Turkish Journal of Thoracic and Cardiovascular Surgery 2023;31(3):352-357

ORIGINAL ARTICLE / ÖZGÜN MAKALE

The prognostic effect of concomitant COVID-19 with spontaneous pneumothorax

COVID-19'un spontan pnömotoraks ile birlikteliğinin prognoza etkisi

Mustafa Akyil[1], Serkan Bayram[1], Pelin Erdizci[1], Fatma Tokgoz Akyil[2], Ayse Ulusoy[1], Serdar Evman[1], Levent Alpay[1], Volkan Baysungur[1]

Institution where the research was done:
University of Health Sciences, Süreyyapaşa Training and Research Hospital, Istanbul, Türkiye

Author Affiliations:
[1]Department of Thoracic Surgery, University of Health Sciences, Süreyyapaşa Training and Research Hospital, Istanbul, Türkiye
[2]Department of Pulmonology, University of Health Sciences, Yedikule Chest Diseases and Thoracic Surgery Training and Research Hospital, Istanbul, Türkiye

ABSTRACT

Background: The aim of this study was to investigate the prevalence of novel coronavirus disease 2019 (COVID-19) in patients hospitalized with primary spontaneous pneumothorax and to evaluate its possible effects on the clinical course, treatment, and the prognosis.

Methods: Between April 2020 and January 2021, a total of 86 patients (78 males, 8 females; mean age: 27±5 years; range, 16 to 40 years) who had no underlying lung disease and were diagnosed with the first episode of spontaneous pneumothorax were retrospectively analyzed. At the same time of diagnosis, all patients were screened for COVID-19 via polymerase chain reaction test of nasopharyngeal swabs. According to the test results, the patients were divided into two groups as COVID-19(+) and COVID-19(–). The duration of air leak, hospital stay, recurrence rates and treatment modalities, and mortality rates of the two groups were compared.

Results: Following a pneumothorax diagnosis, 18 (21%) patients were diagnosed with COVID-19. In COVID-19(+) patients, the mean air leak and lung expansion duration were significantly longer ($p<0.0001$ for both). In these patients, the mean length of hospital stay was also significantly longer ($p<0.0001$). During the median follow-up of six months, no mortality was observed and the recurrence rate was similar between the two groups ($p=0.998$).

Conclusion: Our study results suggest that COVID-19 negatively affects the recovery time in patients with spontaneous pneumothorax.

Keywords: COVID-19, polymerase chain reaction, spontaneous pneumothorax.

ÖZ

Amaç: Bu çalışmada primer spontan pnömotoraks tanısı ile hastaneye yatırılan hastalarda yeni koronavirüs hastalığı 2019'un (COVID-19) prevalansı araştırıldı ve klinik seyir, tedavi ve prognoz üzerindeki muhtemel etkileri incelendi.

Çalışma planı: Nisan 2020 - Ocak 2021 tarihleri arasında altta yatan akciğer hastalığı olmayan ve ilk atak spontan pnömotoraks tanısı konan toplam 86 hasta (78 erkek, 8 kadın; ort. yaş: 27±5 yıl; dağılım, 16-40 yıl) retrospektif olarak incelendi. Tanı sırasında tüm hastalar nazofarengeal sürüntülerinin polimeraz zincir reaksiyon testi ile COVID-19 açısından tarandı. Test sonuçlarına göre hastalar COVID-19(+) ve COVID-19(–) olmak üzere iki gruba ayrıldı. Hava sızıntı süresi, hastanede yatış, nüks oranları ve tedavi yöntemleri ve mortalite oranları iki grup arasında karşılaştırıldı.

Bulgular: Pnömotoraks tanısını takiben, 18 (%21) hastaya COVID-19 tanısı kondu. COVID-19(+) hastalarda ortalama hava kaçağı ve akciğer ekspansiyon süresi anlamlı düzeyde daha uzun idi (her ikisi için de $p<0.0001$). Bu hastalarda hastanede kalış süresi de anlamlı düzeyde uzundu ($p<0.0001$). Medyan altı aylık takip süresince, mortalite gözlenmedi ve nüks oranı iki grup arasında benzerdi ($p=0.998$).

Sonuç: Çalışma sonuçlarımız COVID-19'un, spontan pnömotorakslı hastalarda iyileşme süresini olumsuz etkilediğini göstermektedir.

Anahtar sözcükler: COVID-19, polimeraz zincir reaksiyonu, spontan pnömotoraks.

Corresponding author: Mustafa Akyil.
E-mail: makyil@hotmail.com

Doi: 10.5606/tgkdc.dergisi.2023.23439

Received: March 13, 2022
Accepted: May 20, 2022
Published online: July 27, 2023

Cite this article as: Akyil M, Bayram S, Erdizci P, Tokgoz Akyil F, Ulusoy A, Evman S, et al. The prognostic effect of concomitant COVID-19 with spontaneous pneumothorax. Turk Gogus Kalp Dama 2023;31(3):352-357. doi: 10.5606/tgkdc.dergisi.2023.23439.

The novel coronavirus disease 2019 (COVID-19), caused by severe acute respiratory syndrome-coronavirus 2 (SARS-CoV-2), was declared as a pandemic by the World Health Organization (WHO) on March 11th, 2020, and is still continuing its global impact. The clinical spectrum of the disease varies widely from asymptomatic cases to severe pneumonia and severe respiratory failure.[1,2] Pneumothorax has also been observed as a rare complication of or in association with COVID-19 patients, since the early phases of the pandemic.[3-5] Retrospective studies reported that pneumothorax was observed in 1% of COVID-19 patients requiring hospitalization and in 2% of patients necessitating intensive care unit (ICU).[4,5] Mechanical ventilation is defined as a risk factor for developing pneumothorax in COVID-19 patients.[6] However, pneumothorax can occur even in patients without a pre-existing lung disease and who do not need positive pressure ventilation.[3,7,8] Although the mechanism of spontaneous pneumothorax in COVID-19 is not fully explained, it is thought to be associated with viral alveolar membrane damage.[9,10]

In the present, we aimed to investigate the prevalence of SARS-CoV-2 positivity in patients with spontaneous pneumothorax and its potential effects on the clinical course and treatment of pneumothorax.

PATIENTS AND METHODS

Study design and study population

This single-center, retrospective study was conducted Süreyyapaşa Training and Research Hospital, Department of Chest Diseases and Thoracic Surgery between April 2020 and January 2021. All patients with first episode of spontaneous pneumothorax and undergoing 28 french underwater-sealed tube thoracostomy were included in the study. Patients having any underlying lung disease and those with recurrent spontaneous pneumothorax were excluded (Figure 1). Patients who were already diagnosed with COVID-19 at the time of pneumothorax development or referred for consultation from other clinics were also excluded. Finally, a total of 86 patients (78 males, 8 females; mean age: 27±5 years; range, 16 to 40 years) were included in the study.

Organization of the study unit

From the date of the first case reported in Türkiye and the date of pandemic announcement by the WHO, polymerase chain reaction (PCR) tests are routinely requested twice from all hospitalized patients at the time of hospitalization and the following day after hospitalization to exclude COVID-19. According to the PCR results and radiological findings, patients diagnosed with COVID-19 are transferred to the COVID-19 units of our hospital and also followed and treated by us. Treatment according to the guidelines of the Republic of Türkiye, Ministry of Health[11] was given. Routine prophylactic antibiotics are not used.

Data collection

Demographic characteristics, comorbidities, smoking habits, clinical and radiological characteristics, treatment choices, response duration to treatment, thoracic computed tomography (CT) findings and COVID-19 PCR results of the patients were recorded via the hospital information database system. Additionally, all patients were evaluated for the development of recurrence during follow-up until September 2021. Survival status was also checked using the National Death Reporting System.

The patients were divided into two groups according to the detection of COVID-19: Group 1: patients without COVID-19 (n=68); Group 2: patients with COVID-19 (n=18). The demographic characteristics, clinical and radiological characteristics, treatment types, treatment responses of the patients along with recurrence and mortality rates were compared between the groups.

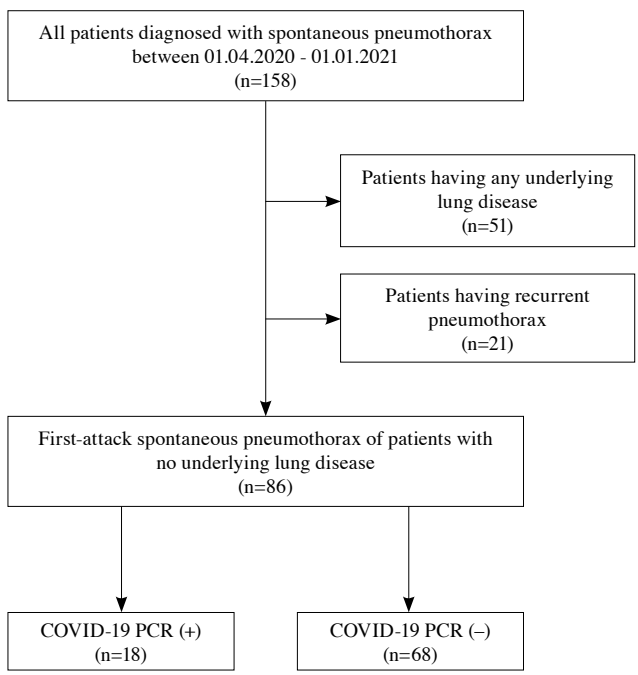

Figure 1. Study flowchart.
COVID-19: Novel coronavirus disease 2019; PCR: Polymerase chain reaction.

Table 1. Patient characteristics and features of pneumothorax according to presence of COVID-19

	All patients (n=86)			COVID-19 (–) (n=68)			COVID-19 (+) (n=18)			
	n	%	Mean±SD	n	%	Mean±SD	n	%	Mean±SD	*p*
Age (year)			27±5			26±5			32±8	<0.0001
Sex										0.356
Male	78	91		63	93		15	83		
Female	8	9		5	7		3	17		
Comorbid disease	5	6		2	3		3	17		0.06
Smoking status										0.723
Current smoker	47	55		26	38		7	39		
Former smoker	6	7		4	6		2	11		
Non-smoker	33	38		38	56		9	50		
Side of pneumothorax										0.014
Right	44	51		34	50		10	56		
Left	40	47		34	50		6	33		
Bilateral	2	2		-	-		2	11		
Laterality										0.042
Unilateral	84	98		68	100		16	89		
Bilateral	2	2		-	-		2	11		
Surgical procedure	10	8		9	13		1	6		0.333

COVID-19: Novel coronavirus disease 2019; SD: Standard deviation.

Statistical analysis

Statistical analysis was performed using the SPSS for Windows version 16.0 software (SPSS Inc., Chicago, IL, USA). Descriptive data were expressed in mean ± standard deviation (SD), median (min-max) or number and frequency, where applicable. Comparisons between the groups were made using the Student t-test and chi-square test. A *p* value of <0.05 was considered statistically significant.

RESULTS

Of a total of 86 patients, five (6%) had any comorbid disease and 33 (38%) were active smokers. Comorbid diseases were diabetes mellitus (n=3), asthma (n=1) and hypertension (n=1). Pneumothorax was mostly right-sided (n=44, 51%). Bilateral pneumothorax was recorded in two (11%) patients, both in PCR (+) Group 2 (Table 1). After the diagnosis of pneumothorax, 18 patients (21%), whose PCR

Table 2. Follow-up results of the patients according to presence of COVID-19

	All patients (n=86)			COVID-19 (–) (n=68)			COVID-19 (+) (n=18)			
	n	%	Mean±SD	n	%	Mean±SD	n	%	Mean±SD	*p*
Duration of air leak (days)			3.6±3			2.5±4			5.4±4	<0.0001
Complete pulmonary expansion duration (days)			2±1.5			1.6±1			3.5±2.2	<0.0001
Duration to removal of the chest tube (days)			4.9±3.3			4.4±2.7			6.7±4.5	0.008
Hospital stay (days)			5.8±3.4			5.1±2.8			8.4±4.2	<0.0001
Recurrent pneumothorax in the follow-up	10	8		8	12		2	11		0.998

COVID-19: Novel coronavirus disease 2019; SD: Standard deviation.

test was positive, were diagnosed with COVID-19. Typical radiological findings of COVID-19 were not detected in any of these patients. Only one patient (6%) had pneumomediastinum with pneumothorax in Group 2.

Tube thoracostomy with wet suction control closed drainage system was applied to all patients. An additional surgical procedure was required in 10 (8%) patients due to prolonged air leak. The rate of need for surgical intervention in patients was similar in the two groups. (6% *vs*. 13%, respectively; p=0.333).

The sex, smoking habit, and comorbidities were similar in COVID-19 and non-COVID-19 patients (Table 1). However, the mean age was higher in COVID-19 patients (32±8 *vs*. 26±5 years, respectively; p<0.0001) and bilateral pneumothorax was more frequent in COVID-19 patients (11% *vs*. 0%, respectively; p=0.042).

The mean air leak duration (5.4±4 *vs*. 2.5±4 days, respectively; p<0.0001) and lung expansion duration (3.5±2.2 *vs*. 1.6±1 days, respectively; p<0.0001) were significantly longer in COVID-19 patients. The mean tube thoracostomy duration (6.7±4.5 *vs*. 4.4±2.7 days, respectively; p=0.008) and length of hospital stay (8.4±4.2 *vs*. 5.1±2.8 days, respectively; p<0.0001) were also longer in these patients (Table 2).

Pneumothorax recurred in 10 (8%) patients during a median follow-up of six (range, 2 to 12) months. There was no mortality. The recurrence rate was comparable between the two groups (p=0.998).

DISCUSSION

Male sex, tall height, slim body structure, and the 10-30 age group are defined as risk factors for the development of primary spontaneous pneumothorax, which occurs without an underlying lung disease.[12] On the other hand, the most frequent etiology of secondary spontaneous pneumothorax are chronic obstructive pulmonary disease, alpha-1 antitrypsin deficiency, cystic fibrosis, tuberculosis, and lung cancer.[13]

In December 2019, COVID-19 epidemic broke out in Wuhan, China and the disease has spread rapidly in whole world.[14] The spectrum of the disease vary widely from asymptomatic disease to mild symptoms such as fever, cough, smell and taste disturbance, or a severe and rapidly progressing acute respiratory failure.[15] Pneumothorax may be seen as a rare complication of COVID-19.[3-5]

Pneumothorax in COVID-19 is mostly reported and investigated in patients with a previously known COVID-19. A recent study has shown the rate of air leak (pneumothorax and/or pneumomediastinum) as 0.56% among 3,377 COVID-19 patients.[16] In the aforementioned study, COVID-19 patients with and without air leak were compared and the risk factors were defined as younger age, higher baseline C-reactive protein (CRP) levels and ventilator requirement. The rates of pneumothorax in COVID-19 are reported as 1% in patients requiring hospitalization, 2% in ICU patients and 1% in deceased patients.[4,5,17] There are a number of risk factors described for pneumothorax occurrence and mechanical ventilation is the main factor. Aiodfi et al.[18] reported two cases with COVID-19 who developed pneumothorax during mechanical ventilation. The risk of pneumothorax and/or pneumomediastinum may increase up to 15% with ventilator support[6] and may be a fatal complication in these critically ill patients.[19]

Apart from ventilator support and barotrauma, pneumothorax may develop spontaneously in asymptomatic cases or during the course of the disease. Cases may have no risk factors or predisposing lung disease.[18,20] Wang et al.[7] presented a case who developed spontaneous pneumothorax, pneumomediastinum and subcutaneous emphysema and did not previously require ventilator support. In a multi-center study, 22 (1.4%) of 1,619 patients with a confirmed COVID-19 diagnosis had spontaneous pneumothorax and 50% of them were not under ventilator support.[8] In a study conducted in the United Kingdom, the coexistence of COVID-19 pneumonia and pneumothorax was described in 71 patients from 16 centers, occurring even in patients having no pre-existing lung disease.[3] A recent multi-center study examined the emergency department admissions with spontaneous pneumothorax in patients with and without COVID-19 and older age, hypertension, having symptoms of either COVID-19 or pneumothorax, higher CRP and procalcitonin levels were found to be higher in COVID-19-related pneumothorax than non-COVID-19 ones.[21] Interestingly, right-sided cases were more frequent in COVID-19 cases (81% *vs*. 19%). In present study, none of our patients had a previous diagnosis of COVID-19 and none of them required ventilator support. The PCR positivity was detected in approximately one-fifth of the patients who were previously diagnosed as primary spontaneous pneumothorax. Structural lung disease was not detected in these patients either, and there were no ground-glass opacification or typical radiological involvement. Despite higher rates of right-sided pneumothorax, a lower percentage was

found in our study than in the study of Miró et al.[21] However, our cases had no symptoms and diagnosis of COVID-19. We believe that further multi-center studies are required for asymptomatic cases of spontaneous pneumothorax.

The mechanism of spontaneous pneumothorax in patients with COVID-19 disease is considered to be associated with structural changes in the lung parenchyma and alveolar membrane damage by SARS-CoV-2.[9,10] Another possible predisposing factor may be prolonged cough, which is a common symptom of COVID-19.[4,22] In addition to the intrathoracic pressure increase caused by prolonged cough and/or mechanical ventilation, cystic and fibrotic changes leading to alveolar tears may also cause pneumothorax.[9] This relationship may be secondary to underlying undiagnosed bullous lung disease and rupture. A recent article reported two patients, one of whom developed pneumothorax, with a cystic lung lesion due to COVID-19 disease.[10] In our study, the patients did not have any radiological findings and/or laboratory diagnosis for COVID-19 before the diagnosis of pneumothorax, and also there was no known history of any lung disease. None of our COVID-19 patients had cystic or bullous lesions, either.

Tube thoracostomy for pneumothorax can be considered as an aerosol-generating procedure and, recently, SARS-CoV-2 viral ribonucleic acid (RNA) has been detected in post-mortem pleural fluid.[23,24] Although the first-line treatment is drainage by tube thoracostomy, videothoracoscopy may be necessary in cases of prolonged air leak or recurrent pneumothorax. Pulmonary surgery for pneumothorax in COVID-19 patients can be performed safely and effectively as needed.[25] In the present study, one COVID-19 patient with prolonged air leak underwent videothoracoscopy.

Contrary results have been published on the prognostic effect of pneumothorax in COVID-19. Martinelli et al.[3] did not identify pneumothorax as an independent marker for poor prognosis. In contrast, there are studies suggesting that this coexistence is an important prognostic marker.[6,26] Miró et al.[21] demonstrated longer hospitalization, higher ICU admission, and mortality rate. Similarly, in the present study, the duration of air leak, expansion failure and hospital stay were significantly longer in patients with COVID-19 disease. None of our patients were admitted to ICU and no mortality was seen in our series. Our patients were younger and free of symptoms at the time of presentation which may have caused the different results. Further multi-center studies may enlighten the prognostic effect of pneumothorax in asymptomatic COVID-19 cases.

The single-center and retrospective design are the main limitations to this study. On the other hand, being a referral center for chest diseases and our close follow-up of all patients are the main strengths of this study.

In conclusion, our study results suggest that the recovery time is prolonged in asymptomatic COVID-19 patients with spontaneous pneumothorax. Ventilator support, intensive care unit requirement, and mortality risks are not increased compared to non-COVID-19 patients. We believe that, as long as the pandemic continues, patients with spontaneous pneumothorax should be monitored for COVID-19 for better diagnostic and prognostic prospects.

Ethics Committee Approval: The study protocol was approved by the Süreyyapaşa Chest Diseases and Thoracic Surgery Non-Interventional Clinical Research Ethics Committee Ethics Committee (date: 03.03.2021, no: 116.2017.R-226). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Consent for Publication: A written informed consent was obtained from each patient.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Idea/concept: M.A., S.B., S.E.; Design, data collection: M.A., P.E., A.U.; Control: S.E., F.T.A., L.A., V.B.; Analysis: F.T.A., S.E., M.A.; Literature review: M.A., S.B., P.E.; Writing the article: M.A., F.T.A., P.E.; Critical review: V.B., F.T.A., L.A., S.E.

Conflict of Interest: The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

Funding: The authors received no financial support for the research and/or authorship of this article.

REFERENCES

1. Wang D, Hu B, Hu C, Zhu F, Liu X, Zhang J, et al. Clinical characteristics of 138 hospitalized patients with 2019 novel coronavirus-infected pneumonia in Wuhan, China. JAMA 2020;323:1061-9. doi: 10.1001/jama.2020.1585.
2. Berlin DA, Gulick RM, Martinez FJ. Severe Covid-19. N Engl J Med 2020;383:2451-60. doi: 10.1056/NEJMcp2009575.
3. Martinelli AW, Ingle T, Newman J, Nadeem I, Jackson K, Lane ND, et al. COVID-19 and pneumothorax: A multicentre retrospective case series. Eur Respir J 2020;56:2002697. doi: 10.1183/13993003.02697-2020.

4. Chen N, Zhou M, Dong X, Qu J, Gong F, Han Y, et al. Epidemiological and clinical characteristics of 99 cases of 2019 novel coronavirus pneumonia in Wuhan, China: A descriptive study. Lancet 2020;395:507-13. doi: 10.1016/S0140-6736(20)30211-7.
5. Yang X, Yu Y, Xu J, Shu H, Xia J, Liu H, et al. Clinical course and outcomes of critically ill patients with SARS-CoV-2 pneumonia in Wuhan, China: A single-centered, retrospective, observational study. Lancet Respir Med 2020;8:475-81. doi: 10.1016/S2213-2600(20)30079-5.
6. McGuinness G, Zhan C, Rosenberg N, Azour L, Wickstrom M, Mason DM, et al. Increased incidence of barotrauma in patients with COVID-19 on invasive mechanical ventilation. Radiology 2020;297:E252-62. doi: 10.1148/radiol.2020202352.
7. Wang W, Gao R, Zheng Y, Jiang L. COVID-19 with spontaneous pneumothorax, pneumomediastinum and subcutaneous emphysema. J Travel Med 2020;27:taaa062. doi: 10.1093/jtm/taaa062.
8. Ekanem E, Podder S, Donthi N, Bakhshi H, Stodghill J, Khandhar S, et al. Spontaneous pneumothorax: An emerging complication of COVID-19 pneumonia. Heart Lung 2021;50:437-40. doi: 10.1016/j.hrtlng.2021.01.020.
9. Zhou C, Gao C, Xie Y, Xu M. COVID-19 with spontaneous pneumomediastinum. Lancet Infect Dis 2020;20:510. doi: 10.1016/S1473-3099(20)30156-0.
10. Liu K, Zeng Y, Xie P, Ye X, Xu G, Liu J, et al. COVID-19 with cystic features on computed tomography: A case report. Medicine (Baltimore) 2020;99:e20175. doi: 10.1097/MD.0000000000020175.
11. COVID-19 rehberi. Available at: https://covid19.saglik.gov.tr/TR-66301/covid-19-rehberi.html
12. Gupta D, Hansell A, Nichols T, Duong T, Ayres JG, Strachan D. Epidemiology of pneumothorax in England. Thorax 2000;55:666-71. doi: 10.1136/thorax.55.8.666.
13. Sahn SA, Heffner JE. Spontaneous pneumothorax. N Engl J Med 2000;342:868-74. doi: 10.1056/NEJM200003233421207.
14. Zhu N, Zhang D, Wang W, Li X, Yang B, Song J, et al. A novel coronavirus from patients with pneumonia in China, 2019. N Engl J Med 2020;382:727-33. doi: 10.1056/NEJMoa2001017.
15. Rodriguez-Morales AJ, Cardona-Ospina JA, Gutiérrez-Ocampo E, Villamizar-Peña R, Holguin-Rivera Y, Escalera-Antezana JP, et al. Clinical, laboratory and imaging features of COVID-19: A systematic review and meta-analysis. Travel Med Infect Dis 2020;34:101623. doi: 10.1016/j.tmaid.2020.101623.
16. Muhammad AI, Mehta M, Shaw M, Hussain N, Joseph S, Vancheeswaran R. Incidence and clinical features of pneumomediastinum and pneumothorax in COVID-19 pneumonia. J Intensive Care Med 2022;37:1015-8. doi: 10.1177/08850666221091441.
17. Yang F, Shi S, Zhu J, Shi J, Dai K, Chen X. Analysis of 92 deceased patients with COVID-19. J Med Virol 2020;92:2511-5. doi: 10.1002/jmv.25891.
18. Aiolfi A, Biraghi T, Montisci A, Bonitta G, Micheletto G, Donatelli F, et al. Management of persistent pneumothorax with thoracoscopy and bleb resection in COVID-19 patients. Ann Thorac Surg 2020;110:e413-5. doi: 10.1016/j.athoracsur.2020.04.011.
19. Wang XH, Duan J, Han X, Liu X, Zhou J, Wang X, et al. High incidence and mortality of pneumothorax in critically Ill patients with COVID-19. Heart Lung 2021;50:37-43. doi: 10.1016/j.hrtlng.2020.10.002.
20. Flower L, Carter JL, Rosales Lopez J, Henry AM. Tension pneumothorax in a patient with COVID-19. BMJ Case Rep 2020;13:e235861. doi: 10.1136/bcr-2020-235861.
21. Miró Ò, Llorens P, Jiménez S, Piñera P, Burillo-Putze G, Martín A, et al. Frequency, risk factors, clinical characteristics, and outcomes of spontaneous pneumothorax in patients with coronavirus disease 2019: A case-control, emergency medicine-based multicenter study. Chest 2021;159:1241-55. doi: 10.1016/j.chest.2020.11.013.
22. Guan WJ, Ni ZY, Hu Y, Liang WH, Ou CQ, He JX, et al. Clinical characteristics of coronavirus disease 2019 in China. N Engl J Med 2020;382:1708-20. doi: 10.1056/NEJMoa2002032.
23. Schaller T, Hirschbühl K, Burkhardt K, Braun G, Trepel M, Märkl B, et al. Postmortem examination of patients with COVID-19. JAMA 2020;323:2518-20. doi: 10.1001/jama.2020.8907.
24. Akhtar MR, Ricketts W, Fotheringham T. Use of an antiviral filter attached to a pleural drain bottle to prevent aerosol contamination with SARS-CoV-2. Clin Med (Lond) 2020;20:e60-1. doi: 10.7861/clinmed.2020-0246.
25. Bellini R, Salandini MC, Cuttin S, Mauro S, Scarpazza P, Cotsoglou C. Spontaneous pneumothorax as unusual presenting symptom of COVID-19 pneumonia: Surgical management and pathological findings. J Cardiothorac Surg 2020;15:310. doi: 10.1186/s13019-020-01343-4.
26. López Vega JM, Parra Gordo ML, Diez Tascón A, Ossaba Vélez S. Pneumomediastinum and spontaneous pneumothorax as an extrapulmonary complication of COVID-19 disease. Emerg Radiol 2020;27:727-30. doi: 10.1007/s10140-020-01806-0.