THORACIC ULTRASOUND IN COVID-19 IN CORRELATION TO LAB AND CHEST COMPUTED TOMOGRAPHY

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ABSTRACT

Background: Despite the widespread utilization of chest CT, the definitive reassurance for repetition remains undetermined. Severe acute respiratory syndrome coronavirus 2 (SARS-CoV2) is responsible for the onset of coronavirus disease 2019 (COVID-19), which leads to the development of viral pneumonia. Diagnosis of this condition may be achieved through the utilization of a chest computed tomography (CT) scan. Furthermore, the application of Lung Ultrasound (LUS) has been found to possess significant diagnostic precision in instances of Alveolar Consolidation and Interstitial Lung Diseases.

Objective: The purpose of this study was to evaluate diagnostic performance of transthoracic ultrasound in COVID pneumonia and correlations of these findings with clinical features, lab and chest CT.

Patients and Methods: This prospective observational study was conducted on (100) patients attending isolation unites (ward or ICU), Benha University hospital, with evidence of COVID-19 pneumonia during the period from June 2021 till January 2022.

Results: The mean age of the studied patients was 53 ±15 years. More than half of the patients were males (58%). fever was the most common manifestation among studied group. GGO was the most common finding and the median CT chest score was 14, ranging from 3-25. B lines were the most common finding in LUS and the median LUS score was 16. There was significant correlation between chest CT, LUS with O_2 saturation in negative way and in positive way with inflammatory markers such as CRP, LDH and D.dimer. Lung US score was correlated significantly in positive way with chest CT score. The best cut-off of lung US score to predict mortality was > 24, at which sensitivity and specificity were 95.2% and 96.2%, respectively while the best cutoff chest CT was > 18, at which sensitivity and specificity were 100% and 87.3%, respectively. LUS score was a significant predictor of mortality.

Conclusion: Lung ultrasound serves as a secure and efficacious diagnostic modality in individuals presenting with COVID-19 pneumonia which reflects CT findings. The LUS score exhibited a strong correlation with various laboratory findings and the CT severity score, thus, rendering it a valuable prognosticator of mortality. The best cutoff of LUS score to predict mortality was > 24, at which sensitivity and specificity were 95.2% and 96.2%, respectively while the best cutoff chest CT was > 18, at which sensitivity and specificity were 100% and 87.3%, respectively.

Keywords: Transthoracic Ultrasound, HRCT Severity score, Coronavirus Pneumonia, point of care US.

Introduction

SARS-CoV-2, which is associated with severe acute respiratory syndrome (SARS), belongs to the family of coronaviruses and a new strain of beta-corona virus which infects humans. SARS CoV-2 spreads globally and this outbreak was declared as pandemic [(1)].

The determination of infection is attainable by utilization of a nasopharyngeal specimen and the preeminent means of detecting the harm and assessing the extent of pulmonary entanglement triggered by COVID-19 disease is high-resolution chest computed tomography (HRCT) (2). Various indices are being researched to assess the severity of lung affection. The severity score of CT suggested by Pan et al. is advantageous in estimating the load of pulmonary disease caused by COVID-19. [(3)].

Point-of-care lung ultrasonography (LUS) is increasingly recognized as a dependable modality for assessing the extent of pulmonary damage caused by COVID-19 [(4)].

The Lung US score is a semi-quantitative measure of the severity of lung injury that is based on the identification of the pleural line abnormalities, B-lines, and pulmonary consolidations [(5)].

Pulmonary ultrasonography has the potential to serve as a substitute for computed tomography of the chest for the purpose of monitoring COVID-19 pneumonia in patients who are critically ill. This is due to its ability to measure the extent of pulmonary involvement, track alterations throughout the illness

duration, and forecast mortality or prolonged ICU admittance exceeding 30 days [6].

The objective of this inquiry was to evaluate diagnostic performance of trans-thoracic ultrasound in COVID pneumonia and correlations of these findings with clinical features, laboratory and chest CT finding.

PATIENTS AND METHODS

This prospective observational study included 100 patients admitted in isolation units (ward or ICU) at Benha University Hospitals, with evidence of COVID-19 pneumonia from June 2021 to January 2022.

- Inclusion criteria:

a) Individuals presenting with pulmonary manifestations on admission in the isolation unit (ward and ICU), identified as afflicted with COVID-19 via detection of SARS-CoV-2 through RT-PCR analysis of nasopharyngeal swabs.
b) Patients with respiratory symptoms on admission with CT findings indicating COVID-19 disease.

- Exclusion criteria:

a) Diagnosis of diffuse parenchymal lung disease (DPLD).
b) Patients with congestive heart failure.
c) Patients with neoplasia in the lung or metastases from other neoplasia.
d) Patients refuse to participate in the study.
e) An interval exceeding 24 hours between pulmonary ultrasonography and radiography.

- All patients were subjected to the subsequent:

1. Full clinical evaluation including history and examination
2. Lab tests: CBC, LDH, ferritin, D.dimer and ABG, liver and kidney functions
3. Nasopharyngeal and oropharengeal swabs for RT-PCR for SARS COV-2,
4. Non-contrast HRCT chest
5. Transthoracic ultrasound

- CT Technique

All subjects involved in the research underwent high-resolution computed tomography (HRCT) immediately prior to admission utilizing a 16-row scanner (manufactured by Toshiba, Japan) while in a supine position at the end of inspiration, with no administration of intra-venous contrast media. The acquisition parameters were set at 110 kVp on the 16-row scanner.

HRCT scans were reviewed by radiologist and determined the existence as well as the magnitude of thoracic abnormalities.

Semi quantitative scoring system (CT-SS)

A semi-quantitative evaluation method was introduced in order to assess the degree of pulmonary complications arising from the aforementioned abnormalities. The assessment was centered on the affected area. The CT-SS was determined by the level of lobar involvement. A visual evaluation of each of the five lung lobes was conducted on a scale of 0-5, where 0 indicates a lack of involvement, 1 indicates less than 5% involvement, 2 indicates 5-25% involvement, 3 indicates 26-49% involvement, 4 indicates 50-75% involvement, and 5 indicates greater than 75% involvement. The total CT score was calculated as the sum of individual lobar scores and ranged from 0 (no involvement) to 25 (maximum involvement) [7] **(Fig. 1).**

In addition, other features such as fibrosis, subpleural lines, pleural and pericardial effusion, and lymph-adenopathy were also outlined**.**

- Ultrasound Procedures and Analysis of Images

All cases were examined by TTUS (Phillips Hd5 Color Doppler Ultrasound Machine, Tokyo, Japan) using both low-frequency convex (Philips C5-2 Curved Array Probe) and high frequency linear (Philips L12-3 linear probe) transducers for lung and pleural examination.

- Technique of transthoracic US

Within 24 hours of admission and CT scanning, a bedside transthoracic US was conducted as a supplementary measure to physical examination. In order to ensure safety, operators utilized appropriate personal protective equipment. The examinations were conducted with the patient positioned in various ways, including sitting, supine, lateral, prone and standing positions. In the event of respiratory discomfort or airway control issues, the supine or prone position was frequently employed, depending on the ventilatory strategy that had been established at that time.

At the start of examination, convex transducer was employed providing a comprehensive view of the pleural line and ultrasonic artifacts associated with lung parenchyma status (A lines, comet-tail artifacts such as B lines, and consolidations). Subsequently, in order to undertake a more thorough examination of the pleural line appearance and subpleural abnormalities, a linear probe was employed [8].

Every side of the thorax was partitioned into anterior, lateral, and posterior segments. Each segment was subsequently dissected into upper and lower portions utilizing the third intercostal space as a point of reference, leading to the acquisition of six distinct regions for each hemithorax [9]. The images were acquired via ultra-sound software and were subsequently assessed post-examination so as to mitigate unwarranted and protracted interaction with patients. A meticulous assessment of the presence, location, and propagation of anomalies, including B lines, thickened or disrupted pleural lines, consolidations, and air bronchograms, was conducted.

Scoring Procedures [10]:

The twelve pulmonary regions, encompassing the superior and inferior segments of the anterior, lateral,

and dorsal aspects of each lung, were examined closely via the lung US methodology.

Utilizing the discrete quartet of ultrasonic aeration patterns, a system of evaluation was implemented to allocate scores to each zone of interest. Scores were assigned to each area of interest predicated on the most severe ultrasonography pattern observed in each zone. No points were granted for A lines or one or two isolated B lines in conjunction with lung sliding. However, a single point was awarded for the observation of three to four B lines accompanied by a marked reduction of lung aeration, also known as septal rockets. In the case of a substantial loss of lung aeration with five or more B lines, referred to as diffuse coalescent B lines, two points were allocated. Furthermore, the existence of a hypoechoic and poorly defined tissue that exhibits a complete lack of lung aeration, also known as consolidation, was conferred with three points **(Fig. 2).**

At procedure end, the highest score for each area were gained. On summing the highest score at each zone, the patient's Lung Score were gained, ranging from 0 to 36. When the score is 1-7, it is considered mild, 8-18 moderate and 19-36 severe lungs involvement [(11)].

- Statistical methods

The management of information and statistical examination were conducted utilizing SPSS version 28 (IBM, Armonk, New York, United States). At the outset, quantitative data underwent an assessment for normality through employment of the Kolmogorov-Smirnov statistic, the Shapiro-Wilk test, and direct data visualization techniques. Dependent on the state of normality, quantitative data were summarized utilizing means and standard deviations or medians and ranges. Categorical data were summarized through numerical values and percentages. For comparison of categorical data, employment of the Chi-square or Fisher's exact test was utilized. ROC analyses were executed for the CT and US scores in prophesying normality. The areas under the curve with 95% confidence intervals, optimal cutoff points, and diagnostic indices were computed. Spearman's correlation was employed to conduct correlations. A multivariate logistic regression analysis was conducted for CT and LUS scores to predict mortality. The odds ratios with 95% confidence intervals were calculated. All statistical tests were two-sided. Values of P less than 0.05 were deemed significant.

- RESULTS

The mean age of the studied patients was 53± 15years. More than half of the patients were males (58%). About one-quarter (26%) had diabetes, and about one-third (30%) had hypertension. IHD, Stroke, CKD and other comorbidities ware detected in 12% of patients. Patients were admitted to the ICU unit more frequently than the ward (63% vs.37 %) (**Table;1)**.

Fever was the most common symptom was (89%), followed by dyspnea (85%), cough (81%), and body aches (27%). More than one-third had other symptoms (43%). The mean duration of symptoms was 6.5±2.9, ranging from 1-15 days. The mean temperature was 37.9±0.7 °C. The mean systolic and diastolic blood pressures were 118±15 and 73±12 mmHg, respectively. The mean respiratory rate was 29 ±6 breath/ minute. The mean heart rate was 105.23 ± 12.4 beat/ minute while cyanosis found only in 5% of the studied patients (**Table;2)**.

The mean O2 saturation in room air was 80.±11%.. The mean pH was 7.4±0.09. The mean PCO2 and PO2 were 35.7 ±7.1 and 52.1 ±13.3 mmHg respectively. The median ferritin was 612.5 ng/mL (130-8046). The median LDH was 430U/L (100-2900). The median D-dimer was 900 ng/mL (150-8000). The median CRP was 56 mg/dl (7-296). The median TLC was $10.8x10^3$ cells/µL (2.8 – 25). The median absolute lymphocyte count was 0.899 x 10^3 (0.5-3.75) cells/µL, while it was 9.5 % (1-37 %) for the relative count (***Table; 3***).

Most patients had bilateral affection (99%). More than half had peripheral distribution (54%), while mixed distribution was reported in more than one-third (46%). The mean number of lobes affected was 4±1. All patients had ground glass opacities. Only 19% had crazy paving. Approximately two-thirds (67%) had consolidation. About one-quarter (28%) had subpleural lines. Only 10% had nodules/reticulation. Holo sign and pleural effusion were found in 7% and 4% respectively. The median CT score was 14(3-25) (**Table; 4).**

Nearly all patients had bilateral affection (99%) while more than half had irregular pleural lines (58%). Only 7% had regular lines while about one-third had broken lines (35%). 50% had confluent B lines, more than one-third (42%) had displaced B-lines, while only one patient had focal B lines. Approximately two-thirds of the patients had consolidations while effusions found only in 4% of them. The median US score was 16 (0-36) (***Table; 5)***.

US score revealed significant positive correlation with respiratory rate (r=0.543, P<0.001), ferritin (r= 0.570, P<0.001), LDH (r=0.543, P<0.001), D-dimer (r= 0.476, P<0.001), CRP (r=0.416, P<0.001), TLC (r=0.355, P<0.001). In contrast, the US score revealed significant negative correlations with SO_2 in room air (r=-0.741, P< 0.001) and PO_2 (r=-0.587, P <0.001)**).** No significant correlations were observed between US score and SBP, DBP, PH, PCO2, absolute and relative lymphocyte counts (***Table; 6, Figure; 3)***.

There was revealed a significant positive correlation between lung US score and computed tomography scores (r=0.886, P<0.001) (***Table; 7, Figure; 4).***

ROC analysis was done for the US score to predict mortality. For LUS, It revealed a significant-excellent AUC of 0.994, with a 95% CI ranging from 0.983 – 1 (P < 0.001). The best cut-off was > 24, at which sensitivity and specificity were 95.2% and 96.2%, respectively. The ROC analysis for the CT score to predict mortality revealed a significant-excellent AUC of 0.991, with a 95% CI ranging from 0.977 – 1 (P < 0.001). The best cutoff was > 18, at which sensitivity and specificity were 100% and 87.3%, respectively ***(Figure 5, 6).***

DISCUSSI0N

In late 2019, an outbreak of a novel beta coronavirus called 2019-nCov emerged in China. This virus was subsequently renamed severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and led to a worldwide pandemic of a newly identified respiratory illness known as coronavirus disease 2019 (COVID-19) [(12)]. This respiratory tract infection has the potential to result in significant systemic involvement, including interstitial pneumonia and respiratory failure. These conditions are frequently accompanied by myocardial injury [(13)], thrombosis [(14)], multiorgan failure, and ultimately, death. [(15)].

The purpose of this study was to assess diagnostic performance of transthoracic ultrasound in COVID pneumonia and correlations of these findings with clinical features, lab and chest CT.

This prospective observational study involved 100 patients, 58 of them were males (58%) and 42 were females (42%), the average age of them was 53 ±15 years. Comorbidities were largely prevalent within the study population, as one-third (30%) have hypertension and about one-quarter (26%) have diabetes. Other co-morbidities such as hypothyroidism and CVD were found only in 12% of the studied patients. About two-thirds of patients (63%) were admitted in ICU because they required high-flow nasal cannula or higher-level oxygen support measures to correct hypoxemia**.**

Higher number of male patients may be a reflection of the protective effect of sex hormones (X chromo-some) which reduce susceptibility to viral infections in females as a function of innate and adaptive immunity. It is highly probable that the COVID-19 virus would affect elderly gentlemen who have long-standing concurrent illnesses due to their feeble immune responses, as per the findings of study [(16)].

These results were supported ***Ibrahim et al.*** [(17)] who correlate computed tomography severity score (CTSS) in COVID-19-infected patients with their clinical, laboratory, method of ventilation, and disease outcome parameters in 139 patients SARS-cov2-infected patients. They found 53.9% of studied patients to be males, which is similar to our results. The mean age of their patients was higher than that of our study (59.81 ± 12.29years), again supporting that severe disease is more prevalent in older peoples. They also found hypertension to be the most prevalent comorbidity in their patients which agrees with this study.

Chen and colleages [(18)] studied COVID-19 pneumonia in 99 patients and found results that agree with our study. They studied 67 men and 32 women. The average age of their patients was 55·5 years (SD± 13·1). 50 (51%) of their patients had chronic diseases. In a study by ***Fratianni et al.*** [(19)], the number of male patients was much higher (88.46%, 23/26) than in our study. Also, the mean age of their patients was higher than that of our patients (66 ± 15), which supports the concept that severe COVID-19 disease is more in older people. They found hypertension to be the most prevalent comorbidity in their patients which is similar to our results.

In the current study, the most frequent symptom among the studied patients was fever (89%), followed by dyspnea (85%), cough (81%), and body aches (27%), while more than one-third of patients had other symptoms such as disturbed consciousness, GIT manifestations, loss smell (43%).

These results were in agreement with ***Chen et al.*** [(18)] who studied the epidemiological and clinical characteristics of 2019-nCoV pneumonia in 99 patients and found that 82 patients (83%) presented with fever, while cough was found in 81 patients (81.8%) and shortness of breath was present in 31 patients (31.3%). The other symptoms such as muscle ache, confusion, headache and diarrhea were found in about 42% of patients.

On assessment of the laboratory parameters of patients in this work, blood gases showed hypoxemia in most of patients with a mean SO2 of 80±11% on room air. The mean PO2 was 52.1±13.3mmHg while PCO2 showed a mean of 35.7±7.1mmHg. Inflammatory markers were significantly elevated with a median ferritin level of 612.5µg/l (130-8046µg/l), a median LDH level of 430U/l(100-2900U/l), a median D-dimer level of 900µg/l(150-8000µg/l) and a median CRP level of 56mg/dl (7-296mg/dl). As regards blood leukocytes, the median TLC was $10.8x10^3$($2.8-25x10^3$) cells/µL while the median of absolute and relative lymphocyte counts was $0.899x10^3$($0.5-3.75x10^3$) cells/µL and 9.5% (1-37%) respectively.

Diminished arterial blood gas (ABG) measurements upon arrival at the emergency department are indicative of an augmented and more extensive inflammatory response, thereby identifying a patient who may possess an elevated prognostic hazard, even in the absence of overt clinical compromise.

These findings concur with the research of ***Mansouri et al.*** [(20)] who explored the correlation among arterial blood gases, acid-base abnormalities, and consequences in individuals suffering from COVID-19 and observed substantial hypoxemia in patients with an average PO2 and SO2 of 42.08±28.77mmHg and 74.37±18.03%, respectively.

Abdul Kader et al. [21] evaluated the value of the LDH, Ferritin, D-dimer, and CRP as biomarkers in COVID-19 patients and observed significant elevation in levels of all these parameters in them. They found a mean LDH of 495.28(±124.9), a mean ferritin of 394.69(±337.1), a mean CRP of 82.34(± 113.5) and a mean D.dimer of 1650.4 (± 2233.2) which agrees with our results.

CRP is an acute phase reactant protein that is produced by hepatocytes in response to inflammation and its serum levels are proportional to the degree of inflammation. It initiates coagulation cascade which by turn activates the complement system leading to the formation of thrombi. It has been found that levels > 40mg/dl are associated with increased risk of thrombosis [20]**.** COVID-19 has been reported to be associated with coagulopathy and 3.75%-68% of COVID-19 patients have raised D-dimer levels [22].

Most of our patients (99%) showed bilateral lung infiltrations on CT which were peripheral in more than a half of them (54%) while mixed (central and peripheral) distribution was reported in less than the half (46%). The mean number of lobes affected was 4±1 ranging from (1-5) and lower lobes were affected in most patients (62%). All patients had ground glass opacities and 19% had crazy paving. Approximately two-thirds (67%) have consolidations and around one-quarter (28%) showed subpleural lines. Nodules/ reticulations were uncommon (10%) while pleural effusion and the holo sign were detected in only 7% and 4% of patients respectively. The median CT score was 14, ranging from 3-25**.**

These results agreed with ***Abdollahi et al.***[23] who found ground glass opacities to be the most frequent imaging findings observed in CT of COVID-19 patients (94.1%) followed by consolidations (91.0%). They found bilateral affection in 95% of cases with peripheral distribution in most of them (96%) while pleural effusions were found in only 8%. They found a CT score of 19(13-23).

Mohamed et al. [24] studied chest CT characteristics and laboratory findings in 164 patients with confirmed COVID-19 pneumonia and their findings supported our results. They found peripheral ground-glass opacities to be the most common radiological appearance followed by consolidations. Also, reticulations were more common in their patients than in ours. Crazy paving and reverse halo signs were characteristic of COVID 19 pneumonia; however, they were uncommon in their patients. Also, enlarged mediastinal lymph nodes and pleural effusions were uncommon.

As regards lung ultrasound findings, nearly all of our patients had bilateral affection (99%). About 93% of patients had pleural abnormalities with irregular pleural line in 58% & broken pleural line in 35%. B lines were found in most patients (displaced in 50% and confluent in 42%) while only one patient had focal B lines. Approximately two-thirds of our patients had consolidations but only 4% got pleural effusions. The median US score was 16, ranging from 0-36.

In a study done by ***Gil-Rodríguez et al.*** [25] to determine COVID-19 findings in LUS, and to assess its relationship to the disease initial severity and prognostic outcomes, they found B lines to be the most common findings in their patients (91%) (especially in ICU admitted patients (99%)). They also found B lines to be confluent in 80% of cases, with at least 3 B-lines in ICU patients (83%). The next most common finding was pleural thickening (84%) which agrees with our findings. In disagreement with our results, consolidations - an indicator of a more severe disease- were less common in all patients (43%). The manifestation of pleural effusion was a rare occurrence (14%) and abnormal LUS findings were distributed bilaterally in 59% of cases. However, the mean LUS score was 11.27 among all studied patients.

Also these results were in agree with ***Tan et al.***[26]. Their study reported that 33.3% of the participants exhibited distinct B-lines and rocket sign, while 100% displayed partially dispersed B-lines. Additionally, 83.3% presented with confluent B-lines or white lung. parenchymal consolidations or subpleural focal lesions were found in 41.6% of their patients. They found pleural effusion in only 8.3%. The small differences between our results and those of **Tan et al.,** [26] might be related to the larger number of studied patients in our work (100 confirmed COVID-19 patients) compared to the smaller number in their study (32 individuals, of which 12 patients had been definitively diagnosed with COVID-19)

In the present work, LUS score was found to correlate significantly and directly to respiratory rate ($P<0.001$). No significant correlation observed between LUS score and age, blood pressure (systolic and diastolic), temperature or heart rate.

Contrary to our results, ***Portale et al.*** [27] investigated LUS scoring in hospitalized COVID patients and showed that LUS score directly correlated with age.

In our work, LUS score has correlated negatively to room air SO2 and PO2 ($r=-0.741$, $P<0.001$& $r=-0.587$, $P<0.001$ respectively) reflecting worsening of oxygenation parameters with higher LUS. No significant correlations were observed between LUS score and blood pH, PCO2, $HCO3^-$, Na^+ or K^+.

Lugara et al. [28] has found PO2 to correlate significantly and negatively with LUS score ($r=-0.400$, $p=0.001$), indicating that a higher LUS scores were associated with decreased levels of PO2 and agrees with our findings. On the other hand, they found negative correlation between SO2 and LUS score ($rho=-0.113$, $p=0.366$) but didn't reach the significant differences, while pH displayed significant negative correlation ($rho=-0.363$, $p=0.003$) which disagrees with our findings.

On correlation of LUS score with laboratory parameters in our patients, we found a significant and

direct correlation with ferritin (r=0.570, P<0.001), LDH (r=0.543, P<0.001), D-dimer (r=0.476, P< 0.001), CRP (r =0.416, P<0.001) and TLC (r= 0.355, P<0.001). No significant correlation was detected between LUS score and lymphocyte count (absolute or relative).

These results were consistent with those of ***Trias-Sabrià et al.*** [29] who studied the potential role of lung US score in 36 cases with COVID-19. They found a significant correlation between LUS score and blood laboratory tests such as D-dimer (r=0.424, P=0.01), C-reactive protein (r=0.373, P=0.02), LDH (r= 0.460, P=0.004). Contrary to our results, the authors found significant correlation between LUS score and lymphocyte count (r=-0.487, P=0.002).

In a retrospective research carried out by ***Senter and colleagues*** [30] with the purpose of evaluating pulmonary sonography findings and the correlation of these findings with clinical and laboratories in the context of COVID-19 pneumonia, the investigators observed both positive and negative correlations between the score of pulmonary ultrasonography (LUS) and indicators of hemo-inflammatory activation and organ impairment. LUS scores directly correlated with CRP, LDH and D-dimer which is concordant with our results. On the other hand and disconcordant with our results, they found lymphocyte count to significantly and inversely correlate with LUS score.

The present work revealed that lung ultrasound (LUS) was significantly associated with a positive correlation with computed tomography (r=0.886, P< 0.001).

These findings were in agreement with ***Elhefnawy et al.*** [31] who tried to classify lung abnormalities by lung ultrasonography in 30 SARS-CoV-2 patients and correlated US finding also with chest CT results. They found a strong positive correlation between LUS and CTSI (p<0.05).

Fratianni et al.[19] when assessed lung ultrasound correlations with chest CT, respiratory impairment, and inflammatory cascade in 26 patients with SARS-COV-2 pneumonia, they found a direct but weak correlation between total LUS score and chest CT score (r = 0.45, P = 0.049).

On the other hand, ***Baciarello et al.*** [32] demonstrated that LUS did not correlate significantly with CT score. This might be due to the different times at which CT and LUS were performed as we did both within 24hr of admission while the authors did LUS by intensivists on referral to the ICU, which happened 7 (5-10) days after admission. Of Corse CT features may progress or regress i.e. will change its features from the first CT and this will affect LUS findings if delay in doing LUS occurs.

In the present work, sensitivity and specificity of LUS score and CT score to predict patient mortality were evaluated. As regard LUS score, it revealed a significant-excellent area under the curve (AUC) of 0.994, with best cutoff was >24 at which sensitivity and specificity were 95.2% and 96.2%, respectively. For chest CT score, It revealed a significant-excellent AUC of 0.991, with a 95% CI ranging from 0.977 – 1 (P < 0.001), with best cutoff was > 18, at which sensitivity and specificity were 100% and 87.3%, respectively (Figure 5, 6).

As regard LUS score***, Sosa et al.*** [33] evaluated the sensitivity and specificity of the LUS score to predict patient mortality in 59 patients diagnosed with COVID-19 and admitted in the ICU. They found an AUC of 0.64, with 25 as the best cut-off point, with sensitivity and specificity of 0.63 & 0.59 respectively. Thus they found a cut-off point similar to our results but with sensitivity and specificity much lower than we have found. For chest CT score, ***Todor et al.*** [34] revealed that the best cut-off value for CT severity score was 18.5 out of 25 with sensitivity 70.1% and specificity 73.5%. The areas under the curve (AUCs) for CT severity score was 0.739 (CI 95%: 0.670-0.809).

CONCLUSION

Lung ultrasound (LUS) constitutes a secure and efficacious diagnostic instrument that possesses significant promise for augmenting the diagnosis and management of COVID-19 pneumonia, both within healthcare facilities and among the general populace. The observations obtained from Lung Ultrasound (LUS) are indicative of the findings derived from Computed Tomography (CT) scans of the chest, and the degree of their intensity is directly proportional to the score of CT severity. The LUS score demonstrates a strong correlation with the score of CT severity as well as the parameters obtained from laboratory tests, thereby serving as a valuable tool in prognosticating the outcome of COVID-19 disease.

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Author contribution: Authors contributed equally in the study.

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Table (1): Demographic and clinical characteristics of the studied patients

Age in years (M±SD)	**53 ±15**
Sex	**No. (%)**
Males	58 (58%)
Females	42 (42%)
Comorbidities	**No. (%)**
No comorbidities	32 (32%)
Diabetes mellitus	26 (26%)
Hypertension	30 (30%)
IHD	4 (4%)
Stroke	4(4%)
CKD	2 (2%)
Other	3 (3%)
Admission unit	**No. (%)**
ICU	63 (63%)
Ward	37 (37%)

Data are presented as mean ±SD or number (percentage

Table (2): Symptoms and signs in the studied patients

Symptoms & signs	
Duration of symptoms (days)	6 (1 - 15)
Symptoms	**No. (%)**
Dyspnea	85 (85%)
Fever	89 (89%)
Cough	81 (81%)
Body ache	27 (27%)
Other symptoms:	43 (43%)
Abdominal pain	7 (7%)
Loss smell & taste	8 (8%)
Diarrhea	5 (5%)
Dizziness	8 (8%)
Fatigue	9 (9%)
Headache	5 (5%)
Loss conscious	1 (1%)
Signs	M±SD
Temperature(°C)	37.9 ± 0.7
Heart rate(beat/minute)	105.23 ± 12.4
Systolic blood pressure (mmHg)	118 ±15
Diastolic blood pressure(mmHg)	73 ±12
Respiratory rate (breath/minute)	29 ±6
Cyanosis	5 (5%)

Data are presented as mean ±SD, median (min-max), or number (percentage)

Table (3): Laboratory results of the studied patients

Lab parameter	Median (range)
PH	7.4 ±0.09
PCO_2(mmHg)	35.7 ±7.1
HCO3(mEq/L)	20.63 ± 2.6
PO_2)(mmHg)	52.1 ±13.3
SO_2 in room air (%)	80 ±11
Na+(mEq/L)	134.8 ±12.3
K+(mEq/L)	3.8 ± 0.6
Ferritin(µg/l)	612.5 (130 - 8046)
LDH(U/l)	430 (100 - 2900)
D-dimer(µg/l)	900 (150 - 8000)
CRP(mg/dl)	56 (7 - 296)
TLC (cells/µL)	10.8 (2.8 - 25)x10^3
Lymphocytes (absolute) (cells/µL)	0.899 (0.5 - 3.75)x10^3
Lymphocytes %	9.5 (1 - 37)

Data are presented as mean ±SD, median (min-max), or number (percentage)

Table (4): CT findings of the studied patients

CT findings	No. (%)
Side	
Unilateral	1 (1%)
Bilateral	99 (99%)
Distribution of lesion	
Peripheral	54 (54%)
Mixed (central & peripheral)	46 (46%)
Number affected lobes	4 ±1
Type of opacities	
Ground glass opacity (GGO)	100 (100%)
Crazy paving	19 (19%)
Consolidation	67 (67%)
Subpleural line	28 (28%)
Nodule/reticulation	10 (10%)
Halo sign	7 (7%)
Pleural effusion	4 (4%)
CT score	14 (3 - 25)

Data are presented as mean ±SD, median (min-max), or number (percentage); GGO: ground glass opacity

Table (5): US findings of the studied patients

Findings	No. (%)
Side	
Unilateral	1 (1)
Bilateral	99 (99)
Pleural line	
Regular	7 (7)
Irregular	58 (58)
Broken	35 (35)
B lines	
Confluent	50 (50)
Displaced	42 (42)
Focal	1 (1)
No	7 (7)
Consolidations	66 (66)
Others	
Effusion	4 (4%)
LUS score	16 (0 - 36)

Table (6) Correlation between US score and clinical and laboratory parameters

	LUS score	
	R	**P**
Age (years)	0.11	0.278
Systolic blood pressure (mmHg)	-0.096	0.340
Diastolic blood pressure(mmHg)	-0.120	0.236
Respiratory rate (breath/minute)	.543	**<.001**
PH	-0.073	0.474
PCO_2(mmHg)	-0.155	0.126
PO_2(mmHg)	-.587	**<.001**
SO_2% in room air	-.741	**<.001**
HCO3(mEq/L)	-0.196	0.051
Na(mEq/L)	-0.0672	0.5068
K(mEq/L)	-0.0447	0.659
Ferritin	.570	**<.001**
LDH	.543	**<.001**
D-dimer	.476	**<.001**
CRP	.416	**<.001**
TLC(cells/µL)	.355	**<.001**
Lymphocytes (absolute) (cells/µL)	-0.155	0.125
Lymphocytes (relative)(%)	-0.121	0.231

r: Correlation coefficient

Table (7): Correlation between LUS score and CT score

	R	P	Significance
LUS score	0.886	<.001	S
CT score			

r: Correlation coefficient, S: significant, NS: non-significant

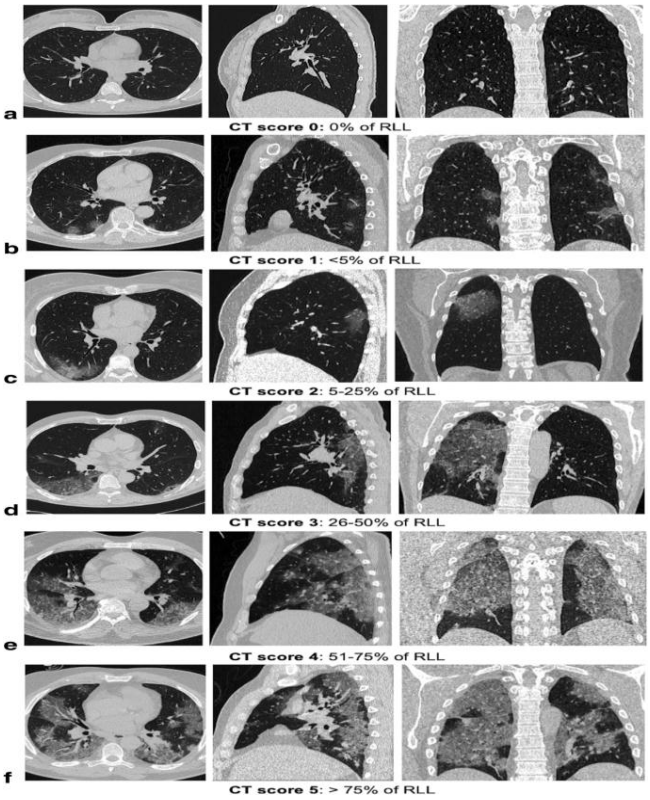


Figure (1): Various CT score of right lower lobe (RLL) affection in COVID-19 pneumonia on axial, sagittal, and coronal images. The RLL lobe involvement rate varies from 0% (a) to <5% (b), 20% (c), 40% (d), 70% (e), and >75% (f) [(6)].

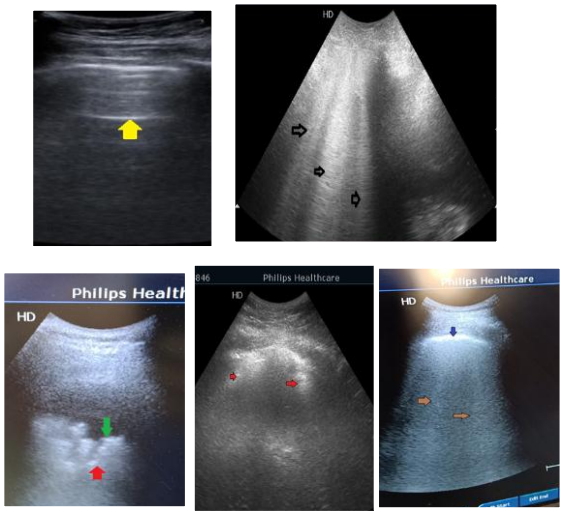


Figure (2): LUS showing (A) normal appearances-A line (yellow arrow), (B) B lines (black arrow), (C-D) Subpleural consolidation (red arrow) & Brocken pleural line (green arrow), (E) thick pleura)(blue arrow) & white lung (brown arrow).

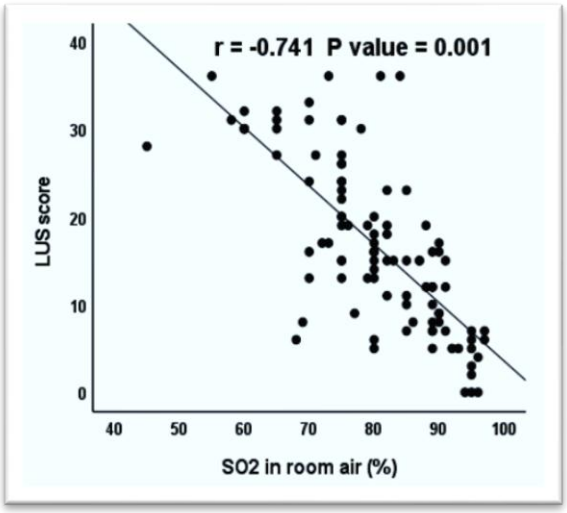


Figure (3): Correlation between US score and SO2 in room air

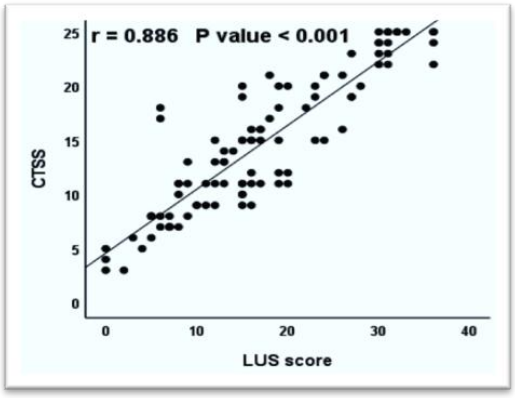


Figure (4): Correlation between CT score and US score

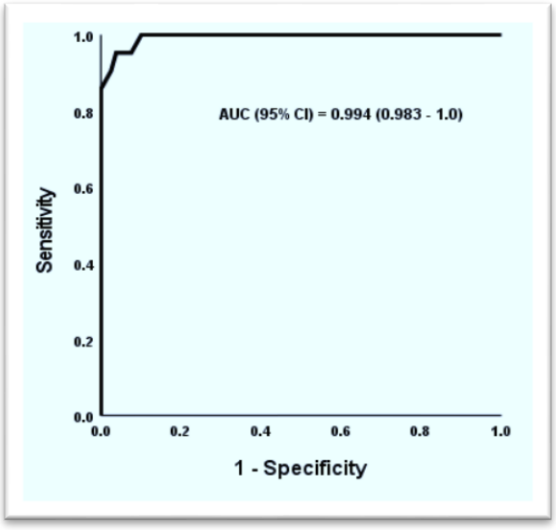


Figure (5): ROC analysis of US score to predict mortality.

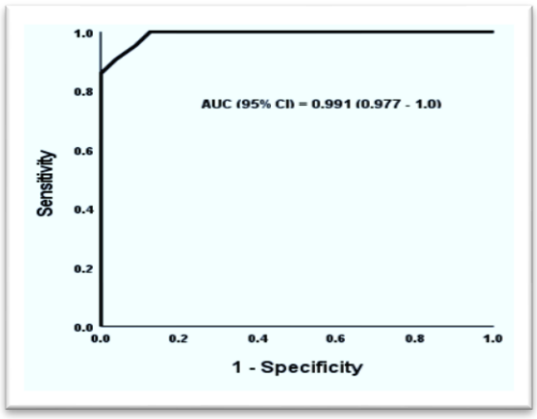


Figure (6): ROC analysis of CT score to predict mortality

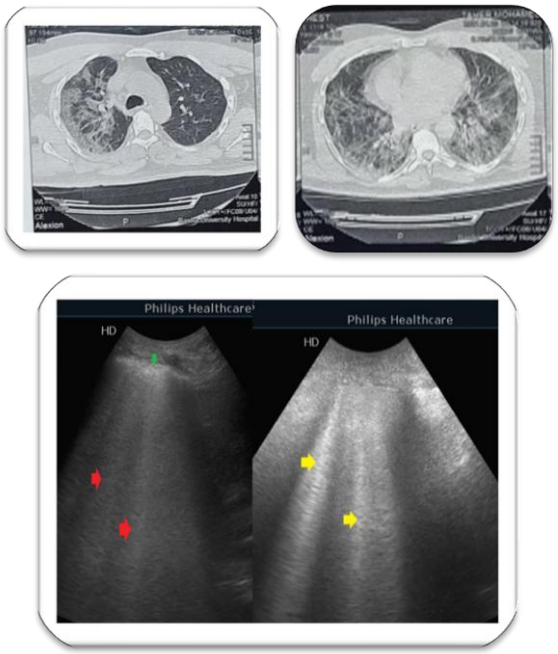
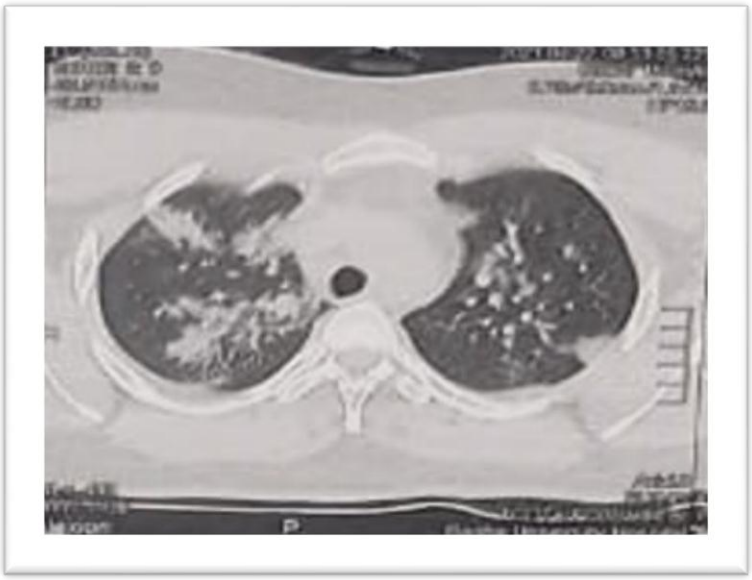


Figure (7, 8): CT chest and TTUS imaging for male patient (48 years) presented with fever, cough and shortness of breath which started 10 days before admission. Chest CT: Bilateral ground glass patches/ reticulation are seen diffusely scattered in both lung fields. TTUS imaging: Thick pleura (green arrow), displaced B line (red arrow & yellow arrow).



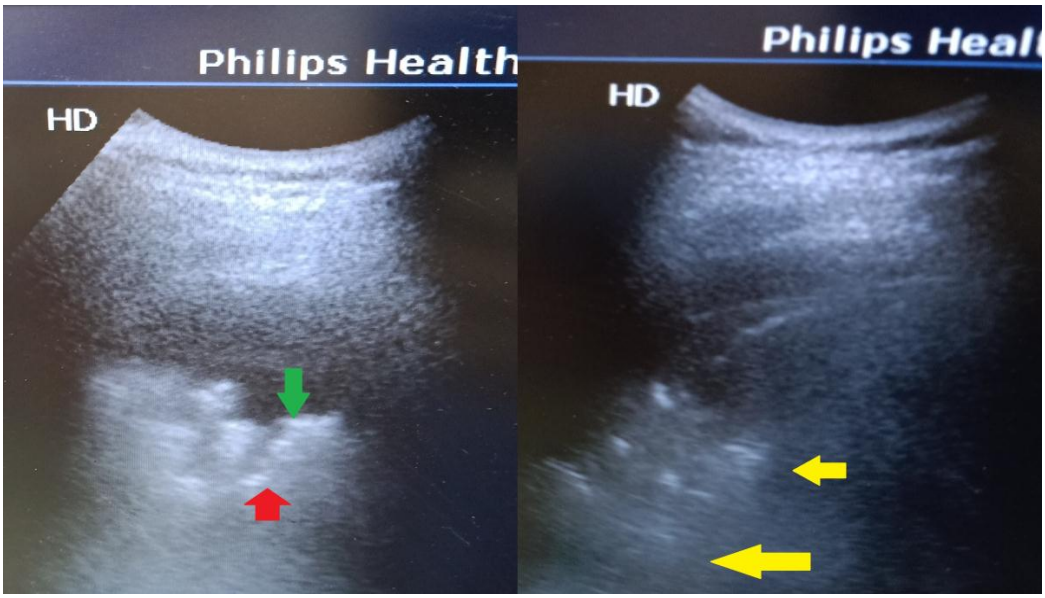


Figure (9, 10): CT chest and TTUS imaging for male patient (32 years) presented with fever, cough and shortness of breath which started 5 days before admission. Chest CT: Bilateral ground glass and consolidating patches are seen diffusely scattered in both lung fields. TTUS imaging: Broken pleura (green arrow), subpleural consolidation (red arrow) and parenchymal consolidation (yellow arrow).