Original Article

Study of the diaphragm in chronic obstructive pulmonary disease using ultrasonography

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ABSTRACT

Aims and Objectives: The study aims to compare the changes in the diaphragm in chronic obstructive pulmonary disease (COPD) patients in Indian population with the help of ultrasound-guided examination. (1) Changes in thickness of the diaphragm during respiration(to rule out diaphragm muscle atrophy). (2) The movement of the diaphragm(correlates with strength and endurance of diaphragm fibres) . (3) Zone of apposition(gives mechanical advantage to diaphragm). (4) Correlation with COPD severity by global initiative for chronic obstructive lung disease (GOLD) staging. **Subjects and Methods:** Forty-eight COPD patients attending OPD of DY Patil Hospital were recruited in the study and twenty age-matched controls were taken. Detailed history, pulmonary function test examination, and diaphragm study under ultrasonography was done. **Results:** The movement of diaphragm was reduced in mild to moderate COPD (A and B) but increased in COPD with Grade C. Movement of diaphragm was significantly more in cases with COPD Grade B (2.329 cm) and C (2.269 cm) as compared to controls (1.891 cm). Mean diaphragmatic thickness during inspiration and expiration, change in thickness, and zone of apposition were significantly higher in patients with COPD score Grade C as compared to Grade A or B. Zone of apposition was significantly decreased in Grade A (3.257 cm) and B (3.429 cm) compared to control (4.268 cm), while it was significantly increased in cases with Grade C (5.138 cm). **Conclusion:** The diaphragm is the main muscle of respiration, and study of diaphragm is very important in COPD. The diaphragm thickness, movement, and zone of apposition were significantly reduced in mild to moderate COPD but increased in severe COPD. This cannot be explained by physiotherapy or collagen accumulation. Hence, diaphragm muscle biopsy and electromyogram study in COPD patients will be required to get a better understanding of this muscle in COPD.

KEY WORDS: Chronic obstructive pulmonary disease, diaphragm, movement, thickness

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INTRODUCTION

Chronic obstructive pulmonary disease (COPD) is defined as a common preventable and treatable disease, characterized by persistent airflow limitation that is usually progressive and associated with an enhanced chronic inflammatory response in the airways and the lung to noxious particles or gases. Exacerbations and comorbidities contribute to the overall severity in individual patients.[1] The global initiative for chronic obstructive lung disease (GOLD) was initiated in 1998 with a goal to produce recommendation for management of COPD based on the best scientific information available. As per the GOLD guidelines, COPD can be classified as mild, moderate, severe, and very severe on the basis of forced expiratory volume 1.

The diaphragm is a muscular tendinous sheath that closes the opening between thorax and abdomen and is pierced

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by structures that pass between these two regions of the body. The diaphragm is the primary muscle of respiration. It is dome shaped and consists of a peripheral muscular part and central tendinous part. The muscular part arises from the margins of the thoracic opening and gets inserted into the central tendon.[2]

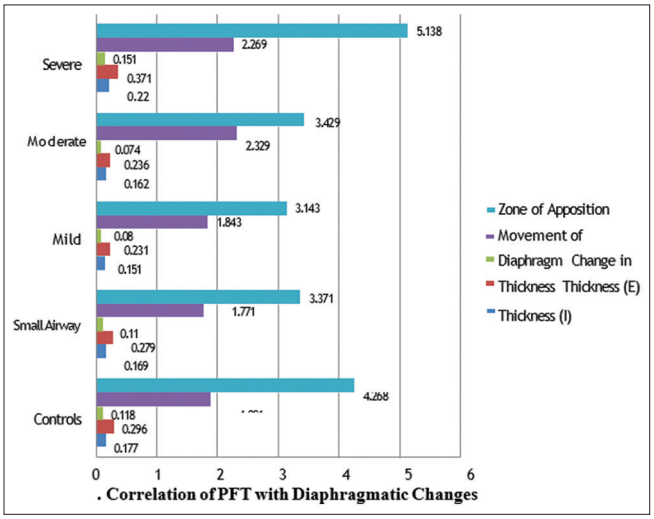


Figure 1: Pulmonary function test versus diaphragm

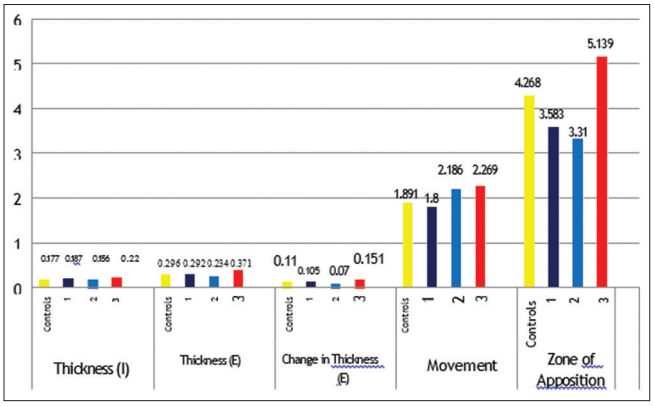


Figure 2: Modified medical research council grading versus diaphragm changes

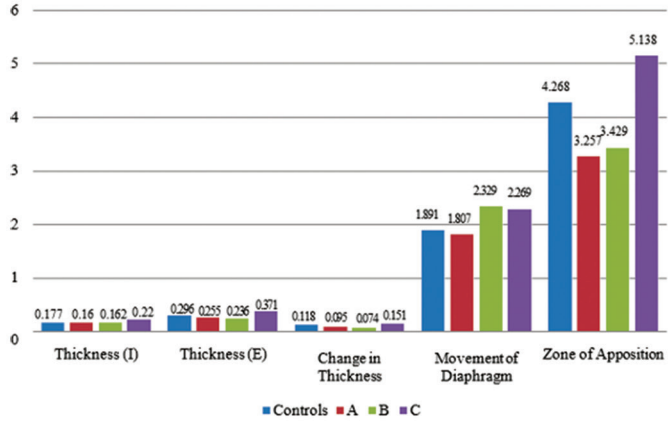
The thickness of the diaphragm changes dynamically between the relaxed phase and maximum inspiration.[3] Thickness of the diaphragm is measured at the end of inspiration and expiration. The contraction of the diaphragm is visualized at the zone of apposition. This zone of apposition is the area where the abdominal contents meet the lower rib cage. On the right side, the diaphragm lies between the lower rib cage and the liver. It is the ideal area to visualize the diaphragm. Zone of apposition ultrasound is done using high-resolution probes of high penetration with 7–10 MHz[4,5] because the costal portion of the diaphragm is close to the skin; the zone of opposition is an ideal area to use ultrasound for assessment of diaphragm thickness and estimation of length. The technique is noninvasive, inexpensive, portable, and free of ionizing radiations. Diaphragmatic ultrasound has been proved useful in the diagnosis of dysfunctions in COPD patients.[6,7]

SUBJECTS AND METHODS

Our study is a cross-sectional study where 48 COPD patients attending OPD of DY Patil Hospital were recruited in the study and twenty age-matched controls were taken. Detailed history, pulmonary function test (PFT) examination, and diaphragm study under ultrasonography was done.

RESULTS

Mean diaphragmatic thickness during inspiration and expiration and zone of opposition were significantly decreased in patients with small airways, mild to moderate obstruction and increased in cases with severe



COPD grade	Controls		A		B		C		p-value (cases)	p- value (Controls)
	Mean	SD	Mean	SD	Mean	SD	Mean	SD		
Thickness (I)	0.177	0.035	0.160	0.040	0.162	0.064	0.220	0.057	< 0.05 (C vs A/B)	NS
Thickness (E)	0.296	0.104	0.255	0.065	0.236	0.076	0.371	0.114	< 0.05 (C vs A/B)	NS
Change in Thickness	0.118	0.117	0.095	0.041	0.074	0.049	0.151	0.114	< 0.05 (C vs A/B)	NS
Movement of Diaphragm	1.891	0.148	1.807	0.279	2.329	0.428	2.269	0.665	< 0.05 (C vs A & B vs A)	<0.05 (severe & Moderate vs Controls
Zone of Apposition	4.268	0.249	3.257	0.682	3.429	0.553	5.138	0.683	< 0.05 (C vs A/B)	<0.05 (all grades)

Figure 3: Chronic obstructive pulmonary disease grade versus diaphragm parameters

Table 1: Correlation of pulmonary function test with diaphragmatic changes

PFT	Controls		Small Airway		Mild		Moderate		Severe		*P* (cases)	*P* (controls)
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD		
Thickness (I)	0.177	0.035	0.169	0.040	0.151	0.042	0.162	0.064	0.220	0.057	<0.05(severe vs others)	NS
Thickness (E)	0.296	0.104	0.279	0.071	0.231	0.052	0.236	0.079	0.371	0.114	<0.05(severe vs. others)	NS
Change in thickness	0.118	0.117	0.110	0.041	0.008	0.037	0.074	0.049	0.151	0.114	0.143 (non-Significant)	NS
Movement of Diaphragm	1.891	0.148	1.771	0.125	1.843	0.387	2.329	0.428	2.269	0.665	<0.05 (Severe & Moderate vs Others)	<0.05 (Severe & Moderate vs Controls)
Zone of appsition	4.268	0.249	3.371	0.594	3.143	0.791	3.429	0.533	5.138	0.683	<0.05 (Severe vs Others	<0.05 (all grades)

Table 2: Correlation of diaphragmatic changes with modified medical research council dyspnea scale grade

Variable	mMRC Grade	Mean	SD	*P* (Cases)	*P* (Control)
Thickness (I)	Controls	0.117	0.035	<0.05	NS
	1	0.187	0.027	(2 vs. 3)	
	2	0.156	0.058		
	3	0.220	0.057		
	Total	0.177	0.054		
Thickness (E)	Controls	0.296	0.104	<0.05	NS
	1	0.292	0.068	(2 vs. 3)	
	2	0.234	0.069		
	3	0.371	0.114		
	Total	0.284	0.101		
Change in thickness (E)	Controls	0.118	0.117	0.089	NS
	1	0.105	0.043		
	2	0.078	0.046		
	3	0.151	0.114		
	Total	0.106	0.091		
Movements	Controls	1.891	0.148	<0.05 (NS)	Sig vs. Grade3
	1	1.800	0.110		
	2	2.186	0.469		
	3	2.269	0.665		
	Total	2.076	0.451		
Zone of apposition	Controls	4.268	0.249	<0.05	Sig. vs. all grades
	1	3.583	0.214	(1 vs. 3 and	
	2	3.314	0.650	2 vs. 3)	
	3	5.139	0.683		
	Total	3.976	0.868		

airway obstruction as compared to controls; movement of diaphragm was significantly more in cases with moderate to severe obstruction as compared to controls.

The zone of apposition was decreased in mild to moderate obstruction compared to controls while it was significantly increased in patients with severe obstruction [Table 1 and Figure 1].

No significant difference was observed in change in thickness of diaphragm between inspiration and expiration in both cases and controls.

Mean diaphragmatic thickness during inspiration and expiration and zone of opposition were significantly higher in patients with dyspnea modified medical research council (mMRC) Grade 3 as compared to Grade 2 and controls. The zone of apposition was significantly higher in patients with mMRC Grade 3 as compared to Grade 1.

Movement of the diaphragm was significantly more in cases with mMRC Grade III as compared to controls. Zone of apposition was more in controls as compared to Grade I and II while it was significantly less than cases with Grade III [Table 2 and Figure 2].

No difference was observed in change in thickness of the diaphragm between inspiration and expiration in both among cases and controls.

Mean diaphragmatic thickness during inspiration and expiration, change in thickness, and zone of apposition were significantly higher in patients with COPD score Grade C as compared to Grade A or B. The movement of diaphragm was significantly higher in patients with COPD Grade C and Grade B as compared to Grade A.

Movement of the diaphragm was significantly more in cases with COPD Grade B (2.329 cm) and C (2.269 cm) as compared to controls (1.891 cm). Zone of apposition was significantly decreased in Grade A (3.257 cm) and B (3.429 cm) compared to controls (4.268 cm), while it was significantly increased in cases with Grade C (5.138 cm) [Figure 3].

No difference was observed in change in thickness of the diaphragm between inspiration and expiration among cases and controls.

DISCUSSION

Diaphragm weakness has been ascribed to hyperinflation-induced diaphragm shortening due to loss of muscle fibers. In emphysema, there is a loss of long sarcomeres and reduced diaphragm length, especially in the zone of apposition of the diaphragm to the rib cage. In addition, Ottenheijm *et al.*[8] postulated that oxidative stress and sarcomeric injury may lead to contractile protein wasting and consequently, loss of force-generating capacity of diaphragm fibers in patients with COPD.

Ultrasound of the diaphragm is a noninvasive, reliable, and relatively inexpensive diagnostic tool that is becoming more readily available with the advent of portable high-resolution machines.

The primary goal of this study was to determine the diaphragm muscle thickness, diaphragmatic movement, and zone of apposition in patients with COPD compared with normal controls.

In this study, we have included 48 stable COPD patients with 22 non-COPD controls; of the 29 (41.42%) female subjects, 21 (72.41%) had COPD, and of 41 male subjects, 27 (65.85%) had COPD, and the rest were controls.

PFT was performed in all COPD patients in which 7 had small airway and mild obstruction, 21 had moderate obstruction, and 13 had severe obstruction.

mMRC dyspnea scale was evaluated from history of the COPD patient in which 6 patients had Grade 1, 29 had Grade 2, and 13 had Grade 3 dyspnea scale.

Diaphragmatic changes were evaluated with help of B mode ultrasound among COPD patients and non-COPD controls.

Correlation of PFT with diaphragmatic changes: The mean diaphragmatic thickness was decreased as compared to controls in small airway, mild and moderate obstruction patients; this can be explained by thinning and shortening of the diaphragm due to hyperinflation in severe COPD.[9,10] Diaphragm thickness in expiration was increased in severe (0.371 cm) compared to control (0.296 cm); this cannot be explained, perhaps patients develop some adaptations in diaphragm muscle like collagen accumulation in chronic severe obstruction. In COPD, the contractile force of diaphragm is reduced when hyperinflation of the lung shortens the diaphragm muscle resting length.

The movement of diaphragm was decreased in mild and small airway obstruction but significantly increased in moderate (2.329) and severe obstruction (2.269) compared to controls. The decreased movement of diaphragm can be explained by air trapping and hyperinflation.[11] The increased diaphragmatic movement in moderate and severe obstruction is not readily explained. Perhaps, severe airway obstruction could lead to hypoxia with hyperventilation leading to increase in diaphragmatic movement. These patients were enrolled in pulmonary rehabilitation[12] with deep breathing exercises and diaphragmatic strengthening exercises during physiotherapy, perhaps increased diaphragmatic movement can be explained by this. Further studies on diaphragmatic movement in COPD may be required, along with diaphragmatic muscle biopsy and electromyogram (EMG) study.

The zone of apposition is decreased in small airways, mild, moderate airway obstruction; but, in severe obstruction, it is significantly increased, compared to controls. This decreased zone of apposition in small, mild, and moderate airway obstruction can be explained by air trapping and hyperinflation in COPD.[13,14] However, significantly increased zone of apposition in severe COPD is difficult to explain. It might be due to some adaptations in diaphragm like collagen accumulation or increase in abdominal pressure in 5 out of 13 patients of severe COPD[15] who had high body mass index. In these patients, truncal obesity may have pushed the diaphragm up increasing the zone of apposition.

Correlation of diaphragmatic changes with mMRC dyspnea scale: The mean diaphragmatic thickness during expiration was decreased with mMRC dyspnea scale Grade 1 and 2 compared to controls and mMRC dyspnea scale Grade 3 was increased as compared to controls. Undernutrition in COPD reduces the muscle mass, thus reducing the diaphragmatic thickness. The diaphragmatic thickness in our study was significantly increased in all 13 patients who had mMRC Grade 3 dyspnea and severe obstruction (PFT GOLD Stage 3). This is difficult to explain perhaps patients develop some adaptations in the diaphragm in severe obstruction, such changes may be explained by diaphragm muscle biopsy and EMG study. The movement of diaphragm was less in mMRC dyspnea scale 1 and increase in mMRC dyspnea scale Grade 2 and Grade 3 compared to controls. This could be due to increased perception of breathlessness[16] in patients with increased movement of diaphragm. The zone of apposition was less in controls as compared to mMRC Grade 1 and 2 while it was significantly more in Grade 3. This is not explained; it might be due to some adaptation (Adaptation in diaphragm muscle fibres in copd include shift from type 2 to type 1 aerobic, slow fatigue fibres)[17,18] in diaphragm and increase in abdominal pressure.

Correlation of COPD Assessment Test (CAT) score with diaphragmatic changes: The mean diaphragmatic thickness was decreased compared to controls in CAT Grade A (low risk, less symptoms) and Grade B (more symptoms, low risk) and increased in CAT Grade C; this could be because of adaptations in diaphragm CAT Grade C (high risk, low symptoms) and may be due to hyperventilation and hypoxemia. The mean movement of diaphragm in control was 1.891 cm while in CAT Grade A was 1.807 cm, CAT Grade B was 2.329 cm, and CAT Grade C was 2.289 cm, thus movement of diaphragm is increased in CAT Grade B and CAT Grade C; this is due to hyperinflation of lungs, but the diaphragmatic movement increase is not explained; this could be due to the fact that there is diaphragmatic muscle fatigue, so the diaphragm is pushed upward during expiration and also there is increase in abdominal pressure. Further studies are required of this diaphragmatic movement; even diaphragm muscle biopsy and EMG study may be required to explain this. The zone of apposition in CAT Grade A and B is less, compared to control. However, it is significantly high in CAT Grade C (high risk, low symptoms). This is also not explained but it could be due to some adaptations in diaphragm and increase in abdominal pressure.

CONCLUSION

The diaphragm is the main muscle of respiration, and study of diaphragm is very important in COPD. The diaphragm thickness, movement, and zone of apposition were significantly reduced in mild to moderate COPD due to overall reduced muscle mass[19,20] in COPD because of systemic inflammation, but in severe COPD, an increase in movement, thickness, zone of apposition were observed, perhaps due to increased transpulmonary

pressure variations and adaptive diaphragmatic changes like collagen accumulation. Even taking into account that these patients were undergoing physiotherapy with diaphragmatic exercises, this increased diaphragmatic movement in severe COPD cannot be explained. There have been no comparable studies of diaphragm in COPD patients. Hence, further studies including diaphragm muscle biopsy[21] and EMG study[20,22] in COPD patients will be required to get a better understanding of this muscle in COPD.

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Conflicts of interest
There are no conflicts of interest.

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