EVALUATION OF DIAPHRAGMATIC FUNCTION BY M-MODE ULTRASONOGRAPHY IN CHRONIC OBSTRUCTIVE LUNG DISEASES

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ОЦЕНКА ДИАФРАГМАЛЬНОЙ ФУНКЦИИ ПРИ УЛЬТРАЗВУКОВОМ ИССЛЕДОВАНИМ В М-РЕЖИМЕ ПРИ ХРОНИЧЕСКОЙ ОБСТРУКТИВНОЙ БОЛЕЗНИ ЛЕГКИХ

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Summary. Aim: to determine the role of M-mode ultrasonography (USG) in evaluating diaphragmatic function in healthy and chronic obstructive pulmonary disease (COPD) patients and the correlation between pulmonary function tests (PFTs) and diaphragmatic function.

Materials and methods: Hemidiaphragmatic excursion and diaphragmatic thickness during tidal ventilation (TV) and deep inspiration (DI) were measured by USG in COPD and control patients. PFTs were performed, and diaphragmatic motion (DM) in both groups was compared. The correlation between PFT and DM was evaluated. Mann-Whitney U and Pearson correlation tests were used for statistical analysis.

Results: Our study included 76 COPD patients and 30 controls. Mean DM during TV was 2.21 ± 0.56 cm in the control group and 1.65 ± 0.66 cm in the COPD patients. The difference between the 2 groups was statistically significant ($P < 0.001$). During DI, the mean diaphragmatic excursion (DE) was 6.23 ± 0.74 cm in the control group and 4.64 ± 1.34 cm in the COPD group. The difference was statistically significant ($P < 0.001$). COPD patients were classified according to the Global Strategy for the Diagnosis, Management, and Prevention of Chronic Obstructive Pulmonary Disease 2011. Group A consisted of mild-moderate COPD patients; group B consisted of severe-very severe COPD patients. In group A, a weak correlation was found between DE and forced expiratory volume for 1 s (FEV1) expressed as a percentage of the forced vital capacity (FVC) (FEV1%) and percentage of FEV1/FVC (FVC%) during tidal volume. During DI, a moderate correlation was determined between DM and FEV1, FEV1%; otherwise, a strong correlation was found between DE and FVC, FVC% during DI. In group B, a weak correlation was found between diaphragmatic function and PFT parameters.

Conclusion: M-mode USG is a noninvasive and inexpensive method of evaluating DM. DE was significantly lower in COPD patients when compared with control subjects. In mild-moderate COPD patients, a strong correlation was confirmed between DE and FVC, FVC% during DI.

Key words: chronic obstructive pulmonary disease, diaphragm, M-mode ultrasonography

Резюме. Цель: определить роль м-режима ультразвукового исследования (УЗИ) в оценке диафрагмальной функции у здоровых пациентов и больных хронической обструктивной болезнью легких (ХОБЛ), определить корреляцию между легочной функцией (ПФТС) и диафрагмальной функцией.

Материалы и методы. Гемидиафрагмальная подвижность и толщина диафрагмы во время дыхательной вентиляции/выдоха (ДВ) и при глубоком вдохе (ГВ) измерялись при помощи ультразвукового исследования в контрольной группе и опытной группе пациентов с ХОБЛ. Были произведены исследования функции легких, а также сравнение диафрагмальной подвижности в обеих группах. Была произведена оценка взаимосвязи между исследованиями функции легких и диафрагмальной подвижностью. Для статистического анализы использовались корреляция Пирсона и тест Mann-Whitney U.

Результаты: в исследовании участвовала группа из 76 пациентов, страдающих ХОБЛ, а также 30 человек контрольной группы. Средние показатели диафрагмальной подвижности во время дыхательной вентиляции/на выдохе составили 2.21 ± 0.56 см в контрольной группе и 1.65 ± 0.66 см в группе пациентов с ХОБЛ. Разница между группами статистически достоверна ($P < 0.001$). Во время глубокого вдоха показатели диафрагмальной подвижности составили 6.23 ± 0.74 см в контрольной группе и 4.64 ± 1.34 в группе пациентов с ХОБЛ. Разница между группами статистически достоверна ($P < 0.001$). Больные ХОБЛ были классифицированы по группам в соответствии со стандартами Глобальной стратегии по диагностике, управлению и профилактика хронической обструктивной болезни легких 2011г. В группу А были включены пациенты с легкой и средней степенью тяжести ХОБЛ, в группу Б были включены пациенты в тяжелом и крайне тяжелом состоянии в следствие ХОБЛ. В группе А наблюдалась слабая взаимосвязь между диафрагмальной подвижностью и объемом форсированного воздуха за 1 секунду (ОФВ 1), выраженная в процентном соотношении от форсированной жизненной ёмкости легких (ФЖЕ 1%), на выдохе. Во время глубокого вдоха была определена умеренная взаимосвязь между диафрагмальной подвижностью и ОФВ 1, ФЖЕ 1%, в остальных случаях наблюдалась сильная взаимосвязь. В группе Б наблюдалось слабое соответствие между диафрагмальной функцией и параметрами исследованиий функции легких.

Заключение: ультразвуковое исследование в М-режиме является неинвазивным и недорогим методом оценки диафрагмальной подвижности, которая была значительно ниже в группе пациентов с ХОБЛ по сравнению с контрольной группой. У больных малой и средней степени тяжести ХОБЛ, наблюдалась сильная корреляция между диафрагмальной подвижностью и ОФВ, ФЖЕ% во время глубокого вдоха.

Ключевые слова: хроническая обструктивная болезнь легких, диафрагма, ультразвуковое исследование в М-режиме

Introduction. Diaphragmatic dysmotility or dysfunction is commonly associated with conditions such as neuromuscular disorders, thoracic or abdominal surgery, and obstructive lung diseases including chronic obstructive pulmonary disease (COPD) and traumatic phrenic nerve injury [1]. Objective measurement of diaphragmatic function is of clinical importance.

Fluoroscopy or electrical or magnetic phrenic nerve stimulation is readily used for measuring diaphragmatic function. However, invasiveness and exposure to ionizing radiation limit the utility of these methods. Ultrasonography (USG) has many advantages over these other techniques, including noninvasiveness, lack of ionizing radiation and the possibility of bedside use. It is inexpensive, efficient and reproducible [2-4]. B-mode USG visualises craniocaudal displacement of the portal vein’s left branch, whereas M-mode tracings are obtained to assess vertical diaphragmatic motion [5].

COPD is characterised by progressive airflow limitation, pulmonary hyperinflation and air trapping accompanied by small airway and lung parenchymal pathologies. Inflammation affects systemic vasculature, peripheral blood and striated muscles as well as the lungs [6]. In COPD patients, the diaphragm has to work against more negative pressure because of hyperinflation and air trapping. Therefore COPD patients have decreased diaphragmatic motility compared with healthy age-matched individuals [6-8].

The aim of our study was to evaluate diaphragmatic function in COPD patients by using a noninvasive method (M-mode USG) and to determine the relationship between diaphragmatic function and pulmonary function tests (PFTs). COPD patients were classified according to severity of obstruction as in Global Strategy for the Diagnosis, Management, and Prevention of Chronic Obstructive Pulmonary Disease (GOLD) 2011. Diaphragmatic movement and the relationship between diaphragmatic movement and PFT parameters in these groups were statistically analysed.

Material and methods. Stable COPD patients admitted to our clinic in 2009 and healthy subjects eligible for the study were included. The diagnosis of COPD was made on the basis of clinical evaluation, physical examination and PFTs using GOLD 2011 criteria [9].

The control group had a forced vital capacity (FVC) > 80%, a forced expiratory volume for 1 s (FEV1) > 80% and an FEV1/FVC > 70%. Subjects having another cardiorespiratory disease or liver disease, history of abdominal or thoracic surgery, ascites, or chest or abdominal pain and pregnant women were not included in the study. Patients with a body mass index (BMI) greater than 30 were excluded. All patients gave written informed consent to participate. Patients underwent clinical, laboratory and radiological evaluation.

After a detailed history and physical examination, signs and symptoms were recorded. PFTs were performed using the Sensor Medics Vmax 22 device. FVC, percentage of FEV1/FVC (FVC%), FEV1, FEV1 expressed as a percentage of FVC (FEV1%), FEV1/FVC, maximum inspiratory pressure (MIP) and maximum expiratory pressure (MEP) values were recorded. It would have been better to measure residual volume that reflected air trapping better, but we have no opportunity to measure static pulmonary parameters in our clinic.

USG was performed by a chest physician blinded to PFTs in B- and M-mode conditions using a General Electric Logic 7 device with 3.5-MHz convex probe. The transducer was applied subcostally on the right upper quadrant between the midclavicular and anterior axillary lines and directed laterally, cephalad and dorsally until the liver dome was visible. The M-mode trace was obtained by adjusting the cursor to cross the liver dome, and measurements were taken and recorded (Figure 1).

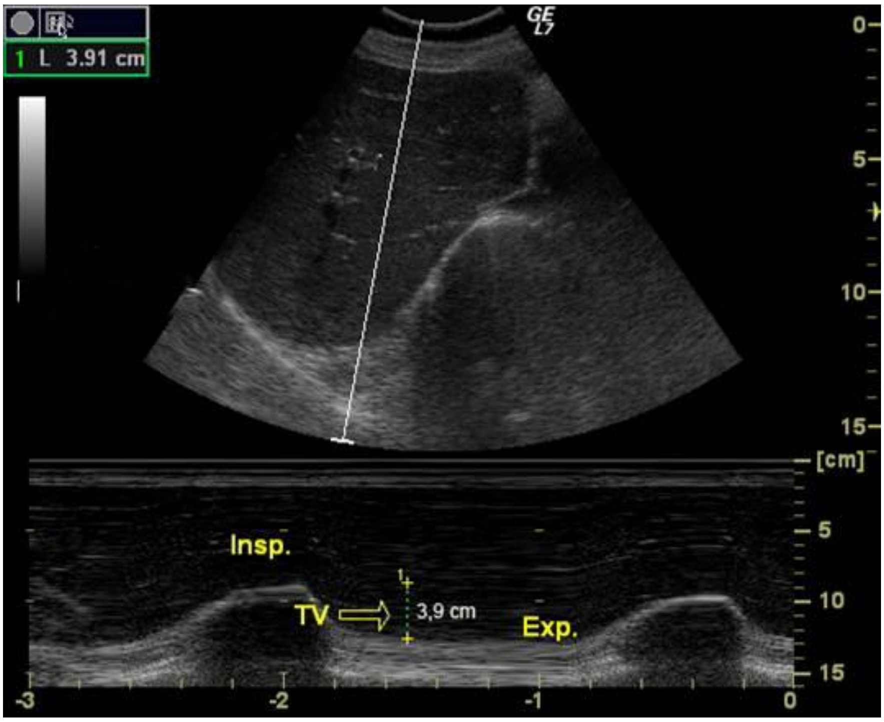

Figure 1- Measuring the diaphragmatic function by M - mod ultrasonography

Vertical movement of the right hemidiaphragm during tidal volume (TV) and deep inspiration (DI) as well as diaphragmatic thickness during inspiration were analysed. Patients were asked to perform tidal and deep breathing while in the supine position. Three consecutive sonographic examinations were performed and the mean of these 3 measurements was recorded. Ultrasonographic measurements of diaphragmatic movement in COPD and control groups were compared and significance was statistically evaluated. COPD patients were classified according to the severity of obstruction. As in GOLD 2011, mild- and moderate-level patients were classified as 1 group; severe and very severe patients were placed in another group. In addition, the relationship between vertical excursion of the right hemidiaphragm and PFTs was determined in both groups.

The protocol was approved by the local ethics committee, and written informed consent was obtained from all the patients included in the study. Statistical analyses were performed using Student *t* and Pearson correlation tests. Diaphragmatic motions were compared statistically by Mann-Whitney U test. The Student *t* test was used in both COPD groups to evaluate the relation between diaphragmatic motion and PFT parameters.

Results. Our study population consisted of 76 COPD patients and 30 healthy subjects. The COPD and control groups had similar statistics with respect to BMI (24.1 ± 3.5 vs 24.2 ± 2.6) and mean age (64.1 ± 10.0 vs 60.0 ± 11.0) (Table 1).

Table 1 - Comparison of COPD and control groups

	COPD Group			Healthy Group			
	Min.	**Max.**	**Mean**	**Min.**	**Max.**	**Mean**	*P value*
Age	38	86	64.1	37	79	60.0	>0.05
BMI	16.1	29.9	24.1	16.4	28.7	24.2	>0.05
TV	0.59	3.45	1.65	1.14	4.11	2.21	<0.05
DI	2.37	9.09	4.64	5.10	8.22	6.23	<0.05
DT	0.47	1.58	0.96	0.43	1.90	0.78	<0.05

Min: Minimum, Max : Maximum, BMI : Body Mass İndex, TV : diaphragmatic motion during TV, DI : diaphragmatic motion during deep breathing, DT : diaphragmatic thickness

COPD patients had smoking history of 42 pack-years, whereas control subjects had smoked 8.6 pack-years, with the difference being statistically significant ($P < 0.0001$). Radiological changes in COPD cases revealed signs of hyperinflation (flattened diaphragm, increased retrosternal air space volume, hyperlucency) (63.4%). In the COPD group, the mean FEV1 value was 1391.1 ± 718.4 mL, the mean FVC was 2955.9 ± 1169.6 mL and the lowest FEV1 was 400 mL, whereas control subjects had FEV1 and FVC values of 3008.5 ± 551.6 mL and 4093.1 ± 714.2 mL, respectively. MIP% and MEP% were 60.9 ± 26 and 26.7 ± 12 in the COPD group, respectively. These values were lower than in the control group with statistical significance ($P = 0.021$ and $P < 0.001$, respectively) (Table 2).

Table 2 - Comparison of pulmonary function tests in COPD and control groups

	COPD Group			Healthy Group			
	Min.	**Max.**	**Mean**	**Min.**	**Max.**	**Mean.**	*P value*
FEV1(ml)	400	3660	1425	1391	4290	3008	<0.001
FVC(ml)	810	5360	2955	2430	5340	4093	<0.001
FEV1/FVC	26	68	47	71	97	79	<0.001
%MIP	15	127	59	61	126	69	<0.129
%MEP	4	63	27	20	57	40	<0.001

Min : Minimum, Max : Maximum,, MIP : Maximal İnspiratuar Pressure, MEP: Maximal Ekspiratuar Pressure

Diaphragmatic vertical excursion movement measured at TV was 2.21 ± 0.56 in the control subjects and 1.65 ± 0.66 in the COPD patients, with the difference being statistically significant ($P < 0.001$). Diaphragmatic movement during DI was significantly lower in the COPD group (4.64 ± 1.34 cm) compared with the control group (6.23 ± 0.74 cm) ($P < 0.001$). Diaphragmatic movements were lower in the COPD group during both TV and DI. Diaphragmatic thickness during inspiration was significantly higher in the COPD group than in the control group (0.96 ± 0.24 vs 0.78 ± 0.28 cm, respectively) (Table 3).

Table 3 - Diaphragmatic motion screened by M - mode USG in both groups

	COPD group		Healthy group		
	Mean	**SD**	**Mean**	**SD**	*P value*
TV(cm)	1.65	0.66	2.21	0.56	<0.001
DI (cm)	4.64	1.34	6.23	0.74	<0.001
Diaphragmatic thickness	0.96	0.24	0.78	0.28	<0.001

TV : Tidal Ventilation, Dİ : Deep Inspiration, SD : Standart Deviation

COPD patients were classified according to the severity of obstruction as in GOLD 2011. Group A consisted of mild and moderate COPD patients; group B consisted of severe and very severe COPD patients as measured by FEV1 in GOLD 2011 guideline. Group A included 35 (46%) COPD patients and group B included 41 (54%) COPD patients. Both groups were similar according to age, smoking history and BMI. Diaphragmatic motion during TV was 1.47 ± 0.72 cm in group A and 1.79 ± 0.58 cm in group B. This difference was statistically significant ($P < 0.004$).

Diaphragmatic motion during deep breathing was 4.68 ± 1.53 cm in group A and 4.59 ± 1.16 cm in group B. The difference between the 2 groups was not statistically significant ($P > 0.005$). In addition, the thickness of the diaphragm was greater in group B than in group A, which was not statistically significant ($P > 0.005$) (Table 4). In group A, MIP and MIP% was 60.37 ± 4.61 and 58.18 ± 4.76, respectively. In group B, these values were 70.43 ± 6.56 and 64.71 ± 6.02. The difference between the 2 groups was not statistically significant ($P > 0.05$). MEP values were 58.38 ± 3.72 in group A and 43.50 ± 0.79 in group B, which was statistically significant ($P < 0.008$). In group A, MEP% was 29.44 ± 2.42; in group B, it was 23.05 ± 2.79, which was statistically significant ($P < 0.035$).

Table 4 - Comparison of diaphragmatic motion in COPD groups

	Group A COPD	**Group B COPD**	**P value**
Diaphragmatic motion during TV(cm)	1.47 ± 0.72cm	1.79 ± 0.58cm	P < 0.004
Diaphragmatic motion during DI(cm)	4.68 ± 1.53cm	4.59 ± 1.16 cm	P > 0.005
Diaphragmatic thickness (cm)	0,92 ± 0,22	1,01 ± 0.24	P > 0.005

TV : Tidal Ventilation, Dİ : Deep Inspiration

In the control group, diaphragmatic excursion during TV was not correlated with FEV1, FVC or FVC% but was moderately correlated with FEV1%. During DI, there was a weak correlation between diaphragmatic excursion and FEV1, FEV 1%, FVC and FVC%. In all COPD patients, FEV1, FEV1%, FVC and FVC% was not found to be correlated with diaphragmatic movement during either TV or DI.

In group A (mild-moderate COPD), a weak correlation was found between diaphragmatic excursion and FEV1% , FVC% during TV. During DI, a moderate correlation was found between diaphragmatic motion and FEV1, FEV1%. Otherwise, a strong correlation was found between diaphragmatic excursion and FVC, FVC% during DI. MEP and MIP were not correlated with diaphragmatic motion during either TV or DI (Table 5).

Tabl 5 - Corelation between pft parameters and diaphragmatic excursion in group A

	FEV1	% FEV1	FVC	% FVC	% MIP	% MEP
TV (cm) Pearson Correlation Sig (2-tailed)	0.443 0.013	0.199 0.284	0.413 0.021	0.168 0.367	-0.198 0.332	-0.257 0.215
DI (cm) Pearson Correlation Sig (2-tailed)	0.430 0.016	0.408 0.023	**0.556** 0.001	**0.649** 0.000	0.145 0.478	-0,222 0.285
Diaphragmatic Thickness Pearson Correlation Sig (2-tailed)	-0.262 0.147	-0.230 0.206	-0.023 0.900	0.090 0.623	-0.003 0.987	-0.079 0.700

TV : Tidal Ventilation, Dİ : Deep Inspiration

In group B, a weak correlation was found between diaphragmatic function and PFT parameters (such as FEV1 and FVC) during both TV and DI. A moderate correlation was found between diaphragmatic motion and MEP% (Table 6)

Tablo 6 - Corelation between pft parameters and diaphragmatic excursion in group B

	FEV1	% FEV1	FVC	% FVC	% MIP	% MEP
TV (cm) Pearson Correlation Sig (2-tailed)	-0.148 0.383	-0.065 0.874	-0.203 0.229	-0.155 0.360	-0.131 0.582	0.322 0.179
DI (cm) Pearson Correlation Sig (2-tailed)	0.005 0.977	-0.026 0.887	0.053 0.769	0.016 0.929	0.158 0.531	0,288 0.263
Diaphragmatic Thickness Pearson Correlation Sig (2-tailed)	0.023 0.896	-0.068 0.704	-0.192 0.277	0.273 0.118	-0.040 0.868	0.322 0.179

TV : Tidal Ventilation, Dİ : Deep Inspiration

Discussion. Increased resistive loads and air trapping impose increased strains on the diaphragm in COPD. In time, this situation induces diaphragmatic dysfunction in COPD. Until the past 3 decades, assessment of diaphragmatic movement relied traditionally on fluoroscopy and phrenic nerve conduction. USG has many advantages over fluoroscopy, including low cost, reproducibility, bedside appliance and lack of ionising radiation [10)]

There are few studies about diaphragmatic evaluation in COPD patients, but several studies have evaluated diaphragmatic excursion in COPD by magnetic resonance imaging (MRI) [8,11,12]. A study by Unal et al. [8] using MRI fluoroscopy for detecting diaphragmatic motility in COPD patients showed that values for hemidiaphragmatic motion were lower in COPD patients than in healthy subjects. The difference between the 2 groups was statistically significant. Iwasava et al. (12) also detected lower diaphragmatic excursion in COPD patients using MRI. Kawamoto et al. studied sonographic evaluation of diaphragmatic flattening, diaphragmatic excursion and correlation between flattening and FEV1. The study revealed that the motion of the anterior diaphragm was poor in 14 COPD patients [13]. Yamaguti et al. measured the craniocaudal displacement of the left branch of the portal vein during DI and expiration by using B-mode USG. They recognised that diaphragmatic motion was restricted in COPD compared with healthy individuals (36.5 ± 10.9 mm vs 46.3 ± 9.5 mm, $P = 0.001$) (5).

Our investigation included 30 controls and 76 COPD patients. COPD and control groups had similar statistics with respect to BMI, mean age and gender distribution. We recorded B- and M-mode USG results of craniocaudal motion of the right hemidiaphragm during both tidal breathing and DI. The mean diaphragmatic movement TV was 2.21 ± 0.56 cm in the control subjects and 1.65 ± 0.66 cm in the COPD patients, with a significant difference of $P < 0.001$. Similarly, during DI, COPD patients had significantly decreased diaphragmatic movement (4.64 ± 1.34 cm) compared with control subjects (6.23 ± 0.74 cm) ($P < 0.001$). Consistent with the literature, our findings revealed that diaphragmatic excursion was significantly lower in COPD patients compared with control subjects. Diaphragmatic thickness was also increased.

Yamaguti et al. investigated the relationship of pulmonary functions and respiratory muscle strength with diaphragmatic excursion [5]. They measured maximal respiratory pressures by using body plethysmography and spirometry. The spirometric findings denoting air trapping were strongly correlated with diaphragmatic mobility. Diaphragmatic excursion was moderately correlated with obstruction and weakly correlated with airway resistance and pulmonary hyperinflation. Nevertheless, it was not correlated with respiratory muscle strength. They concluded that diaphragmatic dysfunction in COPD was mainly the result of air trapping, not respiratory muscle strength or pulmonary hyperinflation [5].

Kawato et al. concluded that the radius of the right hemidiaphragmatic curvature was correlated with FEV1%. They also concluded that motion, flattening of the diaphragm and prolonged expiratory time were possible to evaluate by using abdominal USG and diaphragmatic flattening–reflected FEV1% [13].

Cohen et al. investigated sonographic right hemidiaphragmatic excursion in healthy subjects in the supine position as well as its relationship with spirometry. A linear correlation was found between diaphragmatic excursion and TV (14). Similarly, in 2 studies by Verschakelen et al., a linear relationship was noted between diaphragmatic motility in lung volumes near total lung capacity and inspiratory volumes [15,16].

Unal et al. also concluded that FEV1 was correlated with diaphragmatic motion in their study (8). Iwasawa et al. found a significant correlation between diaphragmatic excursion and total lung capacity [12].

In our study, FEV1, FVC, FEV1/FVC, MIP and MEP values were measured. In the control group, diaphragmatic excursion during TV was not correlated with FEV1, FVC or FVC% but moderately correlated with FEV1%. During DI, there was a weak correlation between diaphragmatic excursion and FEV1, FEV1% and FVC, FVC%. In group A, a weak correlation was found between diaphragmatic excursion and FEV1%, FVC% during TV. During DI, a moderate correlation was determined between diaphragmatic motion and FEV1, FEV1%. Otherwise, a strong correlation was found between diaphragmatic excursion and FVC, FVC% during DI. MEP and MIP were not correlated with diaphragmatic motion during either TV or DI. In group B, a weak correlation was found between diaphragmatic function and PFT parameters during both TV and deep DI. During TV and DI, diaphragmatic motion was moderately correlated with MEP%.

In the literature, there are several studies on diaphragmatic function and lung volumes in healthy subjects. Wang et al. aimed to find out the correlation between thoracic and diaphragmatic movement in healthy subjects in the supine position [17]. Chest wall motion, diaphragmatic excursion and lung volumes were measured simultaneously by optoelectronic plethysmography, fluoroscopy, USG and spirometry, respectively.

The right-side diaphragmatic movement was measured simultaneously by fluoroscopy and USG, and the 2 methods were well correlated ($r = 0.914$). Another finding was that diaphragmatic motion and chest wall motion during TV and deep breathing were highly correlated [17].

Boussuges et al. aimed to determine the reference values for diaphragmatic motion recorded by M-mode USG by studying 210 healthy subjects [1]. The examinations were performed in a standing position during TV, voluntary sniffing and deep breathing. The mean diaphragmatic excursions were 1.8 ± 0.3 cm on the right side and 1.8 ± 0.4 cm on the left. During deep breathing, the right hemidiaphragmatic excursion was 6.6 ± 1.3 cm. Kantarci et al. assessed diaphragmatic motility by M-mode USG in healthy subjects and the effect body composition had on it (18). Mean diaphragmatic excursion during DI was 4.92 ± 1.09 cm on the right side and 5.01 ± 1.17 cm on the left side. In our study, we measured diaphragmatic motion in the supine position and determined the right hemidiaphragmatic excursion as 6.21 ± 0.73 cm in the control group during DI. During TV, we found slightly higher values (2.28 ± 0.58 cm).

According to Boussuges et al., a weak correlation was found between height and diaphragmatic excursion [1]. Kantarci et al. determined that women and subjects with low BMI had less diaphragmatic excursion (18). In our experience, mean diaphragmatic excursion was 6.21 ± 0.21 cm in the control group and was not related to BMI.

Bosseuges et al. noted that in healthy subjects, right hemidiaphragmatic excursion during deep breathing and voluntary sniffing was correlated with FVC and FEV1 [1]. In another study, Scott et al. found weak correlation between diaphragmatic excursion and lung volumes in healthy subjects (19). Aliverti et al. defined a similar correlation between diaphragmatic and abdominal movements in healthy subjects when in a sitting position [20].

In the control group, diaphragmatic excursion during TV was not correlated with FEV1, FVC and FVC% but moderately correlated with FEV1%. During DI, we could discern no relationship between diaphragmatic excursion and PFT parameters. Such a wide discrepancy may be attributed to the fact that inspiratory volumes do not depend entirely on the diaphragm, but also on thoracic expansion and abdominal and thoracic compliance.

One of our study limitations was not being able to measure PFT parameters, which reflect air trapping better than FEV1, FVC. Our study population ideally would have been larger in order to examine the relationship between PFT and diaphragmatic motion more clearly.

Conclusion. We believe M-mode USG can be used as a noninvasive, inexpensive, safe and efficient technique to investigate diaphragmatic motion. In line with previous studies, our study confirms that diaphragmatic dysfunction can be evaluated by USG easily in COPD patients during both TV and deep breathing. However, normal diaphragmatic values in healthy subjects and a correlation with PFT parameters in both healthy and COPD subjects still needs to be documented by larger studies.

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