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Analysis of Diaphragm Mobility in Patients With Chronic Obstructive Pulmonary Disease in Algeria

Amine Meridj*, Redouan Belala, Khaled Tlili and Yacine Djeghri

Department of Medicie, University of Constantine, Algeria.

Corresponding Author: Amine Meridj, Department of Medicie, University of Constantine, Algeria.

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Abstract

In addition to affecting the respiratory system, chronic obstructive pulmonary disease also decreases muscle mass. The respiratory muscles weaken, which impairs ventilation and exercise tolerance. According to recent studies, M-mode ultrasonography provides a dependable and user-friendly method for evaluating diaphragmatic mobility in patients with COPD.

Objective

Evaluate diaphragmatic excursion by ultrasound in M-mode in patients with COPD and correlate with different clinical and ventilatory variables.

Methods

We conducted a prospective, observational study from 2021 to 2024. A total of Sixty-one consecutive patients with spirometry-confirmed stable COPD were included after obtaining informed written consent. Demographic and clinical data, spirometric values, BMI, 6-minute walking test as well as blood gas and Measurement of and Excursion (EXdi) were collected for analysis. This is a prospective study conducted at Constantine Regional Military University Hospital

Results

The mean diaphragmatic excursion, evaluated by ultrasound (EXdi), in our patients with COPD was 5.01 cm ± 1.48 cm, In our study a correlation between the EXdi and spirometric data (FVC; FEV1; FEV1/FVC) was objectified with (P < 0,001) the majority of our patients were classified grade 1 and grade 2 according to MMRC (Figur 4) the average of PaCO2 is 36,57 (mmHg), a negative correlation has been reported between L'EXdi and the dyspné MMRC (P < 0,001) The average BMI is 24.12 4.83 kg/m 2, with extreme values ranging from 14.6 to 36.9 kg/m 2, a positive correlation has been reported between L'EXdi and the BMI (P= 0,015) a positive rrelation has been reported between L'EXdi and the PaO2 (mmHg) (P =0,009),and a negative correlation has been reported between L'EXdi and the PaCO2 (mmHg) (P =0,022), The average distance travelled in this test was 470 129.37 m , our study has shown that the more EXdi increases, the distance patients travel increases (P =0,001)

Conclusion

In patients with COPD, diaphragmatic mobility appears to be associated with airway obstruction and BMI,6- minute walking test as well as blood gas and perception of dyspnea.

Keywords: Pulmonary Disease, Chronic Obstructive, Diaphragm Spirometry Dyspnea Ultrasound

1.Introduction

GOLD 2023 defines COPD as a heterogeneous lung condition characterized by chronic respiratory symptoms (dyspnea, cough, expectoration and/or exacerbations) due to airway abnormalities (bronchitis, bronchiolitis) and/or alveoli (emphysema) that cause persistent, often progressive, airflow obstruction. COPD is a major public health problem and is a leading cause of chronic morbidity and mortality worldwide. Prevalence of COPD is difficult to assess because it requires patient cohorts representative of the entire population using spirometric measurements. Studies have shown a wide geographic disparity in COPD prevalence, this is due to differences in survey methods, diagnostic criteria and target populations. An estimated 384 million people had COPD in 2010 and the global prevalence is estimated at 11.7% (8.4% - 15.0%) in 2015. Chronic obstructive pulmonary disease (COPD) is a major public health problem and a leading cause of morbidity and mortality worldwide, according to the BOLD study. 10.1% of people over 40 years old have COPD with an estimated mortality of three million deaths per year [1-5].

In Algeria, according to the BREATHE study, the prevalence of COPD is estimated at 4% in the general population and

25% among smokers. It is not uncommon for patients with chronic obstructive pulmonary disease (COPD) to have diaphragmatic dysfunction. The main known and oldest cause In patients with COPD, diaphragmatic dysfunction is a mechanical problem caused by excessive swelling of the lungs. The most recently recognized reasons for diaphragmatic weakness are remodeling, exposure to oxidative stress and decreased myosin filaments due to reduced protein production and increased apoptosis of muscle cells. During the last fifteen years, the application of diaphragmatic ultrasound has expanded considerably to patients with chronic lung diseases, including those with neuromuscular conditions and chronic obstructive pulmonary disease (COPD). These conditions are often associated with functional and clinical diafragmatic dysfunction detectable by ultrasound, the results of which are consistent with the severity of the underlying respiratory condition [6-11].

It is assumed that in the future, the use of ultrasound diaphragmatic and quadriceps by pulmonologists and reanimators and even doctors reeducator will be omnipresent and will have new applications in the diagnosis and follow-up of patients with COPD. Use of diaphragmatic ultrasound was also validated for the prediction of mechanical ventilation weaning in patients hospitalized in intensive care units. Ultrasound has distinct advantages over other techniques used to assess diaphragmatic and quadricipital function, as well as COPD. For example, it is non-invasive and does not use ionizing radiation, but it is feasible, reproducible and affordable in the patient's bed Patients with chronic obstructive pulmonary disease have significant abnormalities of diaphragmatic ultrasound compared to healthy individuals. In response to an increase in the ventilatory load, there is an increase in the diaphragmatic excursion and thickening fraction at current volume. However, at total lung capacity (CPT), the diaphragm stroke and thickening rate are reduced. These CPT parameters are correlated with the inspiratory capacity the lower this capacity is, the lower the excursion and thickening fraction values. The anomalies observed at CPT are mainly related to pulmonary hyperinflation [12-20].

and chest distension. Ultrasound abnormalities are also associated with the severity of bronchial obstruction , Ultrasound diaphragm abnormalities are also correlated with dyspnea in patients with COPD. There is a significant association between the thickening fraction or diaphragmatic stroke at current volume and CPT, BODE score, mMRC and Borg scale. These abnormalities are also related to diurnal hypoventilation, with a correlation between the diaphragmatic stroke at current volume and PaCO2 (24), Regarding exercise limitation, there is a correlation between the diaphragmatic stroke at CPT and the exercise capacity measured during the stress test [17-23].

2. Methods

This was a quantitative descriptive cross-sectional study. This is a prospective descriptive observational study conducted in the HMRUC's Department of Pneumology, 61 patients participated in the study. According to the Global Initiative Criteria for chronic obstructive pulmonary disease (GOLD).

2.1 Inclusion Criteria

All patients with COPD, over 40 years of age, in stable condition.

2.2 Criteria For Non Inclusion

Restrictive respiratory pathology, Progressive cardiovascular disease, Recent surgery (less than 3 months). A cross-sectional study design was used. All participants underwent ultrasonographic evaluation, nocturnal oximetry and other measurements (i.e. pulmonary function). This study was approved by the medical ethics committee of Constantine Regional Military University Hospital, The objective and content of the study were explained verbally as well as in written documents to the participants. Written consent was obtained after the subjects were informed that they could decide whether to participate based on their own free will and that their privacy would be reasonably protected. The ultrasound examination was performed by a single specialized and trained professional using aTOSHIBA device, model SSA-370ª Power Vision 6.000.

To assess diaphragmatic mobility, (EXdi) the patient was placed in the supine position and a 3.5 MHz convex transducer was used, which allows theobservation of deeper structures. This transducer was positioned in the right subcostal region, in themidclavicular line, with an incidence angle perpendicular to the craniocaudal axis and to the diaphragm. This was then identified through the hepatic acoustic window and its mobility was assessed bymeasuring, in millimeters (through M-mode) its craniocaudal displacement during breathing at rest (tidalvolume). Then, the measurement was repeated considering the incursion performed from maximuminspiration (total lung capacity level) to maximum expiration (residual volume level). Three serialmeasurements were performed, and the highest value was considered and recorded for this research. The transducer was positioned to observe the entire movement of the diaphragmatic excursion, both inthe tidal volume maneuver and in the maximal inspiratory and expiratory maneuver. This technique waspreviously described and is being widely used, All examinassions were performed on the right side totake advantage of the acoustic window of the liver, which facilitates visualization of the diaphragm. (FIGUR 1,2) [22,25].

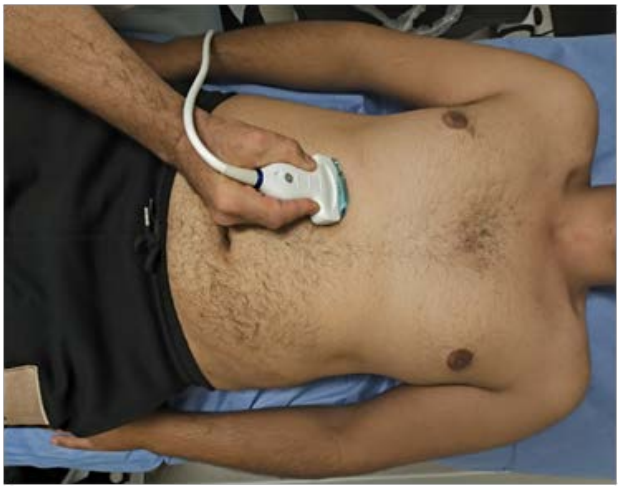

Figure 1 : Ultrasound Measurement of Diaphragm Excursion

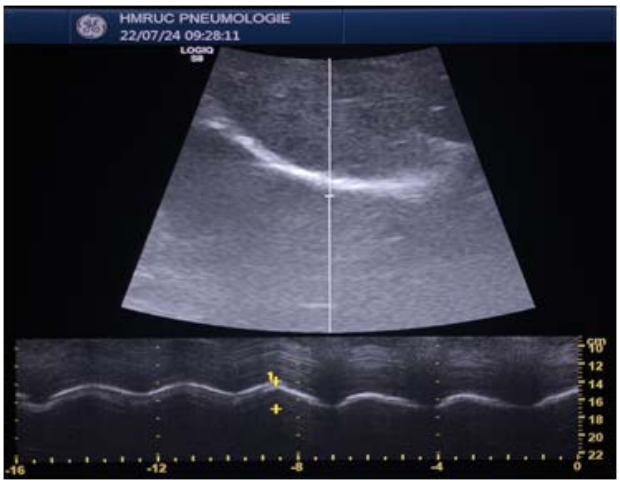

Figure 2 : Ultrasound Evaluation of Diaphragmatic Mobility in B and M Mode

2.3 Other Measurement

An arterial blood sample was obtained by puncture of the radial artery for blood Gas Analysis, namely arterial oxygen pressure (PaO2) and arterial carbon dioxide pressure (PaCO2). Dyspnoea was assessed using the modified Medical Research Council (MMRC) dyspnoea scale. Spirometry was performed with a previously calibrated spirometer, in accordance with the methods and criteria recommended by the American Thoracic Society and the European Respiratory Society, The following parameters were measured FVC, FEV1, FEV1/FVC before and 15 min after inhalation of a bronchodilator (albuterol, 400 µg). Dyspnea was measured with the modified Medical Research Council dyspnea scale, the degree of dyspnea ranging from 0 (no dyspnea) to 4 (very severe dyspnea). Patients were instructed to select the number that best represented their perception of dyspnea. Height and weight were measured and BMI was calculated. Obese patients (BMI 30 kg/m2) have Were excluded from the study [26,27].

2.4 Arterial Blood Gas Analysis

Six-minute walking test (6MWT) : it was carried out in a 30 m long flat corridor. Instructions and standardized incentives were given, in accordance with ATS guidelines [28].

2.5 Statistics Analysis

Data was captured and analyzed using IBM SPSS 24. Many procedures of control at the time of entry have been established to avoid errors as much as possible. We have implemented the following statistical methods

- Frequencies and percentages for qualitative data.
- The means, standard deviation, maximum and minimum for quantitative data.
- The normality of quantitative variables was investigated by the Shapiro-Wilk test.
- Comparisons of summer averages performed by the Student t test or ANOVA test according to the number of modalities of the variable.
- Comparisons between categorical or nominal variables were made by the Chi2 test or, where appropriate, by the exact Fisher test.
- The study of relationships between quantitative variables was analyzed by the Pearson or Spearman correlation coefficient as a function of the statistical distribution of variables.
- The statistical tests used were considered significant when p 0.05 (degree of significance).

3. Results

The majority of patients included in the study are in both

age groups 60 to 70 and 70 to 79, representing 73.8% of the total population (Figure 3), a negative corrélation has been reported between the diaphragm excursion (EXdi) and the age (P= 0,014) The population in our study is almost exclusively male 1 female/60 male. Sex-ratio = 0.017, The average BMI is 24.12 4.83 kg/m 2, with extreme values ranging from 14.6 to 36.9 kg/m 2, a positive correlation has been reported between L'EXdi and the BMI (P= 0,015) The mean diaphragmatic excursion, evaluated by ultrasound (EXdi), in our patients with COPD was 5.01 cm ± 1.48 cm.

Three groups of patients were identified according to smoking status :

- Ex-smokers : They represent the majority of our cohort with 73.8% of patients (n = 45).
- Active smokers : 22.9% of patients are active smokers (n = 14).
- Non-smokers: Only 3.3% of patients have Never smoked (n = 2).
- The majority of our patients were classified grade 1 and grade 2 according to MMRC (Figur 4), a negative correlation has been reported between L'EXdi and the dyspné MMRC (P < 0,001)
- The average of PaCO2 is 36,57 (mmHg) (tabl : 1)
- 62.3% n (38) of patients in our series have a pH between 7.38 and 7.42, 34.4% n (21) have a pH > 7.42 and 3.3% n (2) have a pH < 7.38
- 45.9% n (28) of patients in our series have a PaO2 between 75 and 100 MMHG, 52.5% n (32) have a PaO2 < 75 MMHG
- 85.24% n (52) of patients in our series have a PaCO2 between 35 and 45 MMHG, 11.47% n (7) have a PaCO2 > 45 MMHG and 3.2% n (2) have a PaCO2 < 35 MMHG
- 83.6% n (51) of patients in our series have a SaO2 between 94 and 100%, 14.8% n (9) have a SaO2< 94%

a positive correlation has been reported between L'EXdi and the PaO2 (mmHg) (P =0,009),and a negative correlation has been reported between L'EXdi and the PaCO2 (mmHg) (P =0,022) (Table 5) The average distance travelled in this test was 470 129.37 m , our study has shown that the more EXdi increases, the distance patients travel increases (P =0,001) In our study a correlation between the EXdi and spirometric data (FVC; FEV1; FEV1/FVC) was objectified with (P < 0,001),(Table 3,4)

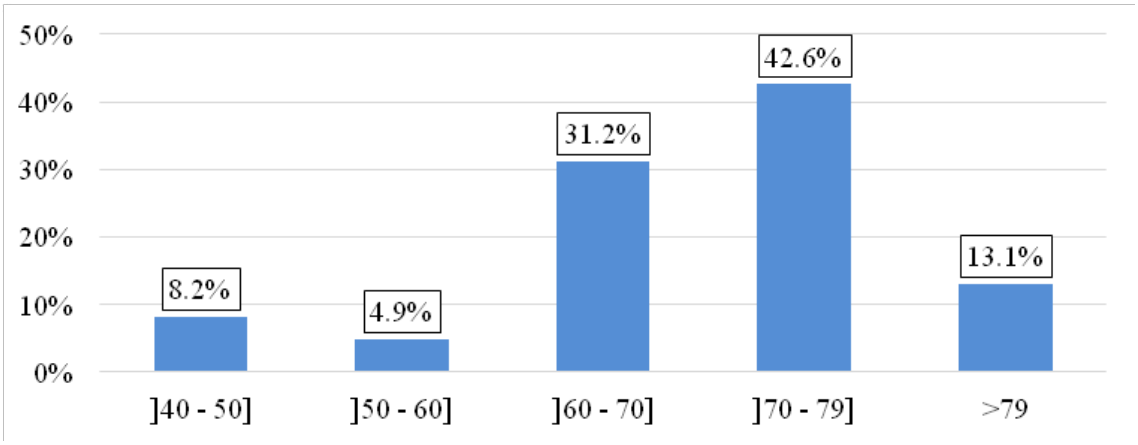

Figure 3 : Distribution of Patients By Age Group

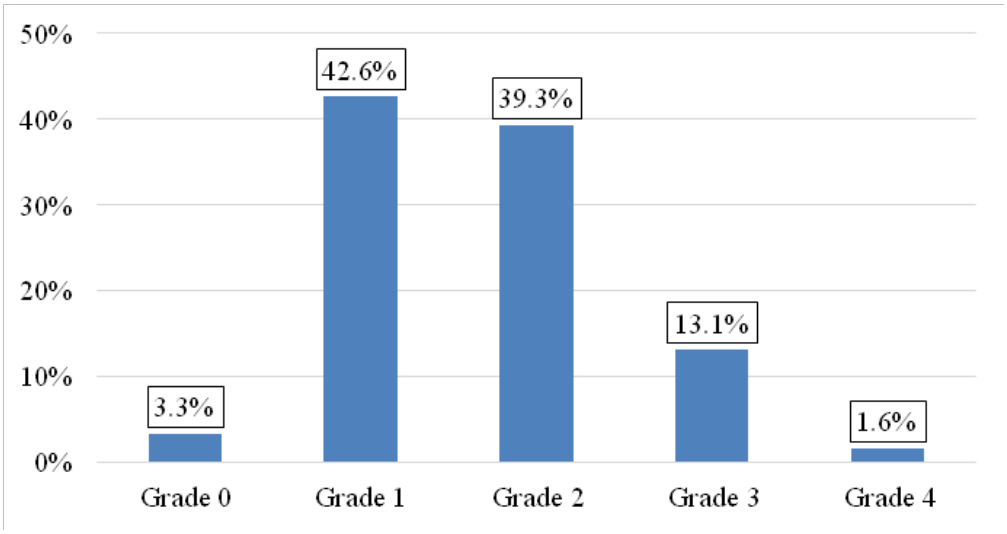

Figure 4 : Patient Distribution According to MMRC Scale

Parameters	Average	Standard Deviation
PH	7,41	0,03
PaO2(mmHg)	73,20	9,08
PaCO2(mmHg)	36,57	4,62
SaO2(%)	95,25	2,14

Table 1 : Gas Characteristics of the Population Studied

	EXdi	Standard Deviation
	Pearson correlation	P value
PaO2 (mmHg)	0,34	0,009
PaCO2 (mmHg)	-0,29	0,022
PH	-0,13	0,301

Table 2 : Correlation Between EXDI and Gas Data

	EXdi	Standard Deviation
	Pearson correlation	P value
FVC	0,587	< 0,001
FEV1	0,700	< 0,001
FEV1/FVC	0,477	< 0,001

Table 3 : Correlation Between EXDI and Spirometric Data

	Average	Standard
FVC		
FVC Pre (L)	3,52	0,92
FVC post (L)	3,63	0,90
FEV1		
FEV1 pré (L/s)	1,91	0,69
FEV1 post (L/s)	2,00	0,71
FEV1/FVC (%)		
FEV1/FVC pre (%)	53,57	10,56
FEV1/FVC post (%)	54,74	11,73
FEV1 post – FEV1 pré (L/s)	110	90
(FEV1 post – FEV1 pre) / FEV1 pre (%)	6,7	5

Table 4 : Spirometric Characteristics of the Studied Population

	EXdi	Standard Deviation
	Pearson correlation	P value
PaO2 (mmHg)	0,34	0,009
PaCO2 (mmHg)	-0,29	0,022
PH	-0,13	0,301

Table 5 : Correlation Between the EXDI and the Gas-Meter Data

4. Discussion

In the present study, we found a significant negative correlation between diaphragmatic excursion (EXdi) and patient age (r = -0.304, p = 0.017). These results are in line with those reported by Hafez, M. et al. In a 2017 study in Egypt of 113 male patients with COPD dividende into two groups. Those with normal diaphragmatic thickness and those with diaphragmatic thinning. They showed that in patients with diaphragmatic thinning, mean age was significantly higher (68.5 7.3 years) compared to patients with normal thickness (62.0 8.7 years), with negative correlation (t = 2.5, p = 0.01). In addition, our study revealed a significant direct correlation between EXdi and body mass index (BMI) (r = 0.343, p = 0.007). A study conducted in China by FU, X. et al. (30) on 81 patients with COPD and 30 healthy controls showed a similar correlation (r = 0.501, p < 0.001). Similarly, Fekri, K. T. et al.

demonstrated a significant difference in terms of BMI and EXdi (p = 0.042). In a study of 164 healthy subjects, Kantarci, F. et al. Reported that the mean EXdi was significantly lower in underweight individuals compared to overweight or obese individuals (F = 9.08, p < 0.05). These results are also in agreement with those of Smargiassi, A. et al (21) who found similar correlations (r = 0.29, p = 0.001). Current and previous studies have shown that EXdi is an effective marker for assessing quality of life in patients with COPD. Therefore, it is recommended that the EXdi be used as an essential indicator of patient clinical status. In our study, CAT and MMRC scores were used as indicators of disease severity, and we observed significant negative correlations between these scores and the EXdi, More specifically, the MMRC score showed a similar correlation (r = -0.527, p = < 0.001). a recent Egyptian study (2024) realised by Esmaeel, H. M., K. A. Atta, et al. (33) showed a negative correlation between the MMRC score and the EXdi (r = -0.234, p = 0.012). Similar results were reported by Rocha, F., et al. (R = -0.48, p = 0.01) and FU, X., J. Wang, et al. (R = -0.615, p < 0.001). A Brazilian study by Paulin, E., et al. in 2007 (35) of 54 patients with COPD and pulmonary hyperinflation also found a negative correlation between EXdi and dyspnea (r = -0.36, p = 0.007). Silva, B., et al. In a study of 49 COPD patients observed that patients with a MMRC score below 2 had a higher EXdi than those with a score above 2 (mean difference 13.20 4.6 mm, p = 0.0059). However, our results differ from those of Yalcin, B., et al, who found no correlation between the MMRC scale and EXdi. Similarly, Cimsit et al. In a study of 53 patients with COPD, did not find a significant correlation between symptom score (mMRC) and diaphragm thickness. Dyspnea may be associated with a decreased ability of the respiratory muscles to respond to increased mechanical load. Airway obstruction and emphysema alter the morphology of the diaphragm, causing diaphragmatic dysfunction which in turn aggravates dyspnea. Changes in diaphragm position due to the disease complicate ventilation, reducing respiratory capacity and exacerbating the sensation of dyspnea. These results confirm the observations of Paulin et al. Which showed that patients with decreased EXdi experienced increased dyspnea after submaximal exercise. In our cohort, we also observed a significant negative correlation between EXdi and the number of smoking packets-years (r = -0.275, p = 0.032), as well as with the duration of smoking (r = -0.291, p = 0.023). These results corroborate those of Saeed, A. et al. In a recent (2024) Egyptian study involving 44 patients with COPD. They demonstrated that the duration of smoking is an independent factor negatively influencing the excursion [29-40].

In our study, we observed a strong correlation between reduced diaphragmatic mobility and airway obstruction (r = 0.70, p = < 0.001). This is consistent with the findings of Yalcin et al. and Shiraishi et al. Who reported that diaphragmatic excursion was significantly reduced in patients with low FEV1. This relationship may be explained by the fact that increased airway obstruction, assessed by FEV1, exerts additional pressure on the chest wall, placing the diaphragm in an un favorable position mechanically [37-43].

Our study found a significant correlation between EXdi and FEV1/FVC (r = 0.477, p < 0.001), in agreement with the results of many previous studies An et al. WAS et al. Qaiser et al. In contrast, the study by Davachi, B. et al. Found no significant link between EXdi and FEV1/FVC. This may be explained by the fact that the majority of patients included in this study were at a moderate stage of disease (mean FEV1/FVC = 59.46%), unlike our cohort, which included patients with more advanced stages, with a mean FEV1/FVC of 54.74%. Therefore, it is likely that in patients with less severe stages of COPD, factors related to airway obstruction are less strongly associated with EXDI [44-46].

Finally, our results also indicate a significant relationship between the functional capacity of patients, measured by the six-minute walking test TM6 and the EXdi. Patients with a lower EXdi traveled significantly shorter distance to TM6. More specifically, our analyses show a positive correlation between EXdi and distance traveled at TM6 (r = 0.422, p = 0.001), as well as a negative correlation with effort intolerance (r = -0.301, p = 0.018). In addition, mean SaO2 at TM6 showed a positive correlation with EXdi (r = 0.471, p = < 0.001), while dyspnea score and overall fatigue, assessed by the Borg scale, were inversely correlated with EXdi (r = -0.442, p = < 0.001). These findings are consistent with many other studies that have found similar results Davachi et al. Silva et al. Amin's et al [36-47].

In our study, we also observed a significant positive correlation between EXdi and PaO2 (r = 0.336, p = 0.009), indicating that the higher the PaO2, the better the EXdi. A study by Hafez, M., et al. in 2017 on 113 patients with COPD showed similar results, showing that patients with diaphragmatic thinning had significantly lower PaO2 levels compared to those with normal diaphragmatic thickness (t = 5.13, p = 0.001) In addition, our results showed that patients with reduced diaphragmatic mobility had higher levels of PaCO2 (r = -0.292, p = 0.024). These observations are in line with those of Bégin, et al. Who showed that hypercapnia increases with severity of obstruction, obesity and inspiratory muscle weakness. Similarly, Scheibe, Nadine, et al. Found a moderate correlation with PaCO2 (r = -0.47). Kang, Hyun Wook, et al. In a study of 37 patients with stable COPD, also demonstrated significant negative correlations between diaphragmatic mobility and PaCO2 (r = -0.373, p = 0.030), confirmed by Amin, A., et al. (R = -0.45, p = 0.02) [48-50].

5. Conclusion

Diaphragmatic ultrasound has been shown to be a valuable tool for assessing the morphology and function of the diaphragm in patients with COPD. It is therefore recommended to systematically integrate this examination in the management of patients, especially those with dyspnea symptoms. Ultrasound, being a non-invasive technique, could be used as an early detection tool to identify patients at risk for diaphragmatic dysfunction even in the early stages of COPD In summary, this study shows that the lower the diaphragm excursion in patients with COPD, the lower the quality of life and exercise capacity. Decreased

diaphragm excursion may be a factor in determining impaired exercise capacity in patients with COPD. Diaphragm excursion can help physicians develop better treatment strategies, which requires more research and applications. Finally, it is recommended to invest in the acquisition and implementation of portable ultrasound devices in health care facilities, especially those that receive patients with COPD. The availability of these devices, as well as training for health care teams in their use, would facilitate access to this diagnostic tool and make it available in intensive care units and rehabilitation centres.

Ethical Compliance

The research experiments conducted in this article with animals or humans have been approved by the ethics committee and the authorities responsible for our research organizations, in accordance with all guidelines, regulations, legal and ethical standards required for Humans or animals.

Conflits of Interest

There is no reason to report.

Contributions From Authors

A. Meridj, Designed and developed the analysis, Witten the article

R. Belala, Collected data

Y. Djeghri Conducted the analysis

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