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Role of Chest Ultrasound in Diagnosis and Assessment of Patients with Severe and Critically Ill COVID-19

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ABSTRACT

Background: Due to the extraordinary severity of the 2019 coronavirus pandemic medical establishments must establish effective and user-friendly ways in the direction of treating patients first and forecast outcomes.

Objective: Our rationale of this work was investigating chest ultrasound's function in the evaluation and diagnosis of patients with severe and critically ill COVID-19.

Patients and methods: This study was observational study performed at Damanhur chest hospital from April 2021 to March 2022. The study was carried-out on 200 COVID-19 infected patients with mean age of 60.55 ± 19.50 year. They were identified as having COVID-19 infection based on a positive Polymerase Chain Reaction test for SARS-CoV-2 and/or standard CT scan findings. Patients were admitted to the intensive care unit, it was only for really ill patients with severe and critically ill COVID-19 infection. At time of admission, we examined them by pleuro-pulmonary ultrasonography.

Results: The results showed elevated scores of lung ultrasonography that had been shown to be significantly related to hypoxemia and clinical severity. The extent of lung injury and hypoxemia during COVID-19 pneumonia were also significantly correlated. Confluent B-lines predominate over consolidation in COVID-19-ARDS, indicating that non-aerated tissue perfusion rather than a true right-to-left shunt is the primary cause of venous mixing. This finding is in accordance with research that claim this is the case.

Conclusion: The study's findings suggested that, in situations with limited resources, lung ultrasonography might be a vital instrument for the diagnosis and prognosis of lung damage in seriously sick COVID-19 pneumonia patients. In such circumstances, this straightforward, easily available, and trustworthy technology has considerable promise. For our findings to be confirmed, larger multicenter investigations are required.

Keywords: Chest ultrasound, Diagnosis, Assessment, Sever COVID-19.

INTRODUCTION

Globally, COVID-19 has become widespread after the first case was discovered in Wuhan, China, in December 2019**.** Later, more people have diagnosed positive for COVID-19, which is a result of the virus's high contagiousness [1]**.**

The government acted swiftly to stop the COVID-19 epidemic from spreading throughout the nation by raising public knowledge of the disease, encouraging social withdrawal, and promoting the widespread usage of masks. Complete nationwide lockdown was proclaimed for the majority of the nations in the world. This was vital to stop the COVID-19 outbreak and get hospitals ready for the influx of COVID-19 patients [2]**.**

Patients and their relatives were unhappy in hospital during the severe acute respiratory diseases' symptoms because of restrictive rules and stringent visitor limitations [3]**.**

Hospitals and other healthcare facilities have been forced to adjust to the "new normal" by delaying "non-emergent" procedures, doing extensive COVID-19 investigations, and moving from out-patient clinics to telemedicine. However, there has been worried among medical professionals for patients whose procedures were postponed or cancelled because of the ongoing COVID-19 epidemic [4]**.**

A new coronavirus species known as the coronavirus disease of 2019, which is caused by the coronavirus 2 associated with severe acute respiratory. syndrome (SARS-CoV-2), pandemic clinical signs range from vague symptoms such as fever, nausea, and dry cough to life-threatening pneumonia. Due to its link with a better and quicker recovery, the available research has suggested early treatment. This emphasises the significance of early screening methods in slowing the disease's course [5].

Real-time polymerase chain reaction (RT-PCR) has drawbacks, regrettably. when the material's viral load is little, it first gives false-negative findings and a low detection. Additionally, it cannot predict the course of an illness or represent disease occurrence. Third, there is a dearth of reagent stock, necessitating extensive research in addition to development for novel reagents. Fourthly, the process takes a long time. These drawbacks are the reason why researchers advise utilizing computed tomography (CT) as the main technique for diagnosing COVID-19.

Additionally, individuals that have positive CT results but negative PCR results who are clinically believed to have COVID-19 should be separated and handled as positive cases as soon as feasible [6]**.** However, the radiological department's capacity could be exceeded by the volume of cases. Additionally, patients might not be able to be transported because of their condition or because there might not be enough staff or personal protective equipment (PPE). Additionally, equipment cleaning might delay the

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publication of test findings. Finally, standard radiology might not be available in areas with limited resources. Since LUS doesn't emit ionising radiation, easy to sterilize, and is considerably less expensive, simplicity of equipment sterilisation, and much cheaper cost, it is considered a fantastic alternative during epidemics. Portable ultrasound devices with a cheap price tag have also lately been created. These tools might greatly lower the expenses associated with implementing lung ultrasound (LUS) [(7)].

Now we can perform LUS instantly by a single operator at the patient's bedside, there is no longer a chance for cross-contamination, lowering the risk of very acute SARS-CoV-2 infection among healthcare workers, and reducing PPE shortages in various healthcare settings [(8)].

Additionally, as LUS is a trustworthy tool for monitoring COVID-19 development in pregnant women and other individuals who are more sensitive to radiation harm, the lack of radiation in LUS is significant [(9)].

Given that CT is not commonly available in many poor nations, a very cheap first diagnostic and screening approach is required for validating suspected COVID-19 cases. Ultrasonography could be a viable option considering its mobility, reliability, and practicality. However, it is advised to employ ultrasonography as a combined diagnostic tool. Additionally, LUS with monitoring of oxygen saturation can be a successful tool for deciding the priority at which COVID-19 patients are treated inside healthcare facilities that have little resources [(10)].

This work aimed to investigate chest ultrasound's function in the evaluation and diagnosis of patients with severe and serious COVID-19.

PATIENTS AND METHODS

This study was observational study that was conducted at Damanhur Chest Hospital from April 2021 to March 2022. The study was carried-out on 200 COVID-19 infected patients whose ages ranged from 25 – 80 years, they were identified as having severe and critically ill COVID-19 infection based on a positive Polymerase Chain Reaction test for SARS-CoV-2 and/or standard CT scan findings. Patients were admitted to the intensive care unit, it was only for really ill patients with severe and critically ill COVID-19 infection. At time of admission, we examined them by pleuro-pulmonary ultrasonography.

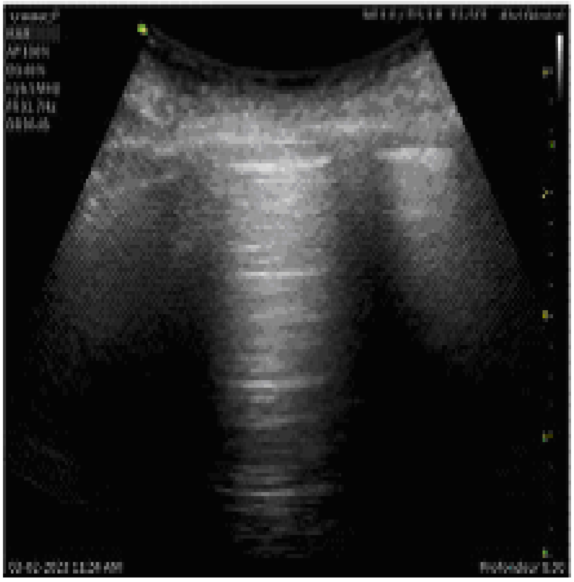
Exclusion criteria: Patients with chronic respiratory problems.

Chest ultrasonography: It was carried out using an ultrasonic machine (Sonoccape 2) with high-frequency linear and low-frequency convex probes. Twelve sections of the lung underwent routine lung ultrasonography examination while the patient was semi-recumbent. To obtain the greatest frequency, we avoided saturation phenomena (by lowering the gain and the mechanical index), employed the convex probe in accordance with the patient's body type in a unifocal mode, and concentrated on the pleural line [(5)].

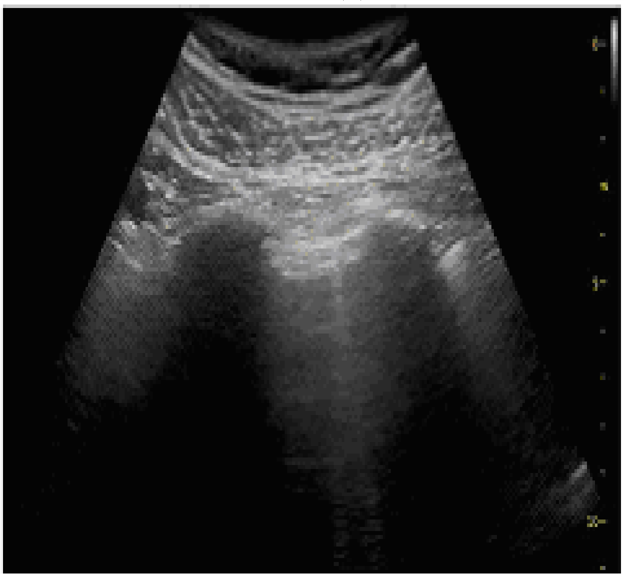
The person in charge would try to find a partial view of the chest's posterior side if the patient were unable to sit up since that region is thought to be a hot zone for COVID-19 infection. If this wasn't an option, lung ultrasound imaging would begin above the diaphragm in the paravertebral lower quadrant area.

The elementary score of each quadrant, which varies from 0 to 3, was used to calculate the lung ultrasonography score, as previously described [(11)]**:** 0 if the pleural line was unbroken and regular with the horizontal artefacts (A lines); 1 if the pleural line had an uneven sawtooth appearance with upright lines (comet tails) evident below the pleural line; 2 if the pleural line was intermittent with small areas of consolidation evident beneath the points of interruption of the pleural line and 3 when there are considerable amounts of "white lung" with or without significant amounts of pulmonary consolidation (Figure 1 showing examples of elementary scores). The sum of the results from the 12 quadrants produced a global lung ultrasonography score that varied from 0 to 36. We also noted the existence of the A line, an uneven pleural line or B line, white lung, and regions of pulmonary consolidation on lung ultrasonography.

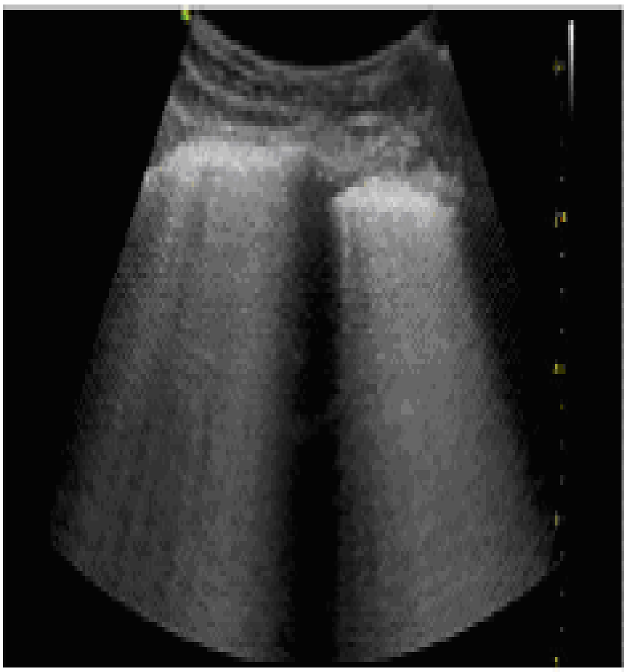
Score (0)



Score (1)



Score (2)



Score (3)

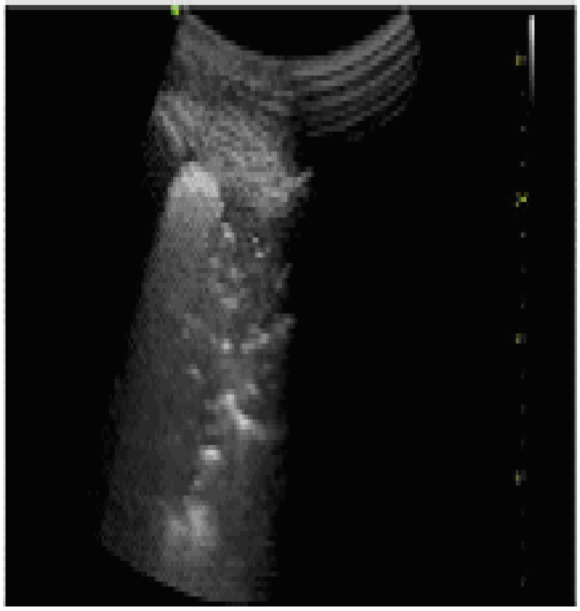


Figure (1): Examples illustrating elementary score [11].

Data gathering:

Age, sex, comorbidities (heart failure, COPD, diabetes, hypertension), room air transcutaneous oxygen saturation (SpO_2), acute respiratory distress syndrome (ARDS, according to Berlin criteria), organ failures, LUS score and features, ventilatory support, and outcome (hospital passing away and duration of stay) were all collected.

Evaluation of lung ultrasound consistency:

To evaluate reproducibility, from the study, 15 recordings (from 15 different participants) were picked. The identical sets of recordings were reviewed separately by two different ultrasonographers in order to evaluate inter-analyzer repeatability.

Ethical approval: Damanhur Chest Hospital Ethics Committee gave its approval to this study. All participants gave written consents after receiving all information. The Helsinki Declaration was followed throughout the study's conduct.

Statistical analysis

The SPSS Version 24 computer program was used to analyze the data. Death was a dependent variable, and it was presented as a binary choice (yes or no). Patients' clinical and biological traits, ultrasound parameters, in addition to management were considered explanatory factors. All variables underwent a descriptive analysis with the median and interquartile range for numerical data and relative frequencies in favor of categorical variables. Mann Whitney, Chi-square, and Fisher's exact tests were applied as necessary for the bi-variate analysis.

In order to compare the various intermediate models, a binomial logistic regression was carried out using the step-down method. Resulting model had been retained based on the lowest Akaike criterion (AIC). Using the Hosmer and Lemeshow test, the final models' and the intermediate models' appropriateness was verified [12]. The intra-class correlation coefficient reflects the repeatability of lung ultrasonography basic patterns [13], determined using a 95% confidence interval and consistency. The coefficient of repeatability reflects the lung ultrasonography score's reproducibility [14], according to Bland and Altman's ideas. The British Standards Institution repeatability coefficient, which is twice the standard deviation of the variations between repeated measurements, was used to compute the coefficient of repeatability [14].

RESULTS

200 patients who met our criteria were enrolled in the trial during the research period. Overall mean age was 60.55 ± 19.50 years and the sex ratio of men to women was 1.85:1 (130/70) (Table 1).

Table (1): Patient demographic information

Demographic characters	Level	
Age		
Range	25- 80	
Mean ± S.D	60.55 ± 19.50	
Sex		
Male	130 (65 %)	Chi^2= 4.25**
Female	70 (35 %)	

** = Significant at ($P < 0.05$)

Comorbidities were present in 65.00 % (130/200) of the patients. At admission time, almost all patients had respiratory failure (190/200), while we observed hemodynamic failure in (80/200) and renal failure (70/200) as shown in table (2).

Table (2): Clinical history and clinical symptoms

Clinical history and symptoms	
Comorbidities	
No	70 (35 %)
Yes	130 (65 %)
hemodynamic failure	
NO	120 (60 %)
Yes	80 (40 %)
hemodynamic failure	
NO	130 (65 %)
Yes	70 (35 %)

Chi2 = 9.75** ** = Significant at ($P < 0.05$)

Lung ultrasound findings:

All individuals who were evaluated had bilateral lung lesions. Overall, the most frequent findings were confluent B lines (190/200), followed by few B lines (150/200). The average ultrasonography result overall was 24 ± 6.40. The ultrasonic score and pulsed oxygen saturation had a very strong negative connection (Pearson correlation coefficient of − 0.40, $p < 0.001$). When compared to other patients, those who experienced substantial desaturation (defined as a pulsed oxygen saturation < 85% upon ICU admission) had a poorer lung ultrasound score (22.8 ± 6.5 vs 26.0 ± 5.5, $p < 0.001$) (Tables 3 & 4).

Table (3): Lung ultrasonography results in various lung quadrants

	Right lung				Left lung			
Parameters	Consolidation	Confluent B-line	B-line	A-line	Consolidation	Confluent B-line	B-line	A-line
Lower posterior	80	80	140	160	80	158	160	-
Upper posterior	20	115	155	160	10	110	150	160
Lower lateral	10	70	150	160	10	120	155	160
Upper lateral	45	125	158	-	20	120	153	160
Lower anterior	30	150	156	-	30	150	156	-
Upper anterior	-	90	158	160	39	110	160	-

Table (4): Results of lung ultrasonography in individuals with and without severe desaturation

	Right lung		Left lung	
Parameters	No-severe destruction	Severe destruction	No-severe destruction	Severe destruction
A-line	25	12.5	25	-
B-Line	150	80	105	55
Confoluent B-line	180	280	220	320
Consolidation	50	130	52	110

Reproducibility of lung ultrasound:

The lung ultrasonography primary pattern intra-class correlation coefficient was **0.80 (95% CI 0.77, 0.85).** For a total score of 25, the coefficient of repeatability of the lung ultrasonography score was 2.17. Most patients were treated with dexamethasone-based corticosteroids **(188/200, 90%),** with antibiotic therapy **(180/200, 90%)** a problem frequently caused by nosocomial bacterial infections **(90/200, 45%).**

Several individuals needed breathing assistance **(180/200, 90%)** either non-invasive (120/200, 62%) or invasive (80/200, 40%). For the management of severe ARDS, 66/200 (33.0%) following tracheal intubation, were laid down prone. The majority (180, 90%) of patients got therapeutic anticoagulation, whereas only 10% (20/200) received prophylactic heparin treatment . (Table 5).

Table (5): Correlation between ultrasound and COVID-19 severity and supportive drugs against COVID-19

Item	Characters
Correlation between ultrasound and COVID-19 severity	R=0.80 CI (0.77 – 0.85)
The lung ultrasound's repeatability coefficient was	2.17
- Patients underwent corticosteroid treatment based on dexamethasone. -Antibiotic therapy. -Nasocomial bacterial infections. -**<u>Patients needed respiratory support</u>** -Either noninvasive -or invasive In order to treat severe ARDS, -Only patients received prophylactic heparin therapy, -Patients received therapeutic anticoagulation.	188/200 = 90 % 90/200 = 45 % 180/200 = 90 % 120/200 = 62 % (80/200, 40%). 66/200 = 33.0 % 10% (20/200) 180/200 = 90 %

E-Outcome:

Nearly half of the patients died (90/200, 45.0%). Patients that died were often older, frailer, or hypertensive. Compared to the survivors, dead patients experienced higher organ failure throughout the ICU stay. In comparison with those who survived, the mean ultrasonography score was much greater in dead individuals. Compared to survivors, non-survivors had higher confluent B lines and consolidations. The multivariable analysis revealed that the patients' age, lung ultrasound score, the therapeutic anticoagulation, and number of organ failures were the variables related with death.

Table (6): Characters of dead and survived patients.

Item	Characters
Died patients	90/200= 45 %
Age of died patients	65.55±5.15
Condition of dead patients	Frail, or hypertensive
Organ failures	More common
Therapeutic anticoagulation,	More common
Lung ultrasound score	Higher than survivors
Survivors characterized by	Pregnancy, asthma, and sickle cell disease were more common in survivors.

DISCUSSION

Due to the extraordinary severity of the 2019 coronavirus pandemic medical establishments must establish effective and user-friendly ways in the direction of treating patients first and forecast outcomes [15].

In the present research, we investigated how the lung ultrasonography score can be used in COVID 19 seriously sick patients in an LMIC context. LUS had been a completely practical investigative technique, and the multivariable analysis showed that a greater lung ultrasound score was related to oxygenation dysfunction and linked to death. COVID-19 patients' mortality was greater than the mortality rate in industrialised nations in recent research that was undertaken in 11 countries in Africa. Insufficient staffing in intensive care units, the prevalence of comorbidities, and how many organ failures there were when people were admitted to the ICU were all linked to this greater mortality, according to their multivariable analysis [16].

The most serious SARS-CoV-2 infection symptom was pneumonia [9, 17]. Because the COVID-19's peripheral distribution of pulmonary infiltrates, ultrasonography is a trustworthy imaging method that can minimise the need for additional CT scans in the future, radiation exposure danger and illness transmission that go along with it [18, 19]. Additionally, it is challenging and complicated to move critically sick patients, whereas ultrasonography may be conveniently administered at the patient's bedside. An effective diagnostic method for detecting severe forms and their progression is lung ultrasonography [20]. Lung ultrasonography was irregularly employed in few of centers during this COVID-19 pandemic to evaluate illness severity and inform treatment choices [5].

According to our results, clinical severity and hypoxemia were significantly correlated with higher lung ultrasound scores. Some writers claim that "silent hypoxemia" occurs during COVID-19 pneumonia. However, the exact cause of this condition is yet unknown [21], or arguing that the size of non-aerated tissue is not the main cause of hypoxemia [22]. Transpulmonary bubble transit or intracardiac (patent foramen ovale) shunts, however, are not the primary causes of hypoxemia in COVID-19 pneumonia [23].

Our findings pointed to a significant correlation between COVID-19 pneumonia's hypoxemia and lung damage severity. The predominance of confluent B-lines over consolidation is consistent with scientists who suggest that ventilation-perfusion mismatch, rather than true right-to-left shunt, is the main contributor to the venous admixture in COVID-19-ARDS) [22]. Our findings are consistent with other research showing a link between rising lung ultrasound score and in-hospital mortality. COVID-19 lung lesions result in an intrapulmonary shunt linked to pulmonary perfusion dysregulation [14, 24].

Our findings demonstrated that lung ultrasonography is a straightforward technique for determining severity and foretelling consequences. The lung ultrasound's excellent sensitivity and specificity, making it a crucial instrument for the identification of severe forms. The lung ultrasound elementary pattern's intra-class correlation coefficient value was close to 0.75, suggesting that the two raters had a high degree of agreement [25, 26, 27].

The intra-class correlation coefficient measures how much of the total variance is attributable to subject variation [28]. With a repeatability coefficient of nearly 2, for a total score of 24, we also discovered high reliability in the evaluation of lung ultrasonography score. The lowest significant difference between repeated measurements is known as the repeatability coefficient [29].

According to our study, an absolute shift of 2 or more in the lung ultrasonography score may be necessary for an appropriate interpretation. The great repeatability of lung ultrasonography in this investigation is consistent with studies in settings with high incomes. The relationship between mortality and advanced age and organ failures is persistent [30].

We also found that therapeutic anticoagulation may raise the risk of bleeding in unselected people, but it did not affect the survival of patients with severe COVID-19 admitted to the ICU, which is consistent with another research [31]. This prospective study's emphasis on very sick patients in Sub-Saharan Africa with limited resources is one of its strong points. Some teams employ a single holistic microconvex probe for all bedside ultrasonography (neither abdominal nor cardiac), which may increase the affordability of ultrasound in limited spaces [29]. The primary drawbacks of this study are its unicentric nature and the absence of patient physiologic data.

CONCLUSION

The findings of this study suggested that, in settings with limited resources, lung ultrasound could be an important tool for the diagnosis and prognosis of lung damage in critically unwell COVID-19 pneumonia patients. This simple, accessible, and trustworthy technology has special potential in such situations. For our findings to be confirmed, larger multicenter studies are required.

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