Original Article DOI: https://doi.org/10.18502/fem.v5i2.5612

Lung Ultrasound Findings Compared to Chest CT Scan in Patients with COVID-19 Associated Pneumonia: A Pilot Study

Hamidreza Hatamabadi[1], Majid Shojaee[2], Mohammad Bagheri[2], Masoomeh Raoufi[3]*

1. Safety Promotion and Injury Prevention Research Center, Shahid Beheshti University of Medical Science, Tehran, Iran.
2. Department of Emergency Medicine, Imam Hossein Hospital, Shahid Beheshti University of Medical Sciences, Tehran, Iran.
3. Department of Radiology, Imam Hossein Hospital, Shahid Beheshti University of Medical Sciences, Tehran, Iran.

***Corresponding author:** Masoomeh Raoufi; **Email:** masomeraoufi@gmail.com

Published online: 2020-06-26

Abstract

Introduction: Lung US has been reported to be as useful as a chest CT scan and much better than a chest x-ray for the evaluation of pneumonia.

Objective: This study aimed to compare the findings of lung ultrasound (US) and chest CT scan of patients with COVID-19-associated pneumonia in the Emergency Department (ED).

Methods: This retrospective observational pilot study was carried out on confirmed COVID-19 patients in the isolation corona ward of the Imam Hussein Hospital ED from March 15 to March 22, 2020. After obtaining demographic data, the patients underwent a pulmonary bedside US examination, with the patients in the sitting position, turning their back to the examiner. A 10-point lung US was performed. Each lung was divided into two areas: posterior (three zones) and lateral (two zones). The patients' lung ultrasound and chest CT scan as the standard imaging were blindly reviewed and recorded. The clinical value of ultrasound was evaluated with different severity of lung involvement according to CT severity score.

Results: Nineteen patients (38 zones), including 13 males, were evaluated with a mean age of 62.5±16.8 years. B2 lines and consolidation observed in the US examinations were significantly correlated with ground-glass opacity and consolidation observed in CT scan examinations, respectively ($p < 0.0001$). US sensitivity and specificity of finding B_2 lines were 90% and 100%, respectively. Also, the sensitivity and specificity of US in identifying consolidation were 82% and 100%, respectively. In the lungs with moderate and severe lobar involvement, US findings were significantly correlated ($p < 0.05$) with CT scan findings.

Conclusions: Ultrasound evaluation is a safe, fast, and rapid technique for the evaluation of patients with moderate to severe COVID-19-associated pneumonia. It is a reproducible procedure and can be implemented by the operator after a short course of training.

Key words: COVID-19; Lung; Tomography, X-Ray Computed; Ultrasonography

Cite this article as: Hatamabadi H, Shojaee M, Bagheri M, Raoufi M. Lung Ultrasound Findings Compared to Chest CT Scan in Patients with COVID-19-associated Pneumonia: A Pilot Study. Front Emerg Med. 2021;5(2):e19.

INTRODUCTION

COVID-19 emerged in Wuhan, Hubei Province, China, and spread all over the world, causing a pandemic (1). More than 2 million and 77 thousand confirmed COVID-19 cases had been officially reported globally and in Iran, respectively, based on the results of reverse transcription polymerase chain reaction (RT-PCR) from February 18, 2020 to April 17, 2020 (2). The most common manifestations at the onset of the disease are fever, coughs, myalgia, and fatigue. Clinical features range from an asymptomatic state to more severe conditions such as pneumonia, respiratory distress, multisystem organ failure, and death (3). Primarily, the most commonly recommended diagnostic protocol relies on clinical symptoms and signs, laboratory tests (especially RT-PCR), chest x-ray, and lung computed tomography (CT) scan (4); and high-resolution computed tomography (HRCT) is an essential COVID-19 diagnostic tool in the emergency department (ED) based on the latest protocols (5). According to previous reports, the most common CT scan pattern of lung involvement in COVID-19 patients is bilateral, peripheral, ill-defined, and ground-glass opacification (GGO), mainly involving the right lower lobe (6). Although a lung CT scan is an accurate diagnostic tool, it has some limitations, including the risk of transporting patients with unstable vital signs, carrying the patients to the CT scan unit, which increases the risk of other individuals' contamination, high cost, and risk of x-ray adverse effects on pregnant women and children. Formerly, the

Copyright © 2021 Tehran University of Medical Sciences
This work is licensed under a Creative Commons Attribution-NonCommercial 4.0 International license (https://creativecommons.org/licenses/by-nc/4.0/). Noncommercial uses of the work are permitted, provided the original work is properly cited.

ultrasonography (US) was used for the evaluation of the lungs in many emergency conditions (7, 8). Lung US has been reported to be as useful as a chest CT scan and much better than a chest x-ray for the evaluation of pneumonia. Rapidity, repeatability, ease of use at the bedside, reliability, and the absence of x-ray exposure are the benefits of using the US technique (9, 10). In this study, we present our initial experience in the evaluation of pulmonary lesions due to COVID-19, using bedside US in the ED to compare the findings of this diagnostic method with those of chest CT scan and propose a rapid and easy method for lung US evaluation in COVID-19 patients in ED.

Methods

Study design and setting

This study was conducted from March 15 to March 22, 2020 in ED of Imam Hossein Hospital, Tehran, Iran. The research protocol was approved by the Ethics Committee of Shahid Beheshti University of Medical Sciences under the code IR.SBMU.RETECH.REC.1399.003. The researchers adhered to the principles of ethics in performing biomedical studies and kept the patients' data confidential throughout the study. Informed consent was obtained from all the patients.

Participants

According to the hospital's protocol, all the patients with signs and symptoms related to COVID-19 associated pneumonia undergo chest CT scan routinely in the ED. Throat swab RT-PCR is used to confirm cases with a suspected chest CT scan.
Patients diagnosed with RT-PCR during mentioned study period were included. They were all admitted to the isolation COVID-19 ward. Patients with a history of lobectomy, atelectasis, lung malignancy, and tuberculosis were excluded.

Radiological assessment

Our team consisted of an emergency physician (EP) specialist and a radiologist. The EP had sixteen years of emergency medicine experience and sufficient experience in the Point of Care Ultrasound (POCUS) examination of different parts of the body; however, he did not have any previous experience in the ultrasound examination of

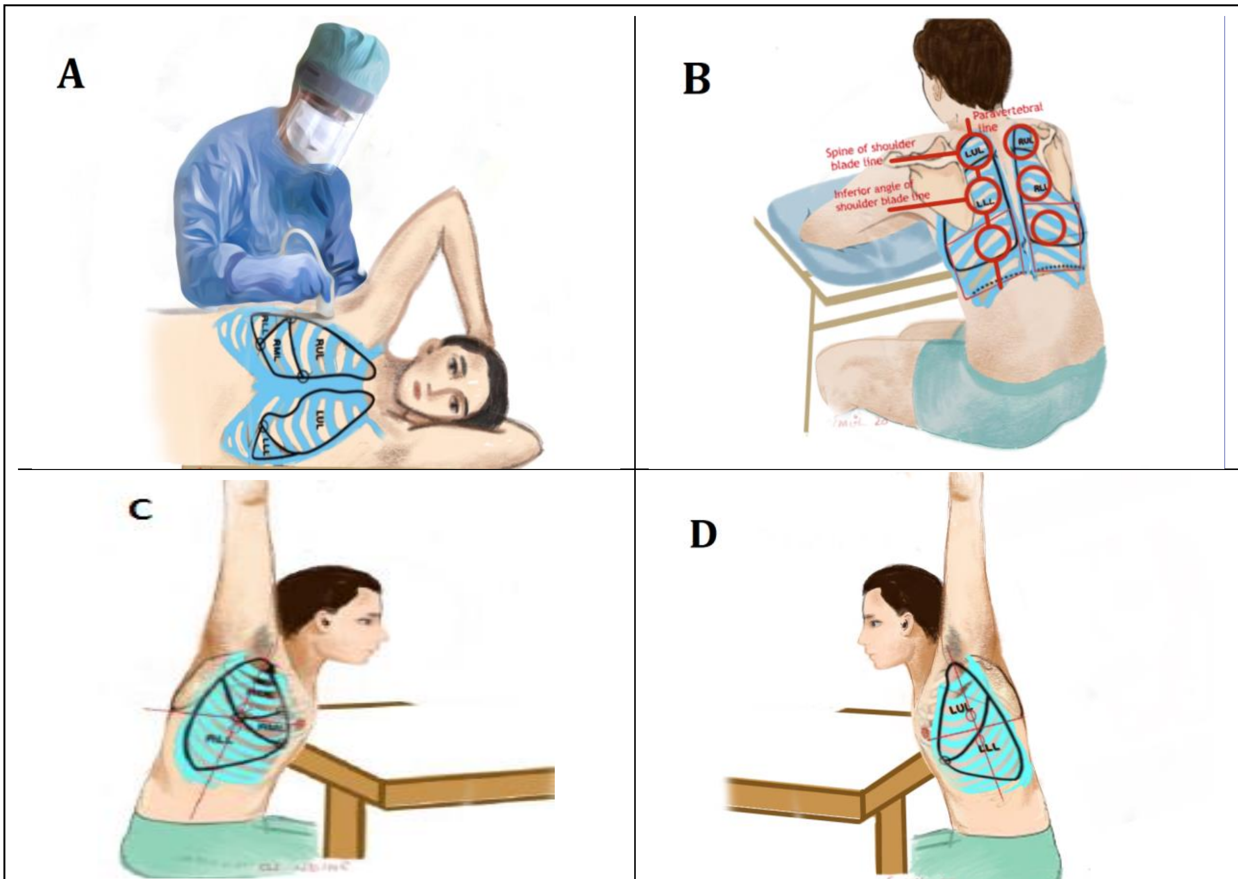

Figure 1: Operator with standard personal protective equipment (PPE) in patients with lateral decubitus position (A). Ten-point lung ultrasound that includes six points posterior (B), two points right axillary (C) and two points' left axillary (D) evaluation. Patients were in a sitting position and turned their backs to the examiner.

Copyright © 2021 Tehran University of Medical Sciences
This work is licensed under a Creative Commons Attribution-NonCommercial 4.0 International license (https://creativecommons.org/licenses/by-nc/4.0/). Noncommercial uses of the work are permitted, provided the original work is properly cited.

COVID-19 patients. Therefore, they studied the possible ultrasound manifestations of patients with COVID-19 associated pneumonia. The US operator wore standard personal protective equipment (PPE), including FFP2, N95, or FFP3 face masks, disposable caps, two pairs of latex gloves, shoe covers, gown and protective face shields or goggles. The operator changed his outer gloves and sanitized his gloved hands with hand sanitizer after every examination. The US transducer was covered by a thin nylon bag and replaced for each patient. A portable Fujifilm SonoSite EDGE II (Bothell, WA, USA) unit was equipped to examine the patients' thoracic cavities using a convex-type probe (bandwidth: 3.5 MHz). With the ultrasound machine preset to the "Abdomen" and the indicator dot on the upper left side of the screen, the patients were asked to sit, lean forward with arms resting on a bedside table, and turn their back to the examiner. In patients who were unable to sit, we used the lateral decubitus position (Figure 1A). Then, the procedures were explained to the patients. We performed a 10-point lung US examination. Each hemithorax was divided into five regions. Anterior axillary line, posterior axillary line, and paravertebral line were used as the landmarks to divide each hemithorax into lateral and posterior zones (Figure 1B, 1C, and 1D). The US examination was carried out in the internal edge of the scapular spine (zone 1), the internal edge of the inferior angle of the scapula (zone 2), and the base of the lung (zone 3) at the paravertebral line. Also, the upper and lower regions of the inter-nipple line at the midaxillary line (zones 4 and 5) were examined. The transducer was kept perpendicular to the ribs in the longitudinal plane and then rotated 90 degrees to scan transversely.

Therefore, we did not report all the lung lesions in ultrasound examinations. Healthy lungs exhibit thin pleural lines, i.e., A lines, and rib shadows (11). The static and dynamic images were recorded and evaluated to find confluent B lines (B2 lines), thickened pleural lines, consolidation, and pleural effusion, which can be found in COVID-19 patients. An experienced radiologist compared the CT scan images blindly with the US examination results. The shape of each lesion on the CT scan images, the number of affected lobes, the characteristics of the lesion, including GGO, consolidation, and pleural thickening, distribution of lesions, and severity of lobar involvement were marked on the checklist. CT severity score (CT-SS) was used to evaluate the severity of lung involvement in the CT scan examinations. In this scoring system, first, each lobe is given a score between 0 and 5. A score of 0 indicates that the lobe is not affected; a score of 1 indicates that <5% of the lobe is affected; a score of 2 shows 5–25% involvement of the lobe; a score of 3 shows that 26–49% of the lobe is affected; a score of 4 indicates that 50–75% of the lobe is affected; and a score of 5 indicates the involvement of >75% of the lobe. The sum of the scores of all the five lobes represents the final score, with a range of 0–25 (12). Scores 1 and 2 are considered as mild, 3 as moderate, and 4 and 5 as severe involvement of the lung lobe. Total CT-SS of 0–10 is considered as mild, 11–15 as moderate, and 16–25 as severe lung involvement.

Data analysis

Continuous and categorical variables were reported as means (SD) and numbers (%), respectively. The variables were compared with Fisher's exact test. Sensitivity, specificity, NPV (negative predictive value), and PPV (positive predictive value) of lung US in identifying COVID-19 pulmonary lesions were calculated, assuming the chest CT scan as the gold standard. SPSS 21.0 (Chicago, IL, USA) was used for statistical analyses. Statistical significance was set at P<0.05.

RESULTS

Demographic, clinical, and radiologic characteristics

Nineteen patients (38 lungs), including 13 males, were evaluated with a mean age of 62.5±16.8 years. The mean length of stay in the hospital was 7.6±4.2 days. Hypertension (HTN) (31%) and diabetes mellitus (DM) (21%) were the most common comorbidities in the patients. Four patients died from respiratory arrest.

All the lung lobes were affected in all the patients with different severity according to lung CT scan findings. Peripheral lung involvement was observed in all the patients. The mean CT-SS of the patients was 12.7±3.3 (Table 1). The right lower lobe (RLL) was involved more than the other lobes (lobar CT-SS of the right lower lobe (3.1) >the left lower lobe (2.9) >the right upper lobe (2.1) >the left upper lobe (1.7) >the right middle lobe (1.6). Table 2 presents the results of the comparison of lung US and CT; 73% (28/38) of the lungs exhibited B_2 lines in US examinations and GGO in CT scans. Three of 38 lungs had GGO's in the CT examination. The US examination of the left lung did not reveal any lesions because GGO was small (Figure 2). Consolidation was observed in both the US and CT examinations in 36% (14/38) of the lungs. Three of 38 lungs exhibited consolidation in CT examination, but the ultrasound examination could

Copyright © 2021 Tehran University of Medical Sciences
This work is licensed under a Creative Commons Attribution-NonCommercial 4.0 International license (https://creativecommons.org/licenses/by-nc/4.0/). Noncommercial uses of the work are permitted, provided the original work is properly cited.

Table 1: Findings of US compared to CT scan in patients one by one

Case	Sex	Age (yr)	Risk factor	LOS (d)	Ultrasound finding	CT scan findings	Pulmonary lobe	CT-SS	Outcome
1	M	72	DM, HTN	15	B2 lines, P/thickening	GGO	RLL	12	Death
					No finding	Small GGO	LLL		
2	M	50	-	7	P/ irregular, P/E, B2 lines	GGO	RLL	13	Death
					No finding	Consolidation	LLL		
3	M	79	-	6	B2 lines, P/ irregular, P/E	GGO	RLL	15	Discharge
					B2 lines, P/ irregular, P/E	GGO, consolidation	LLL		
4	M	73	-	5	B2 lines, consolidation, P/thickening	Mixed Consolidation GGO	RLL	8	Discharge
					No finding (central lesions)	Peribronchovascular consolidation	LLL		
5	F	77	DM, HTN, Cardiac	15	B2 lines, consolidation, P/thickening	Consolidations, GGO	LLL	12	Discharge
					B2 lines, consolidation, P/thickening	Consolidations, GGO	RLL		
6	M	38	-	4	B2 lines and consolidation	GGO and consolidation	LLL	12	Discharge
					No finding	No finding	RLL		
7	M	39	-	5	B2 lines, P/thickening	GGO	RLL	13	Discharge
					B2 lines, P/thickening	GGO	LLL		
8	M	81	-	5	B2 lines	GGO	RML	15	Discharge
					Focal area of B2 lines	GGO	LUL (lingual)		
9	M	67	DM, HTN, Cardiac	15	P/ irregular, B2 lines	GGO	RLL	15	Death
					P/ irregular, B2 lines	GGO	LLL		
10	M	39	-	3	B2 lines, Consolidation, P/E	Consolidation ,GGO	RLL	14	Discharge
					Consolidation	Consolidation	LLL		
11	F	63	HTN	5	Focal P/irregular, B_2 lines	GGO	LLL	6	Discharge
					Focal P/irregular, B_2 lines	GGO	RLL		
12	M	73	-	6	Consolidation, P/thickening	Consolidation	LLL	19	Discharge
					Consolidation	Consolidation and air bronchogram	RLL		
13	F	72	DM, HTN, CVA	9	B2 lines, P/ thickening, consolidation	GGO, consolidation	RLL.	17	Death
					B2 lines, P/ irregular	GGO	LLL		
14	F	37	Breast cancer	12	B2 lines, consolidation, P/ thickening	GGO, consolidation	RLL	13	Discharge
					No finding	Small GGO	LLL		
15	F	40	-	12	B2 lines, P/thickening	GGO, P/ thickening	LUL (lingula)	6	Discharge
					No finding	No finding	RLL		
16	M	79	HTN	5	B2 lines	GGO	LUL	11	Discharge
					B2 lines	GGO	RLL		
17	F	85	-	5	B2 lines, P/thick	GGO	LLL	14	Discharge
					B2 lines, P/thickening	GGO	RLL		
18	M	56	-	2	B2 lines, consolidation	GGO, consolidation	RLL	13	Discharge
					No finding	Small GGO	LLL		
19	M	67	Cortioid therapy	8	B2 lines	GGO	RLL	13	Discharge
					Consolidation, P/thickening	Consolidation	LLL		

P/E: Pleural effusion, P/thickening: Pleural thickening, P/irregular: Pleural irregular, LOS: Length of stay, HTN: Hypertension, DM: Diabetes mellitus, CT-SS: CT severity score, LLL: Left lower lobe, RLL: Right lower lobe, LUL: Left upper lobe, RML: Right middle lobe

Copyright © 2021 Tehran University of Medical Sciences
This work is licensed under a Creative Commons Attribution-NonCommercial 4.0 International license (https://creativecommons.org/licenses/by-nc/4.0/). Noncommercial uses of the work are permitted, provided the original work is properly cited.

Table 2: Correlation between the findings of US and CT scan and US sensitivity, specificity, NPV and PPV of identification of lung lesions in COVID-19 patients

Variable			P-value[1]	Sensitivity	Specificity	NPV	PPV
Consolidation			< 0.0001	82%	100%	87%	100%
B_2 line and GGO			< 0.0001	90%	100%	70%	100%
Pleural thickening and irregularity			1.000	100%	48%	100%	5%
CT-SS (Lobes of the lungs)	Mild (n=8)	Consolidation	-[2]	-	-	-	-
		B_2 line and GGO	0.464	50%	0%	0%	60%
	Moderate (n=18)	Consolidation	< 0.0001	88%	100%	90%	100%
		B_2 line and GGO	0.001	100%	100%	100%	100%
	Severe (n=12)	Consolidation	0.002	100%	100%	100%	100%
		B_2 line and GGO	0.015	100%	100%	100%	100%

[1]Correlation between the lesions founded in the US and CT scan examinations; P<0.05 was considered as significant.
[2]P-value and other parameters were not calculated due to a limited number of cases.

Figure 2: (A) GGO in the LLL (small) and in the RLL (more distinct). (B) US shows the B lines (curved arrow) and the thickening of the adjacent right pleura (thin arrow) (C) Right lung US (M-mode). RLL: Right Lower Lobe, LLL: Left Lower Lobe, GGO: Ground Glass Opacity.

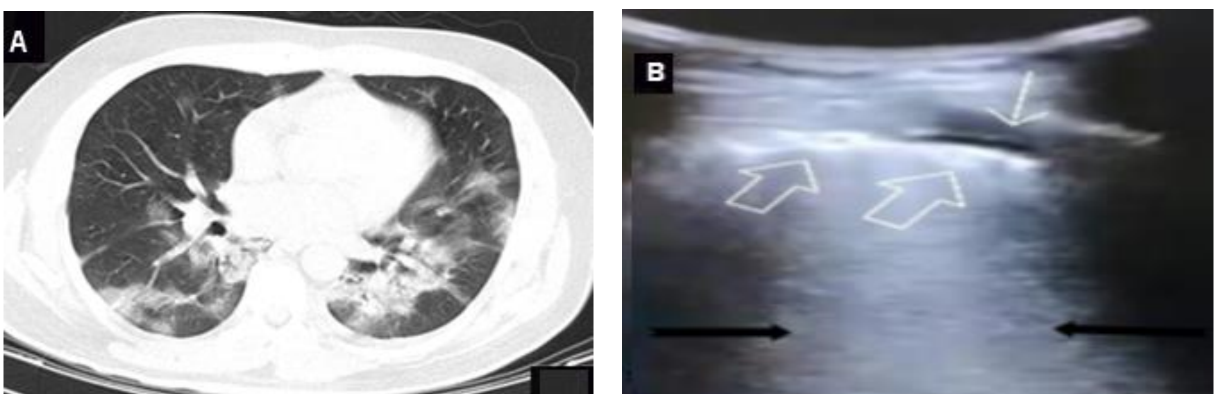

Figure 3: (A) Central, peri-bronchovascular consolidation and GGO in the CT scan. (B) US with pleural irregularity (open arrows) and mild pleural effusion (thin white arrow) and the B_2 lines (between the black arrows). GGO: Ground Glass Opacity.

not identify them because central consolidation was not seen in the US (Figure 3). Consolidation and B_2 lines observed in the US examination were significantly correlated with consolidation and GGO's observed in CT scan examination, respectively (p<0.0001). However, pleural thickening and irregularity in the US examination were not correlated with the same findings in the CT scan examination. The US examination could find 20/38 lungs with pleural thickening and irregularity, but CT examination only identified one. Four of 38 lungs exhibited pleural effusion in the US examination, but the CT examination was unable to detect them. The sensitivity and specificity of finding consolidation in the US examination were 82% and 100%, respectively. US sensitivity and specificity of identifying B_2 lines were 90% and 100%, respectively. We also compared the findings of US and CT examinations in different subgroups of patients according to their severity of lung involvement in CT scan examinations. The lungs were divided into three groups in terms of the severity of the involvement of the lobes studied. In the lungs with moderate and severe lobar involvement, the US and CT findings (consolidation, GGO, and B_2 lines) were significantly correlated (P<0.05). US examination was able to identify lesions (consolidation and B_2 lines) with sensitivity and specificity of 100% in moderate and severe cases except for 88%

Copyright © 2021 Tehran University of Medical Sciences
This work is licensed under a Creative Commons Attribution-NonCommercial 4.0 International license (https://creativecommons.org/licenses/by-nc/4.0/). Noncommercial uses of the work are permitted, provided the original work is properly cited.

sensitivity for observing consolidation in moderate cases. In contrast to moderate and severe cases, in the lungs with mild lobar involvement, there was not significant correlation between B_2 lines in US examinations and GGO in CT scan examinations (P=0.464).

DISCUSSION

Finding a rapid, accurate, and easily applied method to evaluate pulmonary lesions is a matter of concern in the COVID-19 pandemic. Previously, many studies have used the ultrasound technique to evaluate the lungs. Rapidity, repeatability, ease of use at the bedside, absence of x-ray exposure, and low cost are the advantages of lung US examinations compared to CT scan examinations. Also, the CT scan technique has some limitations during the COVID-19 pandemic, such as the high risk of transporting patients with unstable vital signs, risk of other individuals' contamination during patient transportation, and x-ray adverse effects (10).

Our suggested method of lung ultrasound evaluation is a rapid, easy to learn, and accurate method compared to the CT scan technique. Coalescent B2 lines, consolidation, pleural thickening, pleural irregularity, and mild pleural effusion were the US manifestations of COVID-19-associated pneumonia, in the present study. Pleural thickening and irregularity can be detected by the US examination better than the CT scan examination. This superiority can be due to the real-time characteristics of US examinations (13) (Figure 4 and 5).

The US examination findings of this method were compared with the CT scan findings of 19 patients with COVID-19-associated pneumonia one by one, which shows a significant correlation between consolidation, B2 lines, and GGO's observed in the US and CT scan examinations. US examinations exhibited acceptable sensitivity and specificity in identifying pulmonary lesions of COVID-19-associated pneumonia, especially in cases with moderate and severe lung involvement in terms of CT-SS.

Thin pleural line, A lines, and rib shadows can be found in a healthy lung US examination. The pleural line has a horizontal hyperechoic characteristic, 0.5 cm under the rib line in adults. Bat sign, a landmark of the normal lung, is the confluence of the ribs and pleural line. The pleural line in US examinations represents the parietal pleura. Beneath the pleural line, there are horizontal lines, which are the repetitive artifacts of the normal pleural line called the A line. The A line indicates that air is the visible component beneath the pleural line. The M-mode takes the depth from the 2D B-mode image, and graphs this against time. A healthy lung exhibits the seashore sign in the M-mode, which indicates that the lung moves on the chest wall (11). Abnormal B lines, consolidation, pleural thickening, and pleural effusion can be observed in patients with COVID-19-associated pneumonia. B lines are vertical artifacts with different shapes and lengths. They can be found in US examinations when the lung loses its normal aeration, but the affected region is not entirely collapsed (14). B lines are not a specific finding of a pathology. B line characteristics and clinical information can lead to a final diagnosis. In pulmonary edema, B lines are laser-like, regular, and bright, bilaterally on the lung bases without spared lung areas, and the pleural line is regular. However, during the inflammatory process in the lung, such as COVID-19-associated pneumonia, B lines are multifocal, discrete, coalescent, confluent, patchy, or nonhomogeneous, surrounded by spared areas of the lung tissue, with no gravitational distribution (B2 lines). They can be observed as comet-tail artifacts (14, 15). M-mode views in the area of B lines are more apparent, indicating that these lines originate from the pleura as a fragmented view (16) (Figure 6).

Coalescent B2 lines are associated with peripheral GGO in a chest CT scan (8, 17). GGO in a CT scan is observed when minimal thickening of the alveolar walls and septal interstitium happens, or the alveolar lumen is partially filled with fluid (18). Consolidation happens in circumstances in which an area of lung completely or partially collapses, and the alveolar spaces are filled with fluid, which can be found as an irregular hypoechoic area. An air bronchogram can be found among the consolidation (14). The same pathology can cause consolidation in the CT scan (19-21).

High-resolution CT (HRCT) of the chest is critical for the early detection of patients with COVID-19-associated pneumonia. Consistent with previous studies (6, 22), we found that RLL was involved more than the other lobes in COVID-19-associated pneumonia. Peripheral regions of the lungs are more susceptible to this virus. US examinations proved to be a suitable tool to evaluate peripheral lung lesions (23), and our method focused on the most common site of lung involvement in COVID-19.

A similar study compared the lung US and the chest CT findings of 20 patients and concluded that US examinations could be a supplementary method in addition to CT scans in evaluating patients with COVID-19-associated pneumonia (21). They used a

Copyright © 2021 Tehran University of Medical Sciences
This work is licensed under a Creative Commons Attribution-NonCommercial 4.0 International license (https://creativecommons.org/licenses/by-nc/4.0/).
Noncommercial uses of the work are permitted, provided the original work is properly cited.

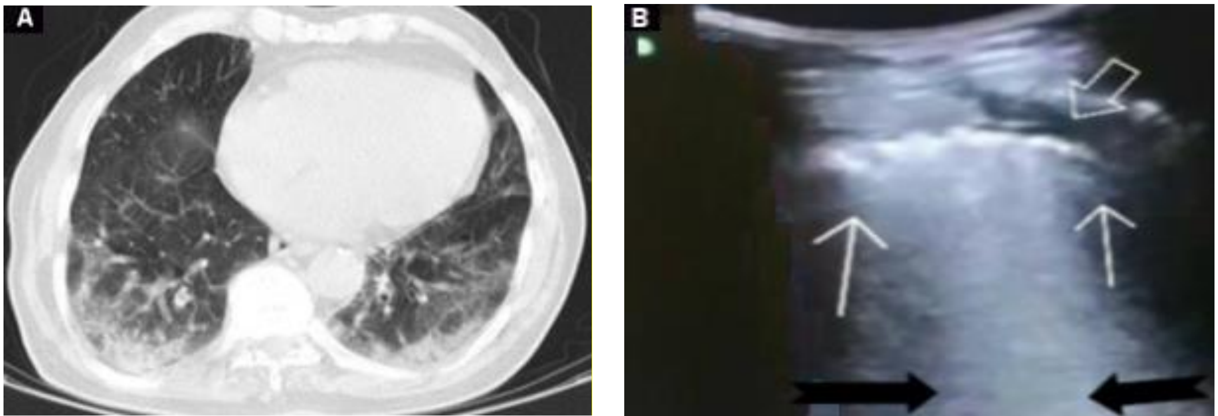

Figure 4: (A) CT scan with GGO and consolidation in the RLL and LLL. (B) US with B_2 lines (black arrows), pleural irregularity (thin arrows), and mild pleural effusion in the RLL (open arrow). RLL: Right Lower Lobe, LLL: Left Lower Lobe, GGO: Ground Glass Opacity.

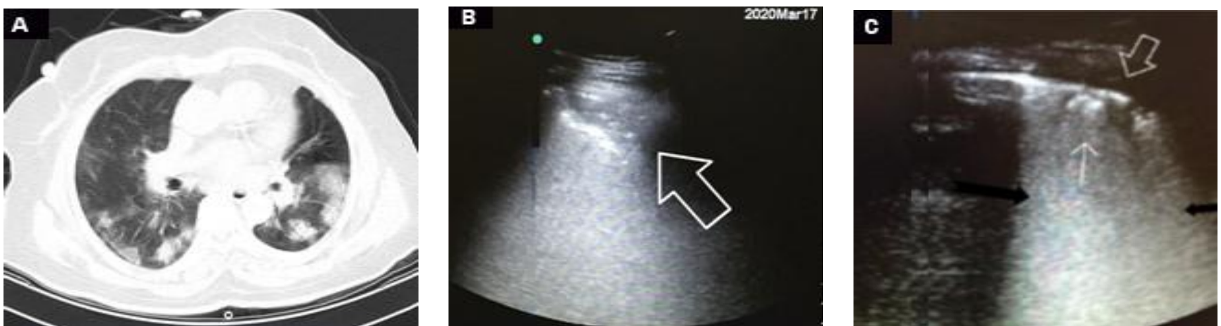

Figure 5: (A) CT scan shows consolidation and GGO in the apical segment of both lobes. (B) US of same region shows the consolidation. (C) US of small consolidation (thin arrow), B_2 lines (thick arrows), and adjacent pleural thickening (hollow arrow). GGO: Ground Glass Opacity.

Figure 6: (A) CT shows consolidation and GGO in the lower lobes. (B) US containing consolidation with comet tail artifacts in the right lower lobe. (C) The pleural line in the M-mode view of the same area shows irregularity and thickening. GGO: Ground Glass Opacity.

12-area examination method in which the two lungs were divided into 12 areas to be explored anteriorly, posteriorly, and laterally. This method was used in other previous studies for the US lung evaluation of COVID-19 patients (24, 25). Other previously recommended methods are 6-point lung examination (11), 8-point lung examination (26), and 14-point lung examination (27). Although methods with more points of evaluation are more accurate, our method is quickly learned by an ED specialist who is not experienced in the lung US examination of COVID-19 patients. Another advantage of this method is that the physician sits behind the patient. Therefore, the risk of contamination by droplets is lower than sitting face to face with the patients (28) in the anterior chest wall evaluation used in previously reported methods. A recent study investigated the clinical value of lung US examinations in the diagnosis of COVID-19 lung lesions (29). Thirty COVID-19 patients' lung US examinations were compared with the chest CT scans as the reference. They divided each lung into six regions and performed a 12-area lung examination.

The most common US manifestations were

Copyright © 2021 Tehran University of Medical Sciences
This work is licensed under a Creative Commons Attribution-NonCommercial 4.0 International license (https://creativecommons.org/licenses/by-nc/4.0/). Noncommercial uses of the work are permitted, provided the original work is properly cited.

interstitial pulmonary edema (B lines) and consolidation, similar to the findings of the present study. The lower lobe and dorsal region and sub-pleural and peripheral pulmonary zones were affected more severely. They found a moderate agreement between the US lesions and CT scan findings in patients with COVID-19 and reported that the diagnostic efficacy of lung US examinations is relatively low for mild to moderate patients, but a high diagnostic efficacy was observed in severe cases. The ultrasound scores to evaluate mild, moderate, and severe lung lesions exhibited sensitivity rates of 68.8%, 77.8%, and 100.0%, and specificity rates of 85.7%, 76.2%, and 92.9%, respectively. We found a correlation between moderate and severe lung involvement in CT scan and US findings, with higher sensitivity and specificity. However, similar to this study, the US examinations were not correlated with CT findings in mild lung involvement.

Limitations

Our study is among the first ones on the comparison of US and CT manifestations of COVID-19-associated pneumonia; however, it has some limitations: the sample size was small, and changes in the US findings over time were not evaluated. However, we tried to present all the 19 cases one by one and compare the US findings with the CT images to provide a guide for ultrasound experts

Conclusions

It was concluded that there was a significant correlation between the consolidation in the US and CT scan examinations and the B_2 lines observed in the patients' US and GGOs observed in CT scan examinations, especially in cases with moderate and severe lung involvement according to CT-SS. Ultrasound can be beneficial in the pulmonary evaluation of COVID-19-associated pneumonia. Rapidity, repeatability, ease of use at the bedside, absence of x-ray exposure, and low cost are the advantages of lung US compared to chest CT scan; however, it cannot replace CT scan examinations. Our method of 10-point lung ultrasound is a safe and suitable method for the evaluation of patients with moderate and severe COVID-19-associated pneumonia.

Acknowledgements

The authors would like to thank Clinical Research development unit at Imam Hossein Medical center for assistance and we have to thank Dr. Ensieh Ghaffari Shad for preparing the medical illustrations of this paper.

Authors' contribution

HH and MR conceived the study, designed the trial, and obtained research findings. HH and MR supervised the implementation of the trial and data collection. MS undertook the recruitment of participating centers and patients and managed the data, including quality control. MB provided statistical advice on study design and analyzed the data. HH chaired the data oversight committee. HH and MB drafted the manuscript, and all authors contributed substantially to its revision. MR takes responsibility for the paper as a whole. All authors have approved the submitted version of the manuscript.

Conflict of interest

None declared.

Funding

This research was supported by grants from Vice chancellor of research and technology of Shahid Beheshti University of Medical Science (Grant number: 22980).

References

1. Wang C, Horby PW, Hayden FG, Gao GF. A novel coronavirus outbreak of global health concern. Lancet. 2020;395(10223):470-3.

2. World Health organization. Coronavirus disease (COVID-2019) situation reports. April 17, 2020. [Available from: https://www.who.int/docs/default-source/coronaviruse/situation-reports/20200417-sitrep-88-covid-191b6cccd94f8b4f219377bff55719a6ed.pdf?sfvrsn=ebe78315_6].

3. 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(10223):507-13.

4. Jin YH, Cai L, Cheng ZS, Cheng H, Deng T, Fan YP, et al. A rapid advice guideline for the diagnosis and treatment of 2019 novel coronavirus (2019-nCoV) infected pneumonia (standard version). Mil Med Res. 2020;7(1):4.

Copyright © 2021 Tehran University of Medical Sciences
This work is licensed under a Creative Commons Attribution-NonCommercial 4.0 International license (https://creativecommons.org/licenses/by-nc/4.0/). Noncommercial uses of the work are permitted, provided the original work is properly cited.

5. Lei J, Li J, Li X, Qi X. CT Imaging of the 2019 Novel Coronavirus (2019-nCoV) Pneumonia. Radiology. 2020;295(1):18.
6. Shi H, Han X, Jiang N, Cao Y, Alwalid O, Gu J, et al. Radiological findings from 81 patients with COVID-19 pneumonia in Wuhan, China: a descriptive study. Lancet Infect Dis. 2020;20(4):425-34.
7. Wongwaisayawan S, Suwannanon R, Sawatmongkorngul S, Kaewlai R. Emergency thoracic US: the essentials. Radiographics. 2016;36(3):640-59.
8. Lichtenstein DA, Meziere GA. Relevance of lung ultrasound in the diagnosis of acute respiratory failure*: the BLUE protocol. Chest. 2008;134(1):117-25.
9. Inchingolo R, Smargiassi A, Mormile F, Marra R, De Carolis S, Lanzone A, et al. Look at the lung: can chest ultrasonography be useful in pregnancy? Multidiscip Respir Med. 2014;9(1):32.
10. Mayo PH, Copetti R, Feller-Kopman D, Mathis G, Maury E, Mongodi S, et al. Thoracic ultrasonography: a narrative review. Intens Care Med. 2019;45(9):1200-11.
11. Lichtenstein DA. Lung ultrasound in the critically ill. Ann Intens Care. 2014;4(1):1.
12. Asefi H, Safaie A. The Role of Chest CT Scan in Diagnosis of COVID-19. Adv J Emerg Med. 2020;4(2s):e64.
13. Skolnick ML. Advantages of Real-time Imaging. In: Real-time Ultrasound Imaging in the Abdomen. Springer, New York, NY; 1981. p. 1-11.
14. Soldati G, Demi M, Smargiassi A, Inchingolo R, Demi L. The role of ultrasound lung artifacts in the diagnosis of respiratory diseases. Expert Rev Respir Med. 2019;13(2):163-72.
15. Moro F, Buonsenso D, Moruzzi MC, Inchingolo R, Smargiassi A, Demi L, et al. How to perform lung ultrasound in pregnant women with suspected COVID-19 infection. Ultrasound Obstet Gynecol. 2020 May;55(5):593-8.
16. Peng QY, Wang XT, Zhang LN, Chinese Critical Care Ultrasound Study Group (CCUSG). Findings of lung ultrasonography of novel corona virus pneumonia during the 2019–2020 epidemic. Intensive Care Med. 2020;46(5):849-50.
17. Wongwaisayawan S, Suwannanon R, Sawatmongkorngul S, Kaewlai R. Emergency thoracic US: the essentials. Radiographics. 2016;36(3):640-59.
18. Engeler CE, Tashjian JH, Trenkner SW, Walsh JW. Ground-glass opacity of the lung parenchyma: a guide to analysis with high-resolution CT. AJR Am J Roentgenol. 1993;160(2):249-51.
19. Walker CM, Abbott GF, Greene RE, Shepard J-AO, Vummidi D, Digumarthy SR. Imaging pulmonary infection: classic signs and patterns. AJR Am J Roentgenol. 2014;202(3):479-92.
20. Brogi E, Gargani L, Bignami E, Barbariol F, Marra A, Forfori F, et al. Thoracic ultrasound for pleural effusion in the intensive care unit: a narrative review from diagnosis to treatment. Crit Care. 2017;21(1):325.
21. Yu M, Hu M, Huang Y, Wang S, Liu Y, Zhang Y, et al. A preliminary study on the ultrasonic manifestations of peripulmonary lesions of non-critical novel coronavirus pneumonia (COVID-19). 2020; Preprint from Research Square.
22. Wang Y, Dong C, Hu Y, Li C, Ren Q, Zhang X, et al. Temporal changes of CT findings in 90 patients with COVID-19 pneumonia: a longitudinal study. Radiology. 2020:200843.
23. Dietrich CF, Mathis G, Cui X-W, Ignee A, Hocke M, Hirche TO. Ultrasound of the pleurae and lungs. Ultrasound Med Biol. 2015;41(2):351-65.
24. Buonsenso D, Piano A, Raffaelli F, Bonadia N, de Gaetano Donati K, Franceschi F. Point-of-Care Lung Ultrasound findings in novel coronavirus disease-19 pnemoniae: a case report and potential applications during COVID-19 outbreak. Eur Rev Med Pharmacol Sci. 2020;24(5):2776-80.
25. Peng QY, Wang XT, Zhang LN, Chinese Critical Care Ultrasound Study G. Findings of lung ultrasonography of novel corona virus pneumonia during the 2019–2020 epidemic. Intensive Care Med. 2020 May;46(5):849-50.
26. Gargani L, Volpicelli G. How I do it: lung ultrasound. Cardiovasc Ultrasound. 2014;12(1):25.

Copyright © 2021 Tehran University of Medical Sciences
This work is licensed under a Creative Commons Attribution-NonCommercial 4.0 International license (https://creativecommons.org/licenses/by-nc/4.0/). Noncommercial uses of the work are permitted, provided the original work is properly cited.

27. Soldati G, Smargiassi A, Inchingolo R, Buonsenso D, Perrone T, Briganti DF, et al. Proposal for international standardization of the use of lung ultrasound for COVID-19 patients; a simple, quantitative, reproducible method. J Ultrasound Med. 2020;39(7):1413-9.
28. Naderpour Z, Saeedi M. A Primer on COVID-19 for Clinicians: Clinical Manifestation and Natural Course. Adv J Emerg Med. 2020;4(2s):e62.
29. Lu W, Zhang S, Chen B, Chen J, Xian J, Lin Y, et al. A Clinical Study of Noninvasive Assessment of Lung Lesions in Patients with Coronavirus Disease-19 (COVID-19) by Bedside Ultrasound. Ultraschall Med. 2020;41(3):300-7.

Copyright © 2021 Tehran University of Medical Sciences
This work is licensed under a Creative Commons Attribution-NonCommercial 4.0 International license (https://creativecommons.org/licenses/by-nc/4.0/). Noncommercial uses of the work are permitted, provided the original work is properly cited.