The Egyptian Journal of Hospital Medicine (January 2023) Vol. 90 (2), Page 2542-2548

Comparison between Lung Ultrasound and Chest Computed Tomography for Assessment of The Severity of Proven Coronavirus COVID-19 Pneumonia

Suzan Bahig Ali Elhefnawy[1], Mohamed Mohsen Tolba Fawzi[2],
Fayrouz Abdel Nour Adeab Gawargios[1], Nourhan Mohammed Hossam El-Din*[1]
[1]Radiodiagnosis Department, Faculty of Medicine, Ain Shams University, Cairo, Egypt
[2]Fellow of Radiodiagnosis at National Hepatology and Tropical Medicine Research Institute (NHTMRI), Egypt
***Corresponding author**: Nourhan Mohammed Hossam El-Din, **Mobile**: (+20)01152045672, **Email**: nor_hossam23@yahoo.com

ABSTRACT

Background: Although chest CT is the most popular scan, the ultimate safety for repetition is not established. Coronavirus disease 2019 (COVID-19) is caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) which results in viral pneumonia and may be diagnosed by a chest computed tomography (CT) scan. In addition, Lung Ultrasound (LUS) has good diagnostic precision for Alveolar Consolidation and Interstitial Lung Diseases. **Aim of the Work**: We looked into the classification of lung abnormalities by lung ultrasonography, the correlation between CT results and lung abnormalities in SARS-CoV-2 infection, and the viability of employing this technology to offer a quantifiable estimation of pulmonary involvement in COVID-19 patients. **Patients and Methods**: This was a cross-sectional study that included 30 patients who had symptoms of variable degrees of fever, cough, and dyspnoea with RT-PCR-confirmed COVID-19 infection by nasopharyngeal swab at admittance or during hospitalization either at the ward or intensive care unit (ICU) at Ain Shams University Hospitals and National Hepatology and Tropical Medicine Research Institute from May 2021 to March 2022, for whom CT chest was ordered before admission. **Results:** This study showed that patients who suffer from respiratory symptoms or associated lung conditions have the propensity to have greater alterations on LUS and more severe illness on CT in a sample of patients with PCR-validated COVID-19. The anomalies identified by the two distinct imaging modalities were related, and the LUS score is related to the clinical characteristics and the severity determined by the chest CT scan. **Conclusion:** Contrarily, the benefits of ultrasonography over CT include mobility, no radiation exposure (for pregnant women and patients at an increased risk for radiation usage), cheap cost, no requirement for support staff, and repeatability. In extreme circumstances, it might be utilized instead of a CT chest scan (especially in ICU cases).

Keywords: Lung Ultrasound, Chest Computed Tomography, Severity, Coronavirus, Pneumonia.

INTRODUCTION

The 2019 coronavirus illness (COVID-19), which was originally identified in the Chinese region of Wuhan, spread quickly over the world before being deemed a pandemic on March 11, 2020 **(1)**.

SARS-CoV-2 is the culprit, and it has a genome that is comparable to the RNA virus families responsible for SARS and other Middle East respiratory syndromes **(2)**.

In especially patients with comorbidities, this common virus can result in severe acute respiratory distress syndrome (ARDS), secondary infections, and septic shock, all of which necessitate rapid medical attention **(3)**.

Since the start of the COVID-19 epidemic, a variety of diagnostic techniques have been used to quickly and accurately identify individuals who may have COVID infection and to categorize them according to the severity of their illness. Chest CT portrayed a significant role in this situation because of its high sensitivity (91–96%), but it also has drawbacks relating to scanner accessibility, cleaning processes, and X-ray exposure **(1)**.

With its low cost and wide availability, lung ultrasonography (LUS) has become a promising imaging method for COVID-19 screening **(4)**.

Additionally, it has recently been proposed as a reliable technique for detecting lung affection in COVID-19 by the Chinese Critical Care Ultrasound Study Group and the Italian Academy of Thoracic Ultrasound. Even while a chest CT is the gold standard for diagnosing lung involvement and has a sensitivity that surpasses even that of a nasopharyngeal swab, an LUS examination can be a viable substitute for a CT scan for pregnant women in particular and has certain benefits. One operator may do ultrasounds right at the patient's bedside, minimizing the possibility of medical staff contracting the illness. Additionally, it provides a reproducible, radiation-free test **(5)**.

We looked into the classification of lung abnormalities by lung ultrasonography, the correlation between CT results and lung abnormalities in SARS-CoV-2 infection, and the viability of employing this technology to offer a quantifiable estimation of pulmonary involvement in COVID-19 patients.

PATIENTS AND METHODS

The current study was a cross-sectional study that included 30 patients who had symptoms of variable degrees of fever, cough, and dyspnoea with RT-PCR-confirmed COVID-19 infection by nasopharyngeal swab at admittance or during hospitalization either at the ward or intensive care unit (ICU) at Ain Shams University Hospitals and National Hepatology and Tropical Medicine Research Institute from May 2021 to March 2022, for whom CT chest was ordered before admission. An acceptance from the ethical committee of the Radiology Department and the ethical committee of the Faculty of Medicine - Ain Shams University and NHTMRI was obtained to use the data stored on PACS with the patient's consent to perform lung ultrasound.

Received: 25/09/2022
Accepted: 28/11/2022

Patients under the age of 18, those with a history of interstitial lung disease, those who had previously undergone lung parenchymal and thoracic wall surgical procedures, those with anatomically abnormal thoracic walls, and those who refused to give their consent to contribute to the study all were excluded from the analysis.

Chest CT scanning protocol Chest

To ensure patient compliance, CT was done using a specialized 160-channel multidetector scan (Toshiba Aquilion Prime, Japan) while the patients were supine and during a single breath-hold. The primary scanning settings were: pitch = 1, matrix = 768 x 768, collimation = 1.5-3 mm, tube voltage = 100–120 kV, and automated tube current modulation. A slice thickness of 3 mm was used to recreate all of the pictures. Following each test, the manufacturer advised disinfecting the CT apparatus and any positioning aids with a 75% ethanol solution.

The radiology department reported and evaluated chest CT scans without knowing any clinical information. The approved thin-slice CT examination approach of **Chang *et al.*** [(6)] was employed as the grading method. The involvement of ground-glass scattered opacities, alveolar consolidation, interstitial lung densities, and areas of air trapping in each of the five lobes of the lung was evaluated as follows: 0% (0 points), 1-5% (1 point), 5-25% (2 points), 25-50% (3 points), 50-75% (4 points), or>75% (5 points). Each lung lobe's value as well as the overall CT score data were recorded, with values ranging from 0 to 25. The CT Severity Score was recorded for the parts of the CT data that corresponded to the LUS rating system.

LUS protocol:

After taking all necessary safety precautions, LUS was carried out with the convex ultrasound probe (1-5 MHz) in the ward or intensive care unit with 25 hours as the maximum of the patient's stay. Patient data, including medical history, laboratory findings, and CT scan results, were hidden from the investigator.

Lung zones were divided into six areas for easy examination in addition to the 12-area protocol, which included six areas for the right lung and six for the left lung: anterior-superior (upper portion of the inter-nipple line in the mid-clavicular line), anterior-inferior (lower portion of the inter-nipple line in the mid-clavicular line), middle-superior (upper portion of the inter-nipple line above the mid-axillary line), and middle (below the line that join the lower trimmings of the scapula in the para-vertebral line).

Each chest region examination was noted for any aberrant findings, especially pleural line anomalies, B lines, consolidations, and pleural effusion. For each category, a scoring methodology was employed. Scores varied from 0 to 3: 0 points for B lines, including A-lines, 1 point for B lines that collectively did not cover more than 50% of the intercostal area (white lung), 2 points for B lines that did cover more than 50% of the intercostal region, and 3 points for consolidation.

The degree of lung affection was reflected by the total of all six regions (assessed in the LUS with 0 to 18 points for each lung). The CT results were noted and compared to the LUS results and scoring methodology.

Ethical approval:

An acceptance from the ethical committee of the Radiology Department and the ethical committee of the Faculty of Medicine - Ain Shams University and NHTMRI was obtained to use the data stored on PACS with the patient's consent to perform lung ultrasound. During this investigation, the Declaration of Helsinki for Human Beings, the international medical association's code of ethics, was observed.

Statistical analysis

The collected data were reviewed, coded, tabulated, and input into a computer using the statistical software for social science (SPSS 23). The type of data collected for each parameter was suitably analyzed when the data were provided. The degree of significance is indicated by the P-value: non-significant (NS) at P>0.05, significant at P-0.05. (S).

RESULTS

Regarding COVID-19 severity by CT and U/S, the mean CTSI was 11.37 ± 4.67 ranging from 4 to 20, LUS score mean was 17.83± 8.72 ranging from 6 to 34. O2 saturation was assessed for the study group and it's mean was 90.47 ± 3.95 ranging from 85 to 98 **(Table 1).**

Table (1): COVID-19 severity for the study group.

		Mean/N	SD/%	Median (IQR)	Range
CTSI (25)		11.37	4.67	11 (8 - 16)	(4 - 20)
Severity by CT	No	11	36.7%		
	Yes	19	63.3%		
LUS score (36)		17.83	8.72	16 (12 - 23)	(6 - 34)
Severity by ultrasound	No	10	33.3%		
	Yes	20	66.7%		
O2 saturation %		90.47	3.95	89 (87 - 95)	(85 - 98)

Table (2): CT and LUS findings for the study group.

		N	%
CT finding	Bilateral crazy paving pattern and subpleural consolidations	13	43.3%
	Unilateral focal B-lines	5	16.7%
	Bilateral scattered GGOs with the crazy paving pattern.	9	30.0%
	Bilateral crazy paving pattern and subpleural consolidations + pleural effusion	3	10.0%
LUS finding	Bilateral diffuse B-lines and subpleural consolidations	13	43.3%
	Unilateral scattered GGO	5	16.7%
	Bilateral diffuse B-lines	9	30.0%
	Bilateral diffuse B-lines and subpleural consolidations + pleural effusion	3	10.0%

The study group was divided into three groups according to the clinical severity of cases, the Mild group was 16.7% of cases, the Moderate group was 30% of cases and the severe group was 53.3% of cases **(Table 3).**

Table (3): Clinical severity of cases for the study group.

		N	%
Severity	Mild	5	16.7%
	Moderate	9	30.0%
	Severe	16	53.3%
Severity of cases	Not severe	14	46.7%
	Severe	16	53.3%

The relation between clinical severity of cases according to CT and US severity scores was done, the mean severity score of CT and US in the severe group was more than in not severe group **with a significant** difference between the two groups as the p-Value was (<0.05) **(Table 4).**

Table (4): Relation between CT and US severity scores and clinical severity of cases.

	Severity of cases		**Student t-test**	
	Not severe	**Severe**		
	Mean ± SD	**Mean ± SD**	**p-Value**	**Sig.**
CTSI (25)	7.43 ± 1.99	14.81 ± 3.41	<0.001	S
LUS score (36)	11 ± 2.8	23.81 ± 7.64	<0.001	S

The relation between clinical severity of cases according to CT and US severity scores was done, the mean severity score of CT and US was the highest in the severe group than in the moderate group and it was the least in the mild group with a **significant difference** between severe group Vs. (Mild and Moderate groups) as p-Value was (<0.05) **(Table 5).**

Table (5): Relation between CT and US severity scores and clinical severity of cases

	Severity			**One Way ANOVA**	
	Mild	**Moderate**	**Severe**		
	Mean ± SD	**Mean ± SD**	**Mean ± SD**	**p-Value**	**Sig.**
CTSI (25)	5.2 ± 1.64	8.67 ± 0.5	14.81 ± 3.41	<0.001*	S
LUS score (36)	8 ± 2.74	12.67 ± 0.5	23.81 ± 7.64	<0.001*	S

*Post-hoc Bonferroni test was significant between the severe group Vs. (Mild and Moderate groups).

The correlation was done to assess the relation between CTSI, LUS score, and O2 saturation **(table 6),** there was a moderate negative correlation with a significant p-Value as it was (<0.05) between O2 saturation and CTSI & LUS score **(Figs. 2 & 3),** while there was a strong positive correlation with significant p-Value as it was (<0.05) between CTSI and LUS score **(Fig. 1).**

Table (6): Correlation between CTSI, LUS score, and O2 saturation.

		LUS score (36)	**O2 saturation**
CTSI (25)	Pearson Correlation	0.963	-0.476
	p-Value	<0.001	0.008
	Sig.	S	S
LUS score (36)	Pearson Correlation	———	-0.53
	p-Value	———	0.003
	Sig.	———	S

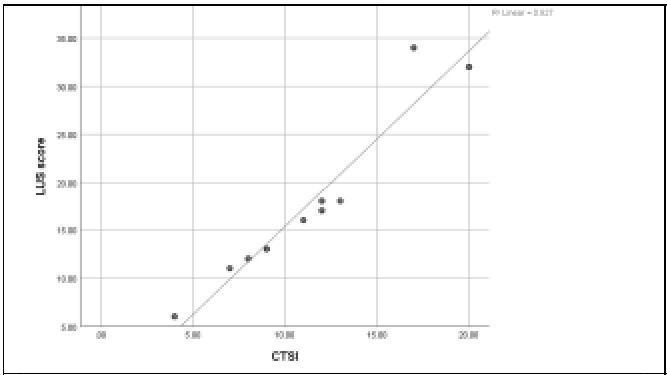

Figure (1): Correlation between CTSI and LUS score for the study group.

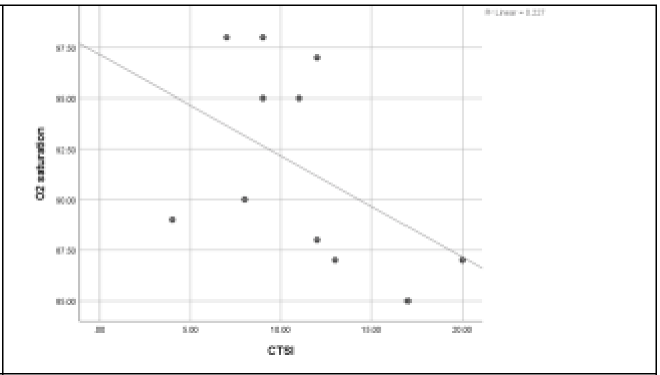

Figure (2): Correlation between CTSI and O2 saturation for the study group.

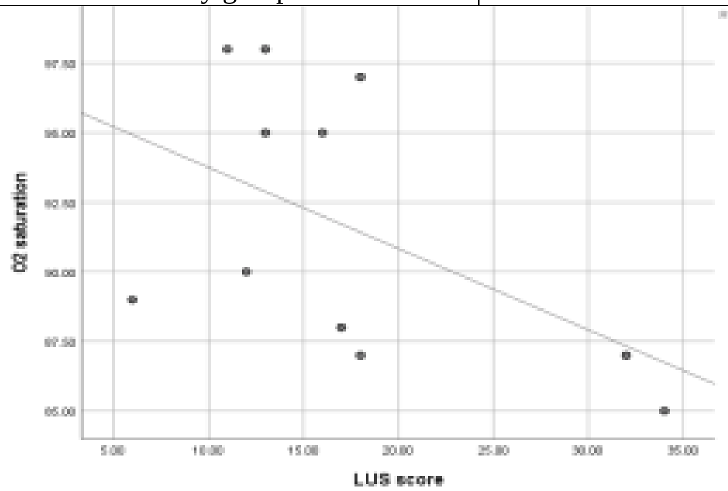

Figure (3): Correlation between LUS score and O2 saturation for the study group.

The CT and US severity scores to use for the prediction of clinically severe cases was 100% for sensitivity and specificity with cut-off value >13 and >9 for US and CT respectively as shown in **(Table 7 & Fig. 4).**

Table (7): Analysis of CT and US severity scores to use them in the prediction of clinically severe cases.

	AUC	95% CI	Sig.	Cut-off value	Sensitivity	Specificity	+PV	-PV
US severity score	1.00	0.884 – 1.00	<0.001	>13	100	100	100	100
CT severity score	1.00	0.884 – 1.00	<0.001	>9	100	100	100	100

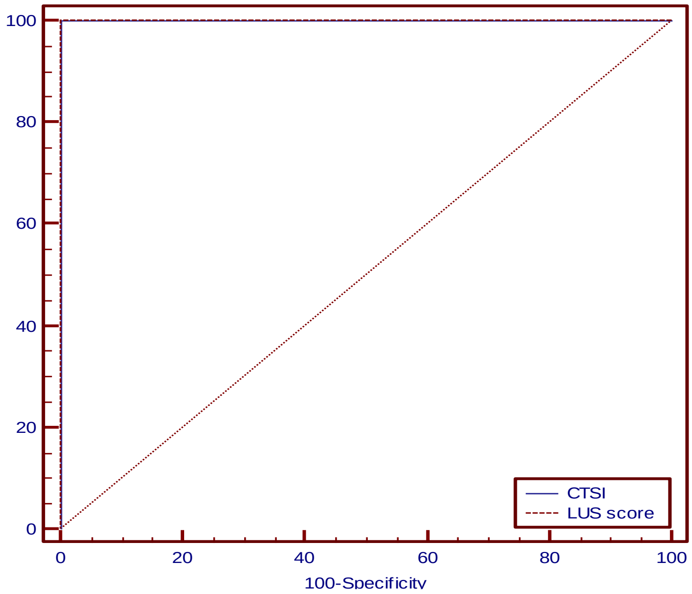

Figure (4): ROC curve of CT and US severity scores to correlate the sensitivity and specificity to predict clinically severe cases.

CASE (1)

A 75 years old female patient, is known to be diabetic and hypertensive. Presented with dyspnea, fever, and cough, PaO2 was 89 %, and PCR result confirmed COVID-19 infection. She was admitted to ICU.

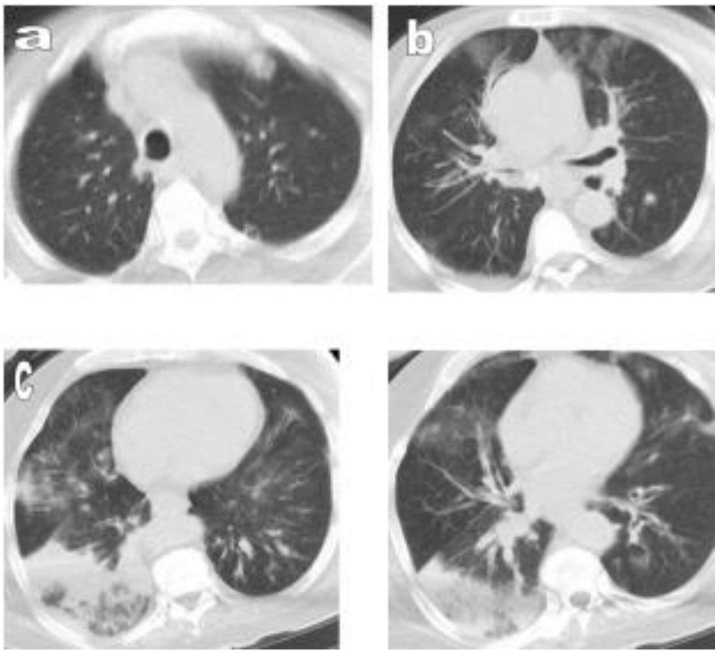

Figure (5): CT chest images revealed (a) ground glass opacities (GGOs) involving about 5- 25 % of both upper lung lobes (Severity Score = 2), about 25-50 % of right middle lung lobe (Severity Score = 3) and (c & d) showing a large consolidative patch affecting more than 75% of the right lobe (Severity Score = 5) and GGO involving about 5% of the left lower lobe (Severity Score = 1). Total CTSS was 13 / 25.

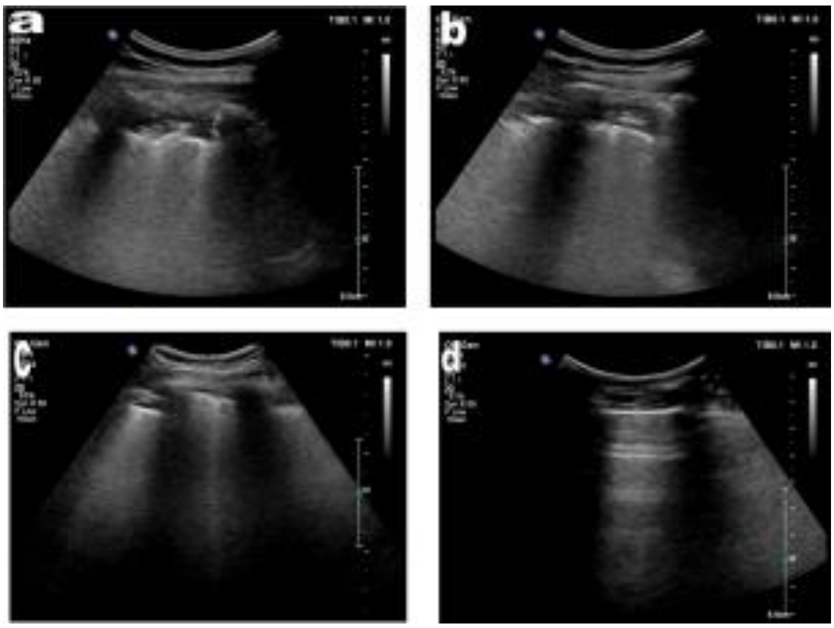

Figure (6): Lung ultrasound showed different patterns of lung affection: (a & b): subpleural consolidations (Severity Score = 3), (c): B lines covering more than 50% of the intercostal space (severity score = 2), (d): A- lines (Severity Score = 0). The total LUS score was 18/ 36.

DISCUSSION

Early identification, thorough detection, and infection surveillance by imaging techniques are necessary due to the transmission and incredibly quick development of COVID-19, notably in the case of COVID-19 pneumonia induced by SARS-CoV-2 [(7)].

The gold standard for determining the severity of pneumonia in SARS-CoV-2 patients is a chest CT scan. A global consensus statement recommends imaging for patients with presumed SARS-CoV-2 who arrive with moderate to severe clinical symptoms and a high-level pre-test risk of disease in a resource-constrained setting. However, using CT carries hazards and has practical restrictions. Transferring ill patients carries the danger of unfavorable outcomes, increases the risk of virus exposure for all healthcare professionals involved, and may result in a shortage of scanning capability if a large number of patients arrive at once. Compared to CT scans, LUS offers the benefits of being accessible at the point of treatment, being conducted by doctors with the necessary training in the emergency room (ED) or ICU, and having a minimal per-examination cost [(8)].

In this study, we included (30) patients with PCR-confirmed COVID-19 pneumonia, 36.7% were males and 63.3% were females with the mean age of the study group 63.87 ± 7.32 years ranging from 51 to 75 years at Ain Shams University Hospitals and National Hepatology and tropical medicine research institute.

Histopathologic lesions in COVID-19 pneumonia affect the distal parts of the lung and exhibit edema, alveolar destruction, interstitial thickening, and gravitational consolidations among other symptoms. Therefore, a surface imaging method aids in the imaging diagnosis of COVID-19 pneumonia. Thus, the fact that SARS-CoV-2 creates lung perivascular lesions, which are particularly favorable for LUS studies, may be used to at least partially explain why LUS has a higher sensitivity than CT. COVID-19 pneumonia patients' lung features are excellent for LUS since the symptoms are seen in the inferior and posterior lung regions as well as in the subpleural spaces, which may be accessible by ultrasound [(7)].

Since COVID-19 pneumonia is one of the many lung diseases that LUS is very sensitive to identifying, aberrant findings in COVID-19 pneumonia have to be handled with caution. This approach does not, however, provide pathognomonic signs of SARS-CoV-2 in the lungs. Other interstitial lung diseases and some alveolar conditions which exhibit B-lines and consolidations, which are anomalous LUS signs in COVID-19 pneumonia, include hypersensitivity pneumonitis, diffuse alveolar hemorrhage, idiopathic or secondary lung parenchymal fibrosis, congestions with heart failure, and pneumocystis jiroveci pneumonia. To differentiate between COVID-19 pneumonia and other illnesses with comparable US symptoms, a differential diagnosis based on clinical data, epidemiologic results, and LUS signals are required. LUS symptoms must thus be taken into account as pertain to the pandemic, and laboratory testing to verify COVID-19 continues to be essential to deliver appropriate clinical decision-making [(7)].

The most common LUS finding was diffuse B-lines, which were detected in more than two-thirds of the individuals in this study. Our findings are consistent with those of **Yasukawa and Minami** [(9)]**,** who saw thick, irregular pleural lines and B-lines in all patients during their examination. Early COVID-19 pneumonia has histopathologic features of alveolar destruction and irregular inflammatory elements that correspond with B-lines on LUS in diverse ways [(7)].

Subpleural consolidative patches on LUS were seen in roughly 40% of cases in our sample, compared to the samples examined by **Xing *et al.***[(10)]**,** who witnessed this finding in 50% of cases, and **Lopes *et al.*** [(7)]**,** who observed it in less than 25% of cases, taking into account that the patients in their study populations were scanned by LUS at an earlier time point, even before hospitalization.

Patients who suffer from respiratory symptoms or associated comorbidities, according to **Lopes *et al.*** [(7)] and our study, had more subpleural consolidation patches on LUS, suggesting the possibility of a connection between clinical signs and LUS, as well as more extensive illness condition on both the LUS and CT, emphasizing the significance of evaluating tomographic data in addition to clinical findings.

In those with COVID-19, there is a correlation between LUS and the outcomes of a chest CT. Our study did establish a connection between subpleural consolidation patches on the LUS and the CT consolidation regions as well as more than two B-lines that were detected by the LUS and peripheral areas of GGO, which was consistent with earlier findings by **Lopes *et al.*** [(7)]**.**

Early detection of B-lines in COVID-19 may be a marker for the acute phase of detecting peripheral areas of GGO lesions when circumscribed patches of lesions alternate with healthy lung tissue early in the course of an active illness. According to prior experiments of tomographic findings in COVID-19 patients, the existence of alveolar consolidations, whether on LUS or CT, correlates with illness sequence and severity. Because the majority of COVID-19 patients have peripherally distributed GGO-like lesions which increase with time to produce more consolidative abnormalities, LUS could detect a substantial number of symptomatic persons who require hospitalization [(7)].

Our findings, which are in agreement with those of **Lopes *et al.*** [(7)] and **Zieleskiewicz *et al.***[(8)] demonstrated a strong correlation between the severity of SARS-CoV-2 pneumonia as determined by LUS and that determined by chest CT scan.

While **Zieleskiewicz *et al.***[(8)] discovered that an LUS score > 23 prophesied severe SARS-CoV-2 pneumonia identified by chest CT scans with an Sp > 90% and a PPV of 70% in 23 patients, we found that CT and US severity scores to use them at the prediction of clinically severe cases was 100% for sensitivity and specificity with cut off values >13 and >9 for US and CT, respectively. A chest CT scan diagnosis of severe SARS-CoV-2 pneumonia with a Se > 90% and an NPV of 92% in 39 individuals was rejected if the LUS score was less than 13. 38 percent of the patients, or 38, were in the grey area [(8)].

According to **Zieleskiewicz *et al.***[(8)] the grey zone, or middle area, of LUS scores is where the difference between LUS and CT scan findings is located. Based on these findings, we propose that a chest CT scan would only be necessary for the 38% of instances when an initial LUS test revealed a score between 13 and 23 (moderate illness) or 13 (severe disease) [(8)].

Taking into account that they included both clinically severe and non-severe patients, it was stated that LUS was inefficient at identifying tiny lesions that did not reach the periphery of the lungs, in contrast to research conducted by **Ökmen *et al.***[(3)] in which alveolar consolidations were examined.

CONCLUSION

This study showed that individuals with respiratory system symptoms or associated comorbidities have the propensity to have greater alterations on LUS and more severe illness on CT in a sample of patients with PCR-proven COVID-19. The anomalies identified by the two distinct imaging modalities were related, and the LUS score is connected to clinical characteristics and severity determined by a chest CT scan.

Contrarily, the benefits of ultrasonography over CT include mobility, no radiation exposure (for pregnant women and patients at an increased risk for radiation usage), cheap cost, no requirement for support staff, and repeatability. In extreme circumstances, it might be utilized instead of a CT chest scan (especially in ICU cases).

Supporting and sponsoring financially: Nil.
Competing interests: Nil.

REFERENCES

1. **Rizzetto F, Perillo N, Artioli D *et al.* (2021):** Correlation between lung ultrasound and chest CT patterns with the estimation of pulmonary burden in COVID-19 patients. European Journal of Radiology, 138: 109650. doi: 10.1016/j.ejrad.2021.109650.
2. **Lopes A, Mafort T, da Costa C *et al.* (2020):** Comparison Between Lung Ultrasound and Computed Tomographic Findings in Patients With COVID-19 Pneumonia. Journal of Ultrasound in Medicine, 9999: 1–9.
3. **Ökmen K, Durdu K, Emel S (2021):** Comparison of lung ultrasonography findings with chest computed tomography results in coronavirus (COVID-19) pneumonia. Journal of Medical Ultrasonics, 48(2): 245-252.
4. **Colombi D, Petrini M, Maffi G *et al.* (2020):** Comparison of admission chest computed tomography and lung ultrasound performance for diagnosis of COVID-19 pneumonia in populations with different disease prevalence. European Journal of Radiology, 133: 109344. doi: 10.1016/j.ejrad.2020.109344.
5. **Buonsenso D, Raffaelli F, Tamburrini E *et al.* (2020):** Clinical role of lung ultrasound for diagnosis and monitoring of COVID-19 pneumonia in pregnant women. Ultrasound in Obstetrics & Gynecology, 56(1): 106-109.
6. **Chang Y, Yu C, Chang S *et al.* (2005):** Pulmonary sequelae in convalescent patients after severe acute respiratory syndrome: evaluation with thin-section CT. Radiology, 236:1067–1075.
7. **Lopes A, Mafort T, da Cal M *et al.* (2021):** Impulse Oscillometry Findings and Their Associations With Lung Ultrasound Signs in COVID-19 Survivors. Respir Care, 66(11):1691-1698.
8. **Zieleskiewicz L, Markarian T, Lopez A *et al.* (2020):** Comparative study of lung ultrasound and chest computed tomography scan in the assessment of the severity of confirmed COVID-19 pneumonia. Intensive Care Medicine, 46(9): 1707-1713.
9. **Yasukawa K, Minami T (2020):** Point-of-Care Lung Ultrasound Findings in Patients with COVID-19 Pneumonia. Am J Trop Med Hyg., 102(6):1198-1202.
10. **Xing C, Li Q, Du H *et al.* (2020):** Lung ultrasound findings in patients with COVID-19 pneumonia. Crit Care, 174(24): 174. https://doi.org/10.1186/s13054-020-02876-9.