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Lung Ultrasound in ICU Admitted COVID-19 Patients; Can LUS Replace CT Chest

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PATIENTS with coronavirus disease (COVID-19) can develop severe bilateral pneumonia leading to respiratory failure. The authors aimed to study the value of lung ultrasound (LUS) in patients with COVID-19 admitted to ICU, in diagnosing pneumonia and predicting of prognosis of patients in comparison with CT chest, aiming at decreasing the radiation exposure dose of patients during the disease from CT chest. A retrospective study was performed of the medical records of patients with confirmed COVID-19 by polymerase chain reaction (PCR) test admitted to ICU due to complications of covid-19 infection and underwent lung ultrasound and CT chest. One hundred twenty-two patients were included. The LUS score was significantly related to the pneumonia severity in ICU-admitted COVID-19 patients and showed high significance in predicting mechanical ventilation and death (P<0.000), respectively. The present study showed that despite some limitations, LUS was a good predictor of pneumonia severity, mortality, and mechanical ventilation and can be used alone in the diagnosis and follow-up of ICU-admitted COVID-19 patients, to reduce exposure to unnecessary radiation.

Keywords: CT chest, ICU COVID-19 patients, Lung ultrasound, Radiation protection.

Introduction

December 2019 saw the start of the coronavirus disease 2019 (COVID-19) pandemic. COVID-19 has a relatively high mortality with contagion spreading around the globe (Caroselli et al., 2021). COVID-19 when symptomatic presents with pneumonia or upper respiratory infection (Tofighi et al., 2020).

During pulmonary interstitial disease, patients usually undergo multiple imaging studies by high-resolution computer tomography (HRCT) as it is the gold standard for lung imaging (Zhao et al., 2020).

The cumulative radiation dose for these patients is directly increased with the cumulative effect of these multiple exams that may be received during their hospitalization and recovery (Beregi & Greffier, 2019). Keeping this vital principle in mind, we must remember that any CT scan we perform should be accompanied by the justification of examination and optimization of radiation dose (Lichtenstein et al., 2004). The as low as reasonably achievable (ALARA) principle states that whenever radiation is expected, the exposure should be as low as reasonably achievable (Smith et al., 2020).

While CT imaging is a great help in establishing the diagnosis and follow-up of ICU patients with COVID-19, the potential for increased radiation exposure to many patients must be addressed (Buda et al., 2020). Balancing practical imaging to aid rapid diagnosis and follow-up while minimizing radiation exposure will be necessary for radiologists and clinicians, as we work together to manage the COVID-19 outbreak (Chiumello et al., 2020).

Using Lung Ultrasound for follow-up of critically ill ICU-admitted patients has been proposed to decrease radiation exposure in these patients (Zieleskiewicz et al., 2020).

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Lung ultrasound (LUS) is being increasingly used. The diagnostic accuracy of a full LUS is 97% for consolidation and 95% for alveolar-interstitial syndrome and may be comparable to that of computed tomography (Chiumello et al., 2020). Until now, numerous studies have already highlighted the clinical value of LUS in COVID-19 diagnosis (Zhao et al., 2020; Caroselli et al., 2021; Sun et al., 2021).

Moreover, in COVID-19 pneumonia, complete LUS may be of a comparable value to CT both as a diagnostic and prognostic tool for disease progression (Peng et al., 2020). Recent studies suggest that LUS may be a valuable tool for monitoring COVID-19 infection, assessing its severity, and identifying patients requiring mechanical ventilation or Extracorporeal Membrane Oxygenation (ECMO) therapy with a specificity of 90% (Tung-Chen, 2020).

Materials and Methods

Data collection

Data were collected via a retrospective study of the medical records of patients with confirmed COVID-19 by polymerase chain reaction (PCR) test admitted to ICU due to complications of covid-19 infection and underwent lung ultrasound and CT Chest from December 2021 to February 2022.

Inclusion criteria: Age ≥18 years, patients admitted to ICU and confirmed COVID-19, LUS, and CT chest both diagnostic and for patients follow-up.

Exclusion criteria: Pregnant females, incomplete image acquisition, missing clinical data, and cardiac failure causing cardiogenic pulmonary edema were excluded.

Methods

Chest CT

All examinations were performed using a 320-MDCT scanner (Aquilion ONE, Toshiba), in the supine position, with the patients instructed to hold their breath after a deep inspiration. Patients were classified into mild, moderate, and severe according to CT chest.

Lung ultrasound

A qualified ultrasound doctor performed US examinations, and the Patient was preferably examined sitting. When this position could not be maintained due to clinical deterioration or poor compliance, the examination was performed in the supine or semi-recumbent position. The posterior lung fields were scanned in the sitting position or, when not feasible, by successfully turning the patient onto a lateral decubitus position on both sides. Lung ultrasounds were performed using GE LOGIC 5 US machine with 1- to 5-MHz convex probes.

LUS protocol involves the examination of 12 lung regions, the upper and lower parts of the anterior, lateral, and posterior aspects of the left and right chest wall. Each region is scored according to four ultrasound aeration patterns. The investigators allocated points for a given region of interest according to the worst ultrasound pattern observed. The final LUS is the sum of points in all 12 regions and ranges from 0 to 36 (Bouhemad et al., 2011; Volpicelli et al., 2020). Patients were divided into three categories according to the severity of their lung score, mild (1-13), moderate (14 -23), and severe (24- 36) (Zieleskiewicz et al., 2020).

Statistical methods

Statistical analysis was performed using SPSS version 20 statistical software (SPSS, Inc. Chicago, IL). Data were expressed using mean and standard deviation for quantitative variables. For comparisons between the three groups, a one-way ANOVA test was applied. P-values less than 0.05 were considered statistically significant. Pearson's correlation was performed for correlation between different variables.

Results

A total of 156 patients with COVID-19 meeting the inclusion criteria were recruited, of whom 27 were excluded due to not doing diagnostic LUS at ICU admission time, and 7 patients were excluded due to suboptimal LUS images (Fig. 1). One hundred twenty-two patients with COVID-19 meeting the inclusion criteria were recruited, who had an LUS exam and CT chest at the time of admission to ICU and follow-up during the course of the disease. Demographic and outcomes of all patients were obtained from electronic medical records Table 1, Patients comorbidities (Figs. 2, 3). A descriptive analysis of the chest CT scan and LUS findings is reported in (Tables 2, 3). The authors compared lung score and CT chest severity with pleural effusion, pneumothorax, consolidation, and interstitial lung disease.

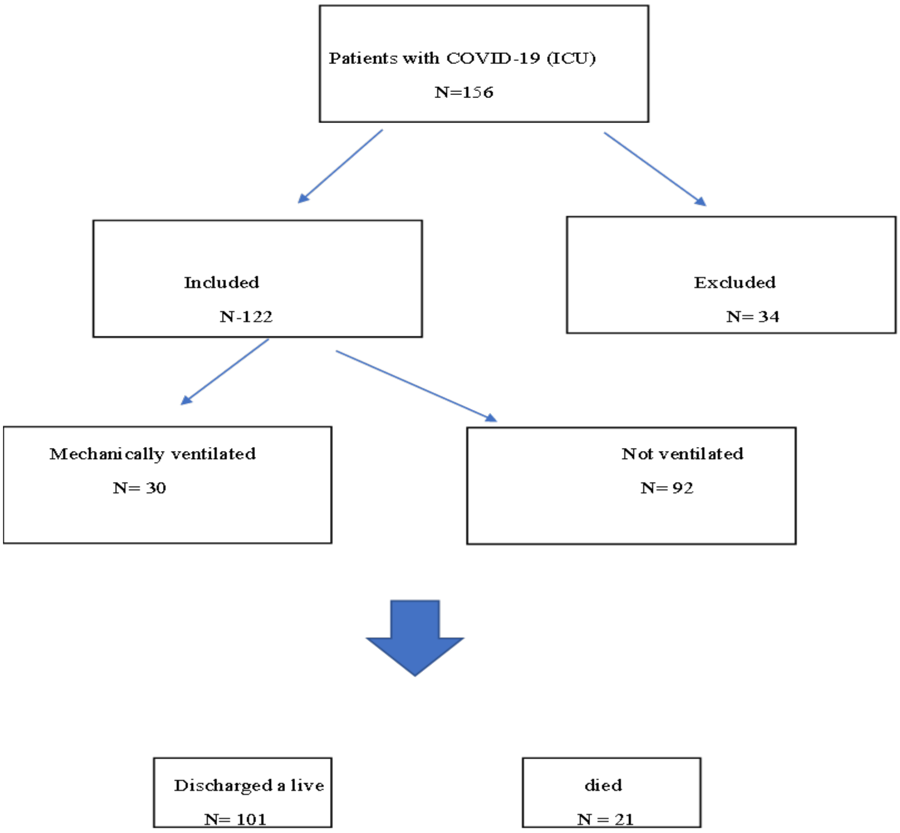

Fig. 1. Study flowchart

TABLE 1. The demographic and clinical data of the patients.

		No.= 122
Age	Mean±SD	51.28 ± 11.05
	Range	30 – 79
Gender	Male	66 (54.1%)
	Female	56 (45.9%)
Comorbidities		
Hypertension	Yes	45 (36.9%)
	No	77 (63.1%)
DM	Yes	37 (30.3%)
	No	85 (69.7%)
COPD	Yes	6 (4.9%)
	No	116 (95.1%)
Cancer	Yes	9 (7.4%)
	No	113 (92.6%)
Clinical outcome		
Discharged alive	Yes	101 (82.8%)
	No	21 (17.2%)
Intubated patients	Yes	30 (24.6%)
	No	92 (75.4%)

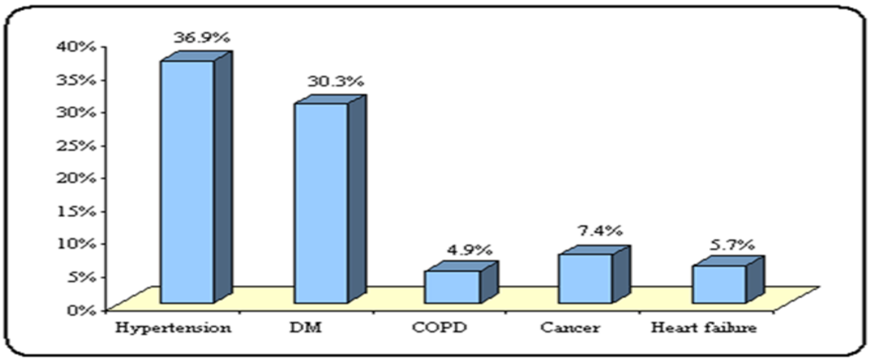

Fig. 2. Patients' comorbidities

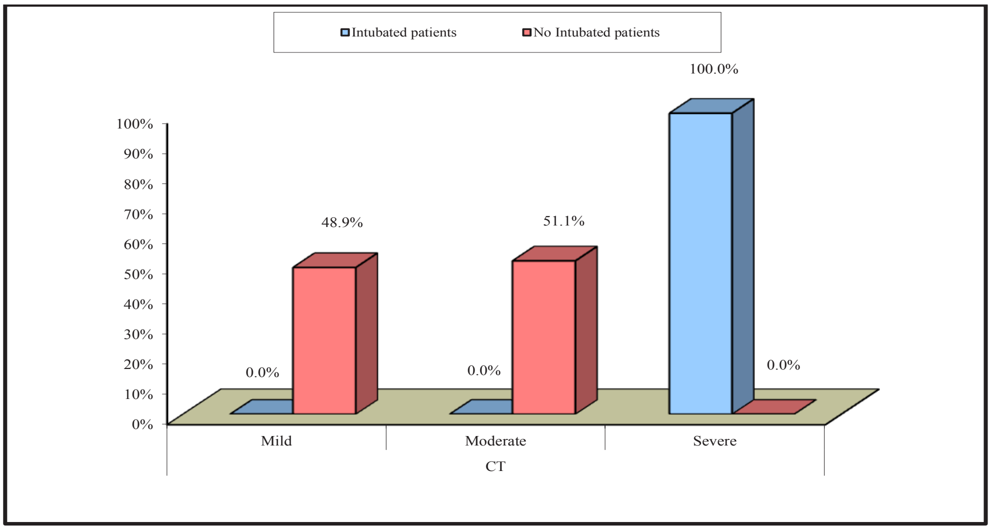

Fig. 3. Relationship between CT chest degree and percent of intubated patients

TABLE 2. CT and LUS findings in intubated patients

		Intubated patients		Test value	P-value	Sig.
		Yes No.= 30	No No.= 92			
Age	Mean±SD	50.90 ±9.71	51.40 ±11.50	-0.215•	0.830	NS
	Range	37 –79	30 –77			
Gender	Male	10 (33.3%)	56 (60.9%)	6.908*	0.009	HS
	Female	20 (66.7%)	36 (39.1%)			
Interstitial syndrome by CT	Bilateral by CT	30 (100.0%)	52 (56.5%)	19.406*	0.000	HS
	Unilateral by CT	0 (0.0%)	30 (32.6%)			
	Absent by CT	0 (0.0%)	10 (10.9%)			
CT	Mild	0 (0.0%)	45 (48.9%)	122.000*	0.000	HS
	Moderate	0 (0.0%)	47 (51.1%)			
	Severe	30 (100.0%)	0 (0.0%)			
Lung score	0 – 13	0 (0.0%)	40 (43.5%)	102.967*	0.000	HS
	14 – 23	0 (0.0%)	48 (52.2%)			
	24 – 36	30 (100.0%)	4 (4.3%)			
Interstitial syndrome by US	Bilateral	30 (100.0%)	47 (51.1%)	23.250*	0.000	HS
	Unilateral	0 (0.0%)	37 (40.2%)			
	Absent	0 (0.0%)	8 (8.7%)			

P-value > 0.05: Non significant; P-value < 0.05: Significant; P-value < 0.01: Highly significant*: Chi-square test; •: Independent t-test

TABLE 3. CT and LUS findings in intubated patients

		Intubated patients		Test value*	P- value	Sig.
		Yes No.= 30	No No.= 92			
Pleural effusion by CT	Bilateral	0 (0.0%)	6 (6.5%)	10.253	0.006	HS
	Unilateral	0 (0.0%)	19 (20.7%)			
	Absent	30 (100.0%)	67 (72.8%)			
Pleural effusion by US	Bilateral	0 (0.0%)	2 (2.2%)	8.272	0.016	S
	Unilateral	0 (0.0%)	19 (20.7%)			
	Absent	30 (100.0%)	71 (77.2%)			
Pneumothorax by CT	Bilateral	0 (0.0%)	0 (0.0%)	–	–	–
	Unilateral	0 (0.0%)	0 (0.0%)			
	Absent	30 (100.0%)	92 (100.0%)			
Pneumothorax by US	Bilateral	0 (0.0%)	0 (0.0%)	–	–	–
	Unilateral	0 (0.0%)	0 (0.0%)			
	Absent	30 (100.0%)	92 (100.0%)			
Consolidation by CT	Bilateral	12 (40.0%)	28 (30.4%)	3.896	0.143	NS
	Unilateral	7 (23.3%)	12 (13.0%)			
	Absent	11 (36.7%)	52 (56.5%)			
Consolidation by US	Bilateral	11 (36.7%)	18 (19.6%)	6.087	0.048	S
	Unilateral	7 (23.3%)	14 (15.2%)			
	Absent	12 (40.0%)	60 (65.2%)			

P-value > 0.05: Non significant; P-value < 0.05: Significant; P-value < 0.01: Highly significant
*: Chi-square test

Discussion

In our study, the LUS score showed a sensitivity of 100%, as sensitivity is the ability of a screening test to detect a true positive case, with a specificity of 72.13%, as specificity is the ability of a screening test to detect a true negative, correctly identifying people who do not have a condition. Consistent with these features, Sun et al. (2021) findings suggested that the global LUS score was highly predictive of death in COVID-19. Long et al. (2017) found a pooled sensitivity of 88% for LUS and pooled specificity of 86% while, Ye et al. (2015) found a pooled sensitivity of 95%, and a pooled specificity of 91%. Using CT is the gold standard, for the diagnosis of pneumonia. These findings supported the clinical use of LUS in patients with COVID-19 given its ease of use at the point of care, low cost, and lack of radiation exposure.

Several studies investigated the application of LUS in the diagnosis of pneumonia either with CT chest or with chest X-Ray, Xirouchaki and his colleagues compared the diagnostic performance of both LUS and chest X-Ray on 42 mechanically ventilated patients. LUS was significantly more sensitive and specific than bedside chest X-Ray in recognizing various lung pathologies (Xirouchaki et al., 2011).

Another study was conducted on 130 patients comparing LUS results to those of CT chest and plain chest X-Ray. The results confirmed the advantage of LUS over chest X-Ray as a diagnostic modality (Koenig et al., 2020).

On the contrary, a CT chest scan is associated with radiation exposure with accumulative radiation dose exposure from repeated scans along the course of the disease, and the risk of the transfer of unwell patient's risks adverse events (Aliaga et al., 2015; Jia et al., 2016). There is increased potential exposure to the virus by all healthcare providers, and there may be a lack of scanning capacity if many patients are present (Mayo et al., 2019).

It was found that LUS can visualize lung consolidation, hepatization, or interstitial alveolar syndromes with significance ($P<0.04$). This agrees with several studies, Amatya et al. (2018) and Alkhayat & Alam-Eldeen (2014), found that LUS demonstrated higher sensitivity for diagnosing pneumonia than chest X-rays.

Ye et al. (2015), found in their systematic review and meta-analysis, that the performance of LUS for the detection of adult community-acquired pneumonia was excellent, as compared to the “gold standard” (CT chest scan).

Alkhayat & Alam-Eldeen (2014), found that LUS imaging is highly accurate for the detection of pneumonia, but similar to most diagnostic tests is not perfect. Although pneumonia is the most common cause of lung consolidation, its appearance is non-specific.

Limitations to our study

The present study has several limitations. First, we included a convenience sample of patients with dyspnea and confirmed by PCR, representing only a tiny percentage of the many cases of pneumonia observed during the pandemic.

Second, all ultrasounds have been performed by a single experienced radiologist. Although ultrasound diagnosis was established based on objective signs, there needs to be a study documenting what level of proficiency is necessary for a reliable ultrasound diagnosis of pneumonia. Interobserver agreement among radiologists with different levels of experience and proficiency should thus be investigated further.

Conclusions

The current study showed that despite some limitations, LUS was a good predictor of pneumonia severity, mortality, and mechanical ventilation and can be used alone in the diagnosis and follow-up of ICU-admitted COVID-19 patients, to reduce exposure to unnecessary radiation.

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