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Ultrasonographic evaluation of post-COVID long-term lung changes and relation to prolonged COVID symptoms: a prospective cross-sectional study

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ABSTRACT

Objectives: This study aims to evaluate lung findings using lung ultrasonography (USG) in patients with PCR-positive COVID-19 pneumonia treated in the ward or intensive care unit and to explore the relationship with prolonged COVID-19 symptoms.

Methods: This prospective cross-sectional study was conducted at the University Medical Faculty Hospital outpatient clinic from December 2022 to April 2023. It involved 54 adult patients with PCR-positive COVID-19 pneumonia, treated and discharged from the ward or intensive care unit (ICU). Clinical and demographic data, lung ultrasonography results, and prolonged COVID-19 symptoms were recorded.

Results: Among the 54 patients, the ICU group had a mean age of 52.84±12.30 years, while the ward group had a mean age of 58.80±11.36 years (P=0.085). Shortness of breath was the most common prolonged symptom in both groups. The ICU group had significantly more right lung B lines than the ward group (P=0.002). Myalgia was more frequent in the ward group (P=0.024). No significant differences were observed in other variables (P>0.05). Prolonged COVID-19 symptoms were interrelated (P<0.05), and the total number of B lines was significantly associated with dyspnea (P=0.023).

Conclusions: Our study demonstrated that lung USG is a valuable tool in the assessment of lung injury after COVID-19 and in the management of long-term COVID-19 symptoms. B lines detected by lung USG are significantly associated with the long-term COVID symptom of shortness of breath, and the number of B lines may be an important biomarker in the management of shortness of breath.

Keywords: Lung ultrasonography, B lines, COVID-19, prolonged COVID, dyspnea

Since the beginning of the COVID-19 pandemic (13/09/2023), 770,563,467 confirmed cases, including 6,957,216 deaths, have been reported to the World Health Organization (WHO) [1]. In our country, it has infected more than 17,000,000 people; more than 100,000 of them have died [1]. COVID-19 and its strains have repeatedly caused and continue to cause disease in humans. Some of those who have had the disease have reported symptoms such as persistent or subsequent dyspnea, cough, muscle pain, fatigue,

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palpitations, extreme forgetfulness, and difficulty concentrating, which reduce the quality of life of patients and cannot be explained by other diagnoses. The term 'prolonged COVID' has been used for patients with these symptoms associated with COVID-19 for more than 12 weeks [2-4].

COVID-19 infection has shown involvement of many organs, including the heart and central nervous system, but it was lung involvement that determined mortality and morbidity. Again, the most common symptoms in patients with prolonged COVID-19 are those related to the respiratory system [5].

Lung USG is widely used as a non-invasive, portable, and reproducible imaging method, especially in intensive care units [6]. It is also precious in evaluating pleura and parenchyma [7]. Artifacts known as (B-lines) in lung USG provide essential clues in diagnosing interstitial or alveolar pathologies [8].

Recent studies have reported that lung ultrasonography (USG) is mainly similar to the results of computed tomography (CT), which is known to be diagnostic in lung diseases [9, 10].

Our study aimed to determine the changes in the lungs of patients with a positive COVID-19 Polymerase Chain Reaction (PCR) test, who were hospitalized in the ward or intensive care unit with a diagnosis of pneumonia and who were discharged after recovery by USG; also to question the prolonged COVID symptoms in these patients and to determine the relationship of common symptoms with lung USG findings.

METHODS

Study Design and Participants

The study was prospective-cross-sectional conducted at the Health Research and Development Centre of the University Faculty of Medicine from December 2022 to April 2023. Patients with a positive COVID-19 PCR test between April 2020 and June 2021 who were diagnosed with pneumonia and discharged after inpatient treatment in the Chest Diseases Service or Respiratory Intensive Care Unit were included in the study.

In December 2022, patients who met the criteria for participation in the study and who had been discharged for at least 18 months after receiving inpatient treatment in our hospital's chest diseases service or intensive care unit were identified from our hospital's automation records, and the study was started on the same date. 73 of these patients were contacted by telephone. Sixty patients who agreed to participate in the study were invited to the University Hospital Health Research and Development Center outpatient clinic for the study. Among the patients who agreed to participate in the study, one patient receiving hemodialysis treatment, two patients receiving chemotherapy treatment, two patients who were pregnant, and one patient with a history of radiotherapy to the thorax region in previous years were excluded from the study.

In a total of 54 patients who agreed to participate in the study and met the inclusion criteria, anamnesis was taken, physical examinations were performed, prolonged COVID symptoms were questioned, thoracic USG was performed, and all findings were recorded. In the anamnesis and physical examination of the patients, symptoms, gender, age, and physical examination findings were recorded on pre-prepared forms. Modified Medical Research Council (mMRC) dyspnea scores were calculated and recorded. All data were entered into the SPSS database and statistically evaluated.

Inclusion criteria include: (1) To be at least 18 years old, (2) to have been diagnosed with pneumonia with a positive COVID-19 PCR test during hospitalization at the University Health Application and Research Center, (3) to have received inpatient treatment due to COVID-19 in the ward or intensive care unit, (4) to have been discharged at least 18 months after discharge, (5) not to be pregnant or suspected of pregnancy during the study, and (6) to sign the consent form by agreeing to participate in the study.

Exclusion criteria iinclude: (1) Being under the age of 18; (2) being pregnant or suspecting pregnancy during the study; (3) having received or currently receiving chemotherapy or radiotherapy before or during the study; (4) having a diagnosis of chronic kidney failure; (5) having a diagnosis of heart failure, (6) having a diagnosis of tuberculosis, chronic obstructive pulmonary disease (COPD), asthma, or malignancy, fibromyalgia, rheumatoid arthritis; and (7) inability to be positioned for ultrasound examination due to general health status. Patients' previous diagnoses and health conditions were verified through the e-Nabız information system and hospital records [11, 12].

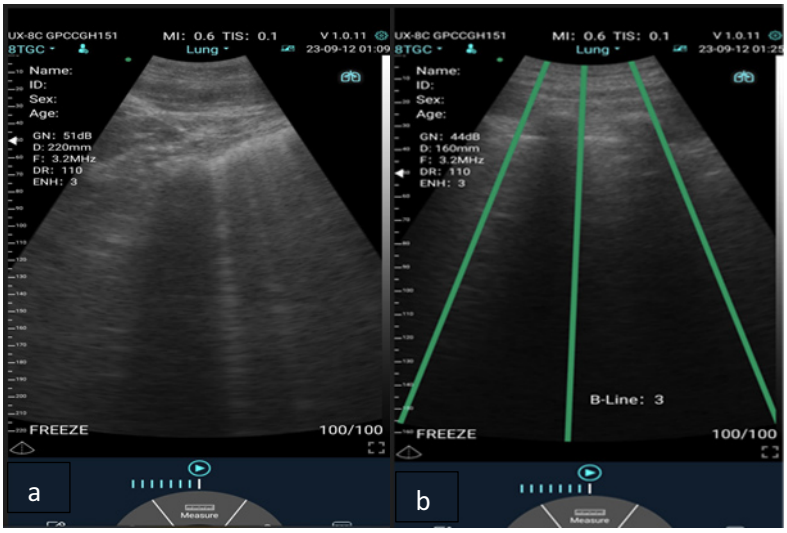

Fig. 1. B lines detected in the lung ultrasonography of participants (a) ET and (b) CB).

Lung Ultrasonography

The evaluation of the lungs was carried out using a wireless ultrasonography device that had a dual probe with a linear and convex tip. The examination was conducted in a standardized manner by dividing each lung into three regions - anterior, lateral (axillary region), and posterior. Each section was further divided into upper and lower regions, and the findings in all six regions were recorded for each hemithorax. Consolidation, air trapping (reverberation artifact), pneumothorax, pleural effusion, pleural thickening, and interstitial syndrome (B-line) findings in each USG region were noted on the form (Fig. 1). USG findings were evaluated based on the International Evidence-Based Recommendations for Bedside Lung Ultrasonography report [10].

Practitioner Information

All participants' ultrasound examinations were conducted by Specialist Dr. NTT, who holds a certificate in 'Emergency and Basic Ultrasound,' under the supervision of Prof. Dr. ONH, who has extensive experience in lung ultrasonography.

Ethical Approval

Ethics committee approval for this study was obtained from the Trakya University Faculty of Medicine Ethics Committee on 14/06/2021, with decision number:13/35 and protocol code: TUTF-BAEK-2021/292. The Declaration of Helsinki performed all procedures in this study. Written informed consent was taken from the patients.

Statistical Analysis

Numerical results were expressed as mean ± standard deviation and categorical data as number (%). The suitability of the normal distribution of quantitative data was tested using the Shapiro-Wilks test. Mann-Whitney U test was used to compare quantitative data between intensive care unit and ward groups. Fisher exact test was used to compare categorical data between groups. The relationship between prolonged Covid symptoms was analyzed using Spearman's test. Logistic regression analysis was performed to determine the factors affecting dyspnea. The appropriateness of the regression model was evaluated by the Omnibus test, Cox & Snell R2, Nagelkerke R2, and Hosmer-Lemeshow test. Activity-induced dyspnea was considered significant dyspnea and was used in the logistic regression analysis with a mMRC scale of ≥2 [13]. A value of $P<0.05$ was accepted as the limit of statistical significance. SPSS 20.0 (SPSS Inc. Chicago, II, USA) statistical package program was used for data analysis.

RESULTS

The study was completed with 54 patients. Of the 54 patients included in the study, 9 of 13 patients dis-

charged from the intensive care unit were male (69.2%), and 4 were female (30.8%), 30 of 41 patients discharged from the ward were male (73.2%), and 11 were female (26.8%).

In our study, demographic and clinical characteristics were compared between the ward and intensive care unit groups (Table 1).

The mean age was 52.84±12.30 for the intensive care unit group and 58.80±11.36 for the ward group. There was no significant difference between the groups (P=0.085) in terms of age. Gender distribution was similar in both groups (P=1.000). When compared in terms of symptoms, myalgia was significantly higher in the ward group (53.7% vs 15.4%, P=0.024). There was no statistically significant difference between the groups in terms of cough, dyspnea, fatigue, and sweating (For all P>0.05). Although higher grades of dyspnea severity were observed in the intensive care group, this difference did not reach statistical significance (P=0.167). In lung ultrasonography findings, the total number of B lines was significantly higher in the intensive care group (14.1±15.1 vs 4.24±5.88, =0.004). Especially the number of B lines in the right lung was significantly higher in the intensive care group (9.8±10.4 vs 2.2±3.0, P=0.002). There was no significant difference between the groups in the number of B lines in the left lung (P=0.055).

To better understand these relationships, the correlations of prolonged COVID symptoms with each other were analyzed with Spearman's test (Table 2).

In our analysis, we found significant correlations between dyspnea and other symptoms. Dyspnea was positively correlated with myalgia (r=0.271, P=0.047) and sweating (r=0.315, P=0.020), indicating an association with these symptoms. However, dyspnea showed no significant correlation with cough (r=0.008, P=0.954) or fatigue (r=0.209, P=0.130). Additionally, myalgia was significantly correlated with fatigue (r=0.725, P<0.001) and sweating (r=0.361, P=0.007). These findings revealed interrelated symptoms such as dyspnea, fatigue, myalgia, and sweating. Considering that shortness of breath is a symptom that

Table 1. Clinical and demographic characteristics of the ward and intensive care groups

	Ward (n=41)	ICU (n=13)	P value
Age (years)	58.80±11.36	52.84±12.30	0.085¥
Gender, male	30 (73.2)	9 (69.2)	1.000*
Cough, yes	22 (53.7)	5 (38.5)	0.526*
Dyspnea,			
mMRC Grade 0	26 (63.4)	6 (46.2)	
mMRC Grade 1	9 (22)	2 (15.4)	0.167*
mMRC Grade 2	6 (14.6)	4 (30.8)	
mMRC Grade 3	0(0)	0 (0)	
mMRC Grade 4	0 (0)	1 (7.7)	
Fatigue, yes	25 (61)	5 (38.5)	0.206*
Myalgia, yes	22 (53.7)	2 (15.4)	0.024*
Sweating, yes	6 (14.6)	2 (15.4)	1.000*
Total B Lines, total	4.24±5.88	14.1±15.1	**0.004¥**
Right lung total	2.2±3.0	9.8±10.4	**0.002¥**
Left lung total	2.0±3.6	4.4±5.6	0.055¥

Data are shown as mean±standard deviation or n (%). ICU=Intensive Care Unit; mMRC=Modified Medical Research Council, Grade 0=Only during heavy exercise, Grade 1=Walking fast on a flat road or going up a slight slope, Grade 2=Due to shortness of breath, I walk more slowly on a flat road or rest from time to time, Grade 3=After walking 100 meters or after walking for a few minutes I have to stop, Grade 4=I can't leave the house because of shortness of breath.

*Fisher exact test, ¥Mann Whitney U test

Table 2. Results of Spearman correlation analysis among prolonged COVID symptoms

		Cough	Dyspnea	Fatigue	Myalgia	Sweating
Cough	r	1.000	0.008	0.224	0.149	0.104
	P value		0.954	0.104	0.282	0.453
Dyspnea	r	0.008	1.000	0.209	0.271	0.315
	P value	0.954	.	0.130	**0.047**	**0.020**
Fatigue	r	0.224	0.209	1.000	0.725	0.373
	P value	0.104	0.130	.	**<0.001**	**0.005**
Myalgia	r	0.149	0.271	0.725	1.000	0.361
	P value	0.282	**0.047**	**<0.001**	.	**0.007**
Sweating	r	0.104	0.315	0.373	0.361	1.000
	P value	0.453	**0.020**	**0.005**	**0.007**	.

r=Spearman's correlation coefficient. Values range between +1 and -1, +1 indicates a perfect positive correlation, -1 indicates a perfect negative correlation, and 0 indicates no correlation, P=Statistical significance value. P<0.05 indicates that the correlation is significant at the 95% confidence level, P<0.01 indicates significance at the 99% confidence level, n=Sample size, which is 54 in this study.

most affects other prolonged COVID-19 symptoms and significantly reduces the quality of life of patients, logistic regression analysis was performed to examine the relationship between independent variables (age, group, gender, total B lines, and other prolonged COVID-19 symptoms) affecting shortness of breath. Since significant dyspnea is considered as mMRC ≥ 2 in clinical practice, significant dyspnea was taken as the dependent variable, and the relationship between this variable and other independent variable was examined by logistic regression analysis.

Omnibus tests were performed to assess the significance of the model before proceeding to logistic regression analysis to examine the independent factors affecting dyspnea (Table 3). The results showed that the model was statistically significant (Table 3, χ^2= 20.883, P=0.007). Statistical analyses were conducted to assess the performance and fit of the model (Table 4).

According to the logistic regression model summary, the -2 Log Likelihood value is 36.325, the Cox & Snell R^2 value is 0.321, and the Nagelkerke R^2 value is 0.491. These values indicate that the model fits the data well and explains a moderate to high portion of the variance in the dependent variable. These findings suggest that the model is effective in predicting the dependent variable and performs well.

Furthermore, the Hosmer and Lemeshow test results show that the model's Chi-square value is 3.429, with 8 degrees of freedom and a p-value of 0.905. These results indicate that the model is valid and reliable.

Logistic regression analysis was conducted to examine the effects of independent variables (age, group, gender, cough, fatigue, myalgia, sweating, and total B lines) on the dependent variable (dyspnea) (Table 5).

According to the analysis's results, as the total B-line score increases, the likelihood of experiencing dyspnea also increases. This relationship is statistically significant (B=0.154, P=0.023). The odds ratio is 1.167, and the confidence interval (1.022 - 1.333) supports that this relationship is positive and statistically

Table 3. Omnibus tests of model coefficients

		Chi-square	P value
Step 1	Step	20.883	**0.007**
	Block	20.883	**0.007**
	Model	20.883	**0.007**

Table 4. Logistic regression model summary

Step 1	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
	36.325[a]	.321	.491

[a]Estimation terminated at iteration number 6 because parameter estimates changed by less than .001.

significant. Other variables were not found to be statistically significant (for all P>0.05).

There was no sign of consolidation, pneumothorax, air trapping, or pleural effusion in the lung USG of the participants. This may be because patients who agreed to participate in the study had no active disease.

Fig. 1 shows the B-lines detected by ultrasound in the lung radiographs of study participants E.T. and C.B.

DISCUSSION

In this study, we investigated prolonged COVID symptoms by performing lung ultrasonography of COVID-19 patients who were discharged after inpatient treatment in the ward or intensive care unit and who had been hospitalized for at least 18 months. Our study revealed that patients hospitalized for PCR-positive COVID-19-induced pneumonia continued to have prolonged COVID symptoms even 18 months after discharge and that the symptoms were interrelated among themselves. It also showed that shortness of breath, a prolonged COVID symptom, significantly increased with an increasing total number of B lines detected on lung ultrasonography.

The onset of the COVID-19 pandemic was characterized by SARS-CoV-2, a rapidly spreading respiratory infection agent detected in China in the last months of 2019. With the World Health Organization (WHO) declaring a pandemic on March 11, 2020, the global impact of this new viral threat was officially recognized [14]. Although it has been over 4 years since the first case was detected, many survivors are still experiencing unexpected symptoms. Because although lung involvement determines hospitalization and mortality in COVID-19, many different organs or systems, such as the heart, central nervous system, kidney, musculoskeletal system, and gastrointestinal system, have been affected by this disease [15].

The occurrence of these unusual symptoms in the patient for more than 12 weeks due to the involvement of many different organs is referred to in the literature as 'Prolonged COVID'. It is thought that the SARS-CoV-2 virus, the causative agent of COVID-19, enters cells by binding to Angiotensin 2 (ACE2) receptors present in many organs, causes severe damage in the organs it infiltrates, and being a neurotropic virus, plays a role in the emergence and persistence of pro-

Table 5. Logistic regression analysis of factors affecting dyspnea

		Beta	P value	Odds Ratio (95% Confidence Interval)
Step 1[a]	Group	1.175	0.364	3.237 (0.256-40.990)
	Gender	-0.854	0.448	0.426 (0.047-3.871)
	Age	0.052	0.362	1.053 (0.942-1.176)
	Cough	0.181	0.843	1.199 (0.199-7.218)
	Fatigue	2.465	0.169	11.765 (.352-393.494)
	Myalgia	-3.197	0.066	0.041 (0.001-1.236)
	Sweating	-1.978	0.125	0.138 (0.011-1.736)
	Total B Lines	0.154	**0.023**	1.167 (1.022-1.333)
	Constant	-3.267	0.322	0.038

[a]Variable(s) entered on step 1: Group, Gender, Age, Cough, Fatigue, Myalgia, Sweating, Total B Lines

longed COVID symptoms [3].

Table 1 shows the clinical and demographic characteristics of the patients who participated in the study. There was no statistically significant difference in age and gender between the intensive care unit and ward patient groups (P=0.085 and P=1.000, respectively).

More than 50 symptoms of prolonged COVID-19 have been identified in studies. The symptoms of prolonged COVID-19 questioned in our study and their frequency of occurrence are shown in Table 1. The most common symptoms are dyspnea, myalgia, cough, and weakness, and the least common symptom is sweating. The TURCOVID study involving 504 patients and 13 different centers reported that the most common symptoms were dyspnea and fatigue [5]. In another study in which 7139 patients participated and prolonged COVID symptoms were questioned, shortness of breath, cough, fatigue, and muscle pain were found among the most common symptoms [16]. In another study conducted in Italy, 143 patients who were discharged after inpatient treatment due to COVID-19 were questioned about their prolonged symptoms after 60 days, and it was reported that at least 1 symptom persisted in 87.4% of the patients and at least 3 symptoms persisted in 55% of the patients and the 3 most common symptoms were fatigue-weakness, shortness of breath and joint pain, respectively [17]. The results of our study were found to be consistent with these studies. Sweating is not included in the common prolonged COVID symptoms and was the least common symptom in our study. The results of our study were consistent with these studies. Sweating is not among the common symptoms of prolonged COVID-19 and was the least common symptom in our study.

In our study, the number of B lines detected in the right lung was significantly higher in patients treated in the intensive care unit than in patients treated in the ward. The right lung is larger than the left lung. Therefore, the area affected by COVID-19 pneumonia is more. After the trachea, the right main bronchus is separated from the left main bronchus at a narrower angle. Therefore, aspiration and aspiration pneumonia are more common in the right lung. In intubated patients, if the tracheal tube is placed further forward than it should be, it enters the right main bronchus more. In this case, the volume or pressure that should be given to both lungs is applied to the right lung; volume and barotrauma complications occur. For these reasons, right lung pneumonia and lung damage due to mechanical ventilation may leave longer-lasting or permanent damage in the right lung [18]. The higher incidence of B lines in this region can be explained in this way, which is consistent with the results of our study and is shown in Table 1.

In our study, the relationship between prolonged COVID symptoms was analyzed using Spearman's test, and significant correlations were found between dyspnea and other symptoms. Dyspnea was positively correlated with myalgia (r=0.271, P=0.047) and sweating (r=0.315, P=0.020). These findings suggest that patients who experience shortness of breath are also likely to experience muscle pain and sweating. Furthermore, myalgia showed significant correlations with both fatigue (r=0.725, P<0.001) and sweating (r=0.361, P=0.007) (Table 2). This analysis suggests that symptoms are interrelated, especially dyspnea, which is the symptom that most affects patients' quality of life, and that myalgia may trigger other symptoms. In an article published in 2023 involving 76 patients, dyspnea scores were measured at 3, 6, and 12 months after discharge, and it was reported that dyspnea persisted in 46% of patients at 12 months, worsened in 24%, and 20% had new onset dyspnea. The same article showed that the clinical scores of the patients during intensive care hospitalization did not affect this situation and found that dyspnea was also associated with other prolonged COVID symptoms [19]. This is consistent with the results of our study. In our study, it was shown that receiving treatment in the intensive care unit and in the ward was not statistically significant in terms of dyspnea (Table 1, P=0.167), and dyspnea was associated with other symptoms of prolonged COVID (Table 2). Many articles on quality of life months after COVID have shown that prolonged COVID symptoms, especially dyspnea, impair physical and mental performances and reduce the quality of life of patients [19, 20]. For these reasons, we investigated the relationship between dyspnea and other prolonged COVID symptoms we questioned in our study, age, gender, place of hospitalization, and total B lines in the lungs. We tested the validity, performance, and fit of the model we built to perform logistic regression analysis (Table 3, Table 4). The results showed that the model was valid, reliable, and significant (Table 3, Omnibus test, P=0.007; Table 4, -2 Log Likelihood=36.325, Cox &

Snell R^2=0.321, Nagelkerke R^2=0.491; Hosmer and Lemeshow test, P=0.905). Logistic regression analysis showed that the total number of B lines was significantly associated with dyspnea risk (Table 5; P=0.023, OR=1.167, 95% CI: 1.022-1.333). This finding suggests that each unit increase in the number of B lines increases the risk of dyspnea by approximately 16.7%. This result suggests that B lines detected on lung ultrasonography may be a potential biomarker for predicting dyspnea symptoms. The effects of being treated in the ward or intensive care unit, as well as gender, age, cough, fatigue, myalgia, and sweating, were not statistically significant (Table 5).

B lines are hyperechoic, vertical lines seen when the ultrasound probe is placed on the surface of the pleura and usually extend vertically into the lung parenchyma [21]. The detection of B lines is associated with alveolar-interstitial conditions. B lines are seen in diseases characterized by fluid accumulation or fibrosis in alveolar and interstitial tissues, especially acute pulmonary edema, pneumonia, acute respiratory distress syndrome, and interstitial lung diseases. Therefore, to evaluate only COVID-induced B lines, patients with disease diagnoses in which B lines are likely to be seen were excluded from our study. A 2006 study pointed out that lung USG in alveolar-interstitial syndromes is rapid, reproducible, and sensitive, without radiation exposure, and more advantageous to be used instead of chest radiography and CT, which are traditional methods for monitoring disease progression or response to treatment [22]. In the same study, some disadvantages of lung USG were also mentioned. Among these disadvantages, it was stated that deep tissues could not be visualized, and the method was user-dependent. User dependency and the inability to visualize deep tissues make it difficult to detect lesions, especially in deeper parts of the lung or in more central areas such as mediastinal structures [22].

The detection of B lines on lung USG in the post-COVID-19 period has been accepted as an essential indicator of interstitial damage in these patients. In a study, lung USG was performed in patients diagnosed with COVID-19 within 6 weeks following the diagnosis, and B lines were detected in all patients. A correlation was found between the frequency of B lines and dyspnea, one of the symptoms of prolonged COVID [23]. This result is compatible with our study. However, the same study reported that the detection of B lines decreased to 31% after 3 months and to 6% after 12 months. The reason for this was that lung USG findings changed over time, but gas exchange disorders detected by the Diffusing Capacity of the Lungs for Carbon Monoxide (DLCO) continued, indicating that lung USG after COVID may reflect gas exchange disorders, especially in the early stages of the disease. This result contradicts our study. Because, we performed lung USG 18 months after COVID-19 and found a significant positive correlation between the total number of B lines and dyspnea. This difference may be since the long-term effects of COVID-19 on the lungs have yet to be discovered. Because the study by Kimmel *et al*. covered 12 months after the diagnosis of COVID [23]. However, our study examined patients who were at least 18 months post-COVID. The results of a follow-up study in which dyspnea and lung function were evaluated for 1 year in recovered COVID-19 patients support this contradictory situation in favor of our study. In this study, 45% of patients complained of new-onset dyspnea, and lung function tests, especially DLCO, tended to improve over time; however, persistent deterioration was observed in some patients. In these patients, regional ventilation distribution was evaluated by electrical impedance tomography, and ventilation disorders were detected in some regions [24]. These studies show that the effects of COVID-19 on the lungs change with time.

Recent literature shows that myalgia after COVID-19 is one of the common symptoms of prolonged COVID-19, just like in our study [25]. One of the studies suggests that the SARS-CoV-2 virus infects skeletal muscle cells by binding to the ACE2 receptor [26]. Another is that the virus acts by binding to skeletal muscle cells through TMPRSS2 receptors independent of the ACE2 receptor [27]. During symptomatic COVID-19, cytokines such as interleukin-6, interleukin-1β, interleukin-8, interferon-gamma, interferon-gamma inducible protein 10, and tumor necrosis factor alpha released due to the cytokine storm have been suggested to cause symptoms of chronic fatigue and myalgia by causing proteolysis in muscle fibers and reducing protein synthesis and disrupting the myogenic process [28-30]. However, since the patients included in the studies were mostly inpatients, it should be considered that prolonged immobilization may cause musculoskeletal symptoms.

This suggests that the musculoskeletal symptoms observed may be due not only to COVID-19 infection but also to immobilization and related complications of prolonged hospitalization.

Previous studies have found that myalgia as a symptom of prolonged COVID is more frequent and severe in patients treated in the intensive care unit [31, 32]. This may be related to both the disease itself and factors such as prolonged hospitalization and immobility in the intensive care unit. However, in our study, myalgia, one of the symptoms of prolonged COVID, was found to be more common in patients treated in the ward compared to patients treated in the ICU. This finding suggests that patients treated in the ward reported myalgia symptoms more commonly. The reason for this is that the number of patients receiving treatment in the intensive care unit in our study was lower than in the ward group.

In the follow-up of patients presenting with prolonged COVID symptoms, it is recommended to perform a complete blood count, biochemical tests, pulmonary function tests, and Thoracic CT and chest radiography [33]. However, CT cannot be easily applied due to its disadvantages, such as additional radiation exposure, inability to use in pregnant women or those who are likely to become pregnant, transferring the patient to the department where CT will be performed, and the need to position the patient. Similar disadvantages apply to chest radiography. The position of the patient is significant for a good chest radiograph. Lung USG is almost equivalent to CT in detecting parenchymal tissue and pleural pathologies [9]. In addition, it is more advantageous than both CT and chest radiography because it is non-invasive, does not emit X-rays, is easily applicable, reproducible and cost-effective, and is portable and wireless. In a study of 212 patients diagnosed with COVID-19, lung USG, and chest radiography were compared, and it was shown that lung USG was more successful than chest radiography in detecting early pulmonary findings [34]. For all these reasons, the use of lung USG in the follow-up or triage of patients is becoming increasingly common.

It is known that lung USG was used effectively during the COVID-19 pandemic, reducing the number of chest radiographs and CT scans. Studies have shown that the use of wireless or bedside lung USG is an effective way to determine the prevalence and severity of lung involvement and to be used in the daily follow-up of patients [35-38].

Limitations

Our study's limitations include its single-center design and the relatively small number of patients in the intensive care unit.

CONCLUSION

This study examined the effectiveness of lung USG in evaluating structural changes in the lungs after COVID-19 and the relationship between these structural changes and prolonged COVID symptoms. The results revealed that B lines detected on lung USG had a significant association with dyspnea, one of the prolonged COVID symptoms. In addition, symptoms such as dyspnea, myalgia, and sweating were found to be associated with each other.

Considering that long-term lung damage continues after COVID-19 and causes permanent respiratory problems in some patients, patients recovering from COVID-19 should receive long-term follow-up and support. Our study shows that lung USG can make essential contributions to the follow-up of post-COVID patients as a non-invasive, reproducible, and portable method in the post-COVID period. In addition, the number of B lines may be an essential biomarker in managing dyspnea, a prolonged COVID symptom. Monitoring B lines with lung USG can be a valuable tool for monitoring treatment efficacy and long-term management of patients.

Authors' Contribution

Study Conception: NTT; Study Design: NTT; Supervision: ONH; Funding: N/A; Materials: NTT; Data Collection and/or Processing: NTT; Statistical Analysis and/or Data Interpretation: NS; Literature Review: İY; Manuscript Preparation: NTT and Critical Review: PH.

Conflict of interest

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