted points on the graph, as can be seen below (Figure 2).

Using the cut-off points in the following chart, the 37mm diaphragmatic movement in COPD patients, with 73% sensitivity and 70% specificity, represents disease severity (whether the severity is more or less than moderate).

Discussion

In the current study, there was a significant difference between the rates of diaphragmatic movement in COPD patients and healthy subjects; this finding has been confirmed by several other studies (9, 15-17). Although the reduced rate of

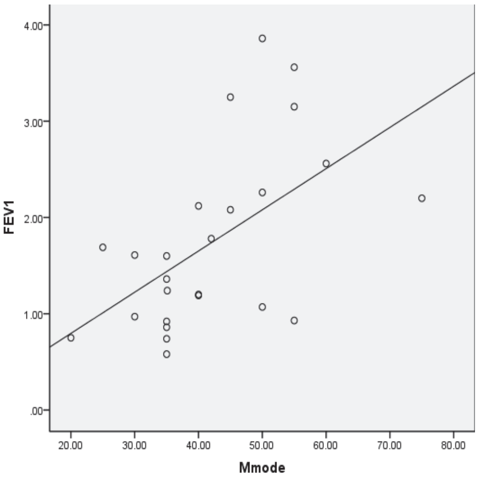

Figure 1 A. Correlation between diaphragmatic movement and FEV1

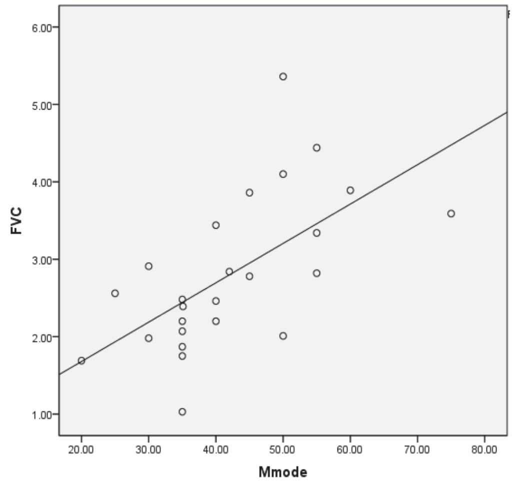

Figure 1B. Correlation between diaphragmatic movement and FVC

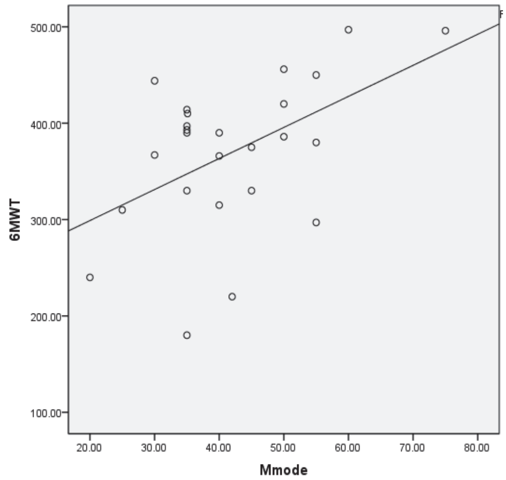

Figure 1C. Correlation between diaphragmatic movement and 6MWT

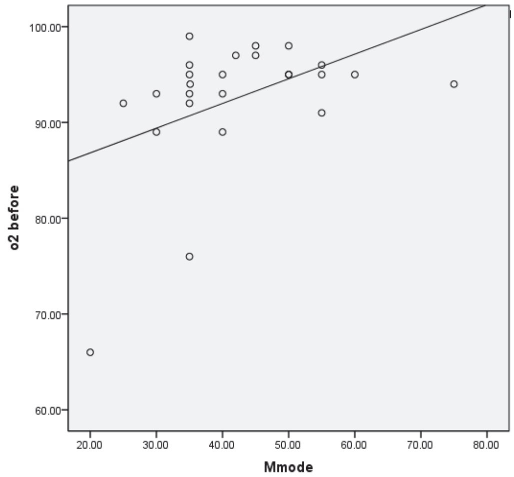

Figure 1D. Correlation between diaphragmatic movement and O 2 before 6MWT

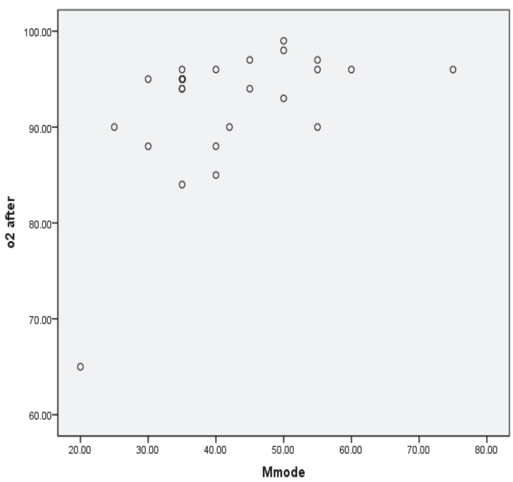

Figure 1E. Correlation between diaphragmatic movement and secondary o_2 saturation

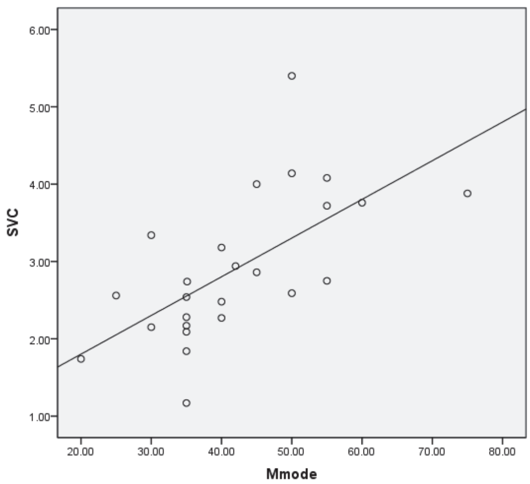

Figure 1F. Correlation between diaphragmatic movement and slow vital capacity

diaphragmatic movement in COPD patients is well established, the cause of this reduction is not fully understood.

One of the mentioned explanations is that the increased resistance and elastic load is due to the decreased pulmonary dynamic compliance, which leads to mechanical stress and stretch of the respiratory muscles. Additionally, thoracic hyperinflation, caused by air retention in COPD patients, can lead to diaphragmatic activities in abnormal positions within the thorax, which eventually have mechanical effects, and increase

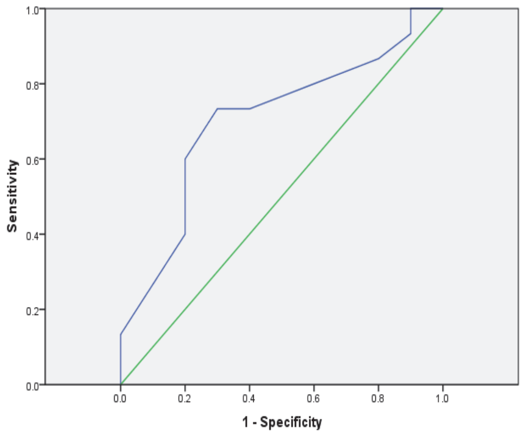

Figure 2. ROC diagram for diaphragm movement in 2 defined group based on disease severity

the mechanical load exerted on the diaphragm.

In this regard, some previous studies have suggested that the diaphragm is the most influenced muscle in COPD patients, which undergoes a 40% reduction (5, 18). In fact, diaphragmatic movement can be due to the excessive overlap of actin-myosin filaments or remodeling sarcomeres, or both.

The mean reduction in the diaphragmatic movement in the present study was higher compared to other studies. This could be related to the fact that 24% of the patients were in stage zero of the disease (based on the GOLD criteria) and less than 50% were in the severe and very severe stages. On the contrary, in the studies of Wook et al. (15) and Yamaqati et al. (9), the mean FEV1/FVC ratio was significantly lower than that of the present study.

So far, different methods have been applied for the measurement of diaphragmatic movement in various studies. For instance, so that Unal et al. (10) used fluoroscopy, and Suga et al. (13) and Iwasuma et al. (3) both employed MRI in their studies. The reduction in diaphragmatic movement in COPD patients (compared to healthy subjects) is confirmed in all conducted studies.

Sonography, as a modality without any associated radiation risks, is simply performed and provides valuable data; therefore, it could be more efficient compared to other diagnostic methods. However, sonographic evaluation is normally associated with two limitations. Firstly, it is performed in the supine position, while pulmonary tests are carried out in a sitting position. Secondly, in most studies, including the present one, only the displacement of the right diaphragm and the left branch of the portal vein are considered.

In this context, it should be noted that other diagnostic modalities are also performed in the supine position and this problem is found in other diagnostic techniques. Moreover, Boussagus et al. (17) and Suga et al. (13) in healthy and COPD subjects, respectively, showed no significant differences between the left- and right-side diaphragmatic movements.

In the present study, the rate of diaphragmatic movement was significantly associated with FEV1 and disease severity. In addition, FEV1/FVC ratio was significantly lower in the group with movement less than 40mm. These findings in fact, show that diaphragmatic movement is associated with airway obstruction and pulmonary function in COPD patients.

However, the present study did not indicate a relationship between diaphragmatic movement and TLC which represents pulmonary hyperinflation; also, diaphragmatic movement was not linked to RV and RV/TLC which represent air retention in COPD patients.

The finding of the present study regarding the relationship between airway obstruction and diaphragmatic movement was consistent with the results of other studies in this field (15-17).

Lack of a significant relationship between diaphragm displacement and factors associated with hyperinflation and air retention in the current study is inconsistent with some other studies. This could be due to the fact that the majority of patients in this study were in the moderate stage of the disease. Unlike the present research, in other studies, COPD patients with higher stages of the disease were selected. In fact, we can say that if these subjects were in lower stages of the disease, factors related to air retention and hyperinflation (RV, TLC and RV/TLC) would have a less significant association with diaphragmatic movement.This can be confirmed by the study of Scott et al. (19), who conducted a research on healthy subjects and demonstrated that the rate of diaphragmatic movement was not associated with TLC and RV. However, this finding could be justified by the mechanism of diaphragm injury. Since it is well established that one of the main mechanisms of reducing diaphragm movement is increased hyperinflation, there is less damage to the diaphragm in patients in lower stages of COPD in the present study (compared to the other studies). As a result, the patients had not reached a significant level of diaphragmatic movement or hyperinflation. Although FEV1 is considered an essential factor for diagnosis in COPD patients, it is not sufficient to demonstrate the systemic manifestations of COPD, caused by insufficient ventilation (20). Therefore, it has been suggested that another parameter be considered for the evaluation of functional changes in COPD patients. The results of this study show that the rate of diaphragmatic movement can be used as another parameter, which provides data about the functional capacity and respiratory mechanics in COPD patients.The results of this study also indicate a significant relationship between activity capacity and the rate of diaphragmatic movement. In fact, patients with a lower rate of diaphragmatic movement covered a significantly shorter distance in 6MWT test. This finding could be due to the mechanical failure of diaphragm, since it leads to ventilation defects (21). Defects in ventilation, due to air retention in COPD patients, leads to diaphragm flattening, and as a result, the length/tension ratio of diaphragm muscle cells changes and causes a reduced function and defect in ventilation, particularly during physical activities. It is recommended that more studies be performed with larger sample size. Also, more attention should be paid to different stages of the disease in order to analyze the results with more confidence.

Conclusion

The results of the present study showed that the rate of diaphragmatic movement could provide extensive data about functional capacity and respiratory mechanics. In addition, these results indicated that sonography along with factors related to pulmonary function could be used as a diagnostic method in COPD patients. The rate of diaphragmatic movement, as a parameter for determining exercise capacity in COPD patients, can provide more information about the activity limitations of these patients. It can also help clinicians select a treatment strategy suitable for these patients.

Conflict of Interest

The authors declare no conflict of interest.

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