BNS University
Critical Care Departement

The Egyptian Journal Of Intensive Care And Emergency Medicine (JICEM)

Correlation between Lung Ultrasound and Chest CT in COVID-19 Pneumonia Patients on Hospital admission

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Abstract:

Purpose: This study aimed to assess capability of lung ultrasound to distinguish different pulmonary patterns of COVID-19 and compare it to chest CT. **Materials and Methods:** This is a prospective randomized controlled study carried upon sixty-five patients from beginning of November 2021 to the end of October 2022 admitted to Isolation Hospital for COVID -19 patients and in isolation ward in Tanta Emergency Department. **Results:** Lung Ultrasound can significantly predict mild to moderate COVID-19 pneumonia (P=0.003 and AUC=0.704) with 98.04% sensitivity, 42.86 %specificity, 86.2% PPV and 85.7% NPV and severe COVID-19 pneumonia (P=<0.001 and AUC=0.885) with 92.00% sensitivity, 85.00% specificity, 79.3% PPV and 94.4% NPV. By dividing the patients into two groups according to Computed Tomography Severity Score and Lung Ultrasound Scoring System, there was a substantial agreement between CTSS and LUSS (P value<0.001, Kappa = 0.632). **Conclusions:** Lung ultrasound can substitute CT chest in predicting, screening and diagnosis of COVID-19 pneumonia.

Keywords: Corona virus disease-19; COVID-19; Lung ultrasound; Chest Computed Tomography; Emergency

1. Introduction:

Corona virus disease-19 (COVID-19) is characterized by severe pneumonia and/or acute respiratory distress syndrome in about fifth of infected patients [1]. The increasing number of confirmed COVID-19 cases is noticeable, so we need new diagnostic tools to guide clinical convention [2].

Computed tomography (CT) is the conventional technique imaging for monitoring and diagnosis of COVID-19 pneumonia. Chest CT has high sensitivity for diagnosis of COVID-19 but is not accessible universally. Unstable or infected patient to be moved to the radiology unit with potential exposure of several people is risky, needs proper sterilization of the CT room after use and is not usually used in children and pregnant women due to over radiation exposure [3].

Lung ultrasound (LUS) is a non-invasive bedside technique used in emergency to diagnose interstitial lung syndrome through evaluation and quantitation of the number of B-lines, pleural irregularities and nodules or consolidations [4].

In patients with COVID-19 pneumonia, LUS shows a typical pattern of diffuse interstitial lung syndrome, characterized by multiple or convergent bilateral B-lines with spared areas, thickening of the pleural line with pleural line irregularity and peripheral consolidations [5]. So, LUS can assess the severity of COVID-19 infection [6].

LUS has several advantages over CT, like reduction of exposure to radiation, repeating follow up examination bedside, low cost, and easy to applicate in low-resource settings [7]. Therefore, LUS may decrease utilization of traditional diagnostic imaging resources (CT scan and chest X-ray) [8].

Lung ultrasound helps in diagnosis, follow-up, treatment decisions and monitoring of COVID-19 pneumonia, particularly in the critical care cases and in pregnant women, children in areas with high rates of community transmission [9].

The current work aimed to assess the capability of LUS to distinguish the different pulmonary patterns of COVID-19 and quantify the disease burden compared to chest CT.

2. Material and methods:

This prospective randomized controlled study was carried out upon sixty-five patients over a duration of one year from beginning of November 2021 to the end of October 2022 (the end of COVID -19 outbreak). They were selected from those admitted to Isolation Hospital for COVID -19 patients and Emergency Department (ED) (in isolation ward) in Tanta University Hospitals for suspect COVID-19 pneumonia. All patients provided written, informed consent and approval of the institutional research ethics committee was obtained (Approval code:35081/11/21).

Eligibility criteria included all patients aged ≥ 18 years old and infected with COVID-19 [by clinical diagnosis, laboratory investigations, CT chest and/or confirmed by reverse transcription-polymerase chain reaction (RT-PCR)], whereas those with critical conditions, pulmonary embolism, previous heart or chest surgery, need for intensive care support at the time of admission or severe cardiorespiratory illness other than COVID-19 were excluded. Patients with history of pulmonary diseases (chronic obstructive pulmonary disease or Restrictive pulmonary disease) and pregnant women were also excluded from the study.

Clinical and radiological assessment:

Full history taking was obtained from all patients which include age, sex, comorbidities like; hypertension (HTN), diabetes mellitus, history of autoimmune disease or immunosuppressive therapy (e.g. steroids). Symptoms like; dyspnea, cough, fever, anosmia, ageusia or gastrointestinal symptoms (diarrhea, abdominal pain, vomiting) were recorded.

This was followed by complete clinical examination (heart rate, respiratory rate**,** SpO_2, temperature, blood pressure, etc), Laboratory investigations **(**complete blood count, C-reactive protein, serum ferritin, lactate dehydrogenase enzyme, D-dimer**)**.

After that, PCR samples were collected using nasal swabs. When a laboratory scientist received the sample, he isolated (extracts) genetic material from the rest of the material in the sample.

Every patient was examined by chest CT and LUS to assess the capability of LUS to distinguish the different pulmonary patterns of COVID-19 and quantify the disease burden compared to chest CT.

CT chest:

CT chest was done to all patients included in the study immediately before admission as part of the ED evaluation route of suspect COVID-19 cases.

CTs were done in supine position at end inspiration without contrast. A chest radiologist reviewed the CT scans and defined the presence and extent of ground glass opacities (GGO) and consolidation and scored according to CT severity score (CT-SS). In this score, each lobe could be awarded a CT score from **0** to **5**, depending on the percentage of the involved lobe:

Score 0: 0% involvement, **score 1**: < 5% involvement, **score 2**: 5–25% involvement, **score 3**: 26–49% involvement; **score 4**: 50–

75% involvement, and **score 5**: ＞75% involvements. The total CT score was the sum of the points from each lobe and ranges from 0 to 25 points. In a qualitative evaluation, total CT severity scores of 1-5, 6-14, and 15-25 were categorized as mild, moderate, and severe involvement, respectively [10]**.**

CT images were classified according to the COVID-19 Reporting and Data System (CO-RADS) score (Figure 1), which is based on the level of suspicion of pulmonary involvement in severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection [11].

CO-RADS* Level of suspicion COVID-19 infection		
		CT findings
CO-RADS 1	No	normal or non-infectious abnormalities
CO-RADS 2	Low	abnormalities consistent with infections other than COVID-19
CO-RADS 3	Indeterminate	unclear whether COVID-19 is present
CO-RADS 4	High	abnormalities suspicious for COVID-19
CO-RADS 5	Very high	typical COVID-19

Figure 1: COVID-19 Reporting and Data System (CO-RADS) score

Lung US:

Bedside LUS was performed within 24 hours from ward admission and CT scanning. A portable ultrasound system [wireless hand-held ultrasound SN: KXALA033] (Fig 2A) and (PHILIPS Affinity 50 G) device with convex and linear probes was used **(Figure 2B)**. Examinations were performed with the patient in the sitting position, scanning the front and the back side of each hemi thorax systemically. Each hemithorax was divided into anterior, lateral and posterior sectors, and each sector was then split into upper and lower halves using the third intercostal space as reference to obtain 6 areas for each hemithorax **(Figure 3)** [12]. The presence, site, and distribution of abnormalities, such as B lines, pleural line thickening, consolidations, and air bronchograms, were evaluated. Abnormal findings in each scan were graded according to LU scoring system [LUSS score] **(Figure 4)** [13].

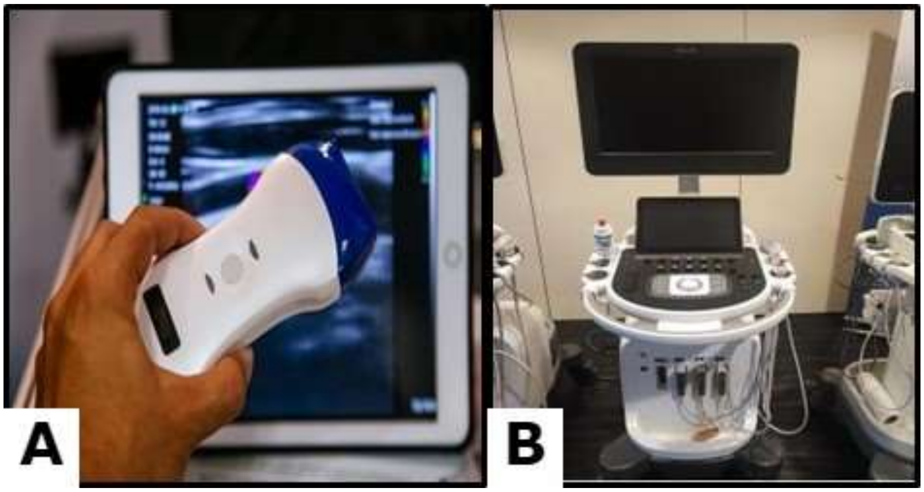

Figure 2: Ultrasound device A) Wireless Handheld Ultrasound; B) PHILIPS Ultrasound Device)

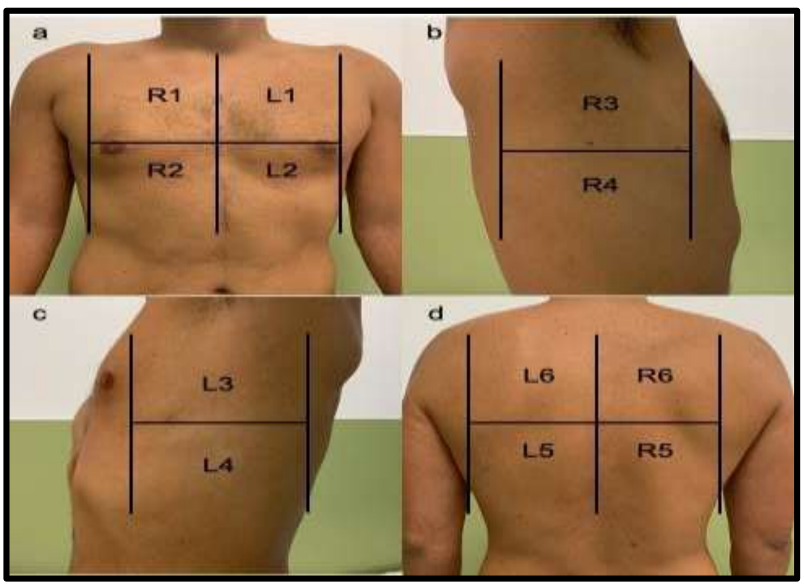

Figure 3: Areas of lung ultrasound examination. a) The anterior region of the chest with its upper anterior and lower anterior quadrant of the right (R1-R2) and left (L1-L2) hemi-thorax. b), c) The axillary thorax with its upper lateral and lower lateral quadrants of the right (R3-R4) and left (L3-L4) hemi-thorax. d) The lower and upper quadrants of the posterior thorax of the right (R5-R6) and left (L5-L6) hemi-thorax

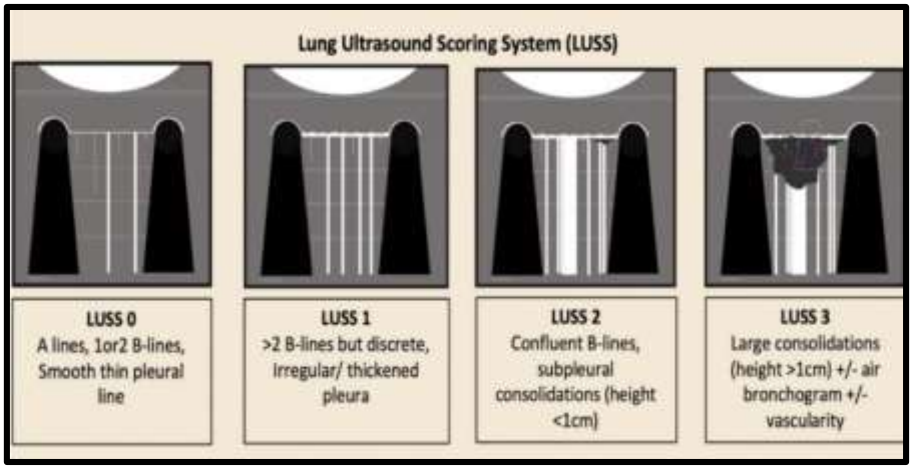

Figure 4: Lung ultrasound scoring system (LUSS) points range from 0 to 3, with higher points allocated to severe lung changes. Based on the total score from 12 lung zones, the severity classified as mild (score 1-5), moderate (>5-15) and severe (>15). A normal lung will have a total score of 0

Statistical analysis:

Data were analyzed using SPSS (Statistical Package for the Social Sciences, version 23.0). Categorical data were expressed using numbers and percentage whereas Numerical data were expressed using mean, standard deviation after testing normality using Kolmogrov-Smirnov test.

Pearson's correlation coefficient was performed to investigate the correlation between CTSS, LUSS and the different studied variables. Cohen's kappa coefficient was used to study the concordance between CTSS and LUSS [14]. To analyze the predictive power of CTSS and LUSS, the receiver operating characteristics (ROC) curve was performed and area under the curve (AUC) value was determined. P values of < 0.05 were considered statistically significant.

3. Results:

This study was carried out upon sixty-five patients over one year from the beginning of November 2021 to the end of October 2022 (the end of Covid-19 outbreak). In this study, 83 patients were assessed for eligibility, 11 patients did not meet the criteria and 7 patients refused to participate in the study (Fig 5). The remaining patients were included in our study and analyzed statistically.

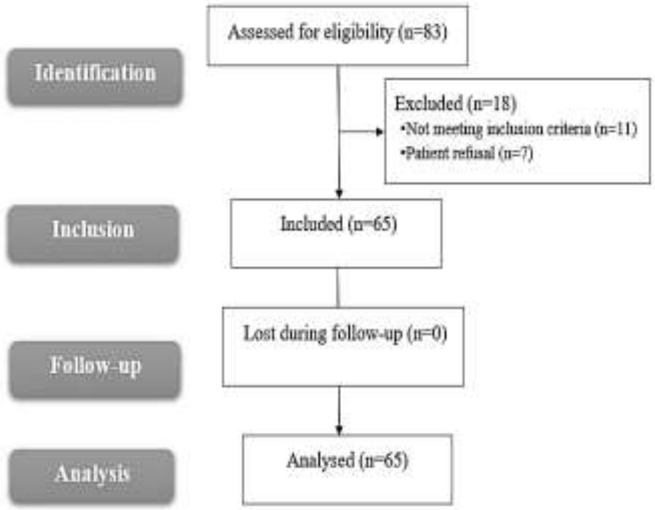

Figure 5: Flow chart of the enrolled patients

Patients' characteristics

Table 1 demonstrates patients' characteristics. The mean age of the studied cases was 46.4±13.29 years. There were 45(69.23%) male and 20(30.77%) females. Diabetes Mellitus was present in 25(38.46%) patients. Hypertension was present in 16 (24.62%) patients. Regarding symptoms, dyspnea was present in 47(72.31%) patients, cough was present in 49(75.38 %) patients, fever was present in 46(70.77%) patients, anosmia was present in 29 (44.62%) patients and GIT symptoms were present in 29(44.62%) patients. The onset of symptoms ranged from 3 to 7 days with a mean value (± SD) of 4.2 (±0.97) days. Vital signs and laboratory investigations of the studied patients are illustrated in table 2.

Radiological imaging of the studied patients:

CT chest showed pleural thickening in 22(33.85%) patients, GGO in 60(92.31%) patients (Figure 6), Septal thickening in 33(50.77%) patients, crazy paving in 30(46.15%) patients, subpleural consolidation in 25(38.46%) patients and effusion in 8(12.31%) patients. Regarding CO-RAD score, 11(16.92%) patients was CO-RADS 3, 27 (41.45%) patients was CO-RAD 4 and 27 (41.45%) patients was CO-RAD 5. Total CT severity score was mild in 14 (21.54%) patients, moderate in 26 (40%) patients and severe in 25 (38.46%) patients as demonstrated in table 3.

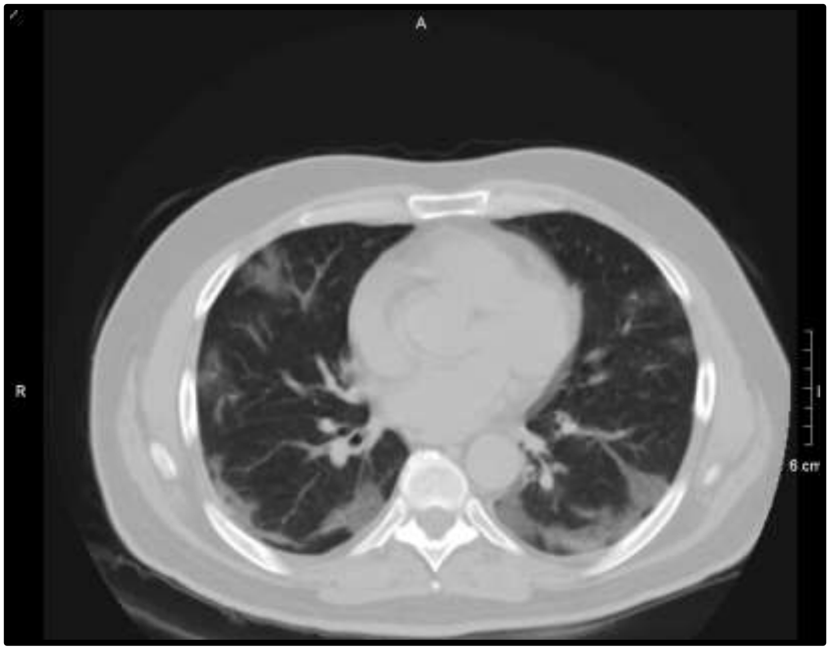

Figure 6: CT chest of a case showing areas of ground glass opacities distributed peripherally in both lung fields

Lung US Findings of 12 Lung zones of the studied patients are shown in table 4 indicating that the presence of isolated or confluent B- lines is the most common finding with higher percentage in lower posterior lung zones 19 (29.23%) [Figure 7]. Total LUS score was mild in 7 (10.76%) patients, moderate in 29 (44.61%) patients and severe in 29 (44.61%) patients.

Figure 7: Lung ultrasound (LUS) of a case showing pleural thickening (black arrow) & confluent B lines (white arrow) in left lower lobe

Correlations between LUSS & CTSS with Age, vital signs & laboratory investigations of the studied patients were illustrated in table 5. There was a negative correlation between CTSS and both P/F ratio and lymphocytes (P value<0.001 for both). Similarly, there was a negative correlation between LUSS and both P/F ratio and lymphocytes. (P value 0.009 and 0.027 respectively). There were no significant correlations between CTSS and age, respiratory rate, O_2 saturation, TLC, D dimer, LDH, CRP, Ferritin and PCR.

Concordance between CTSS score and LUS score of the studied patients: There was a substantial agreement between CTSS and LUSS (P value<0.001, Kappa = 0.632) as shown in table 6 and figure 8.

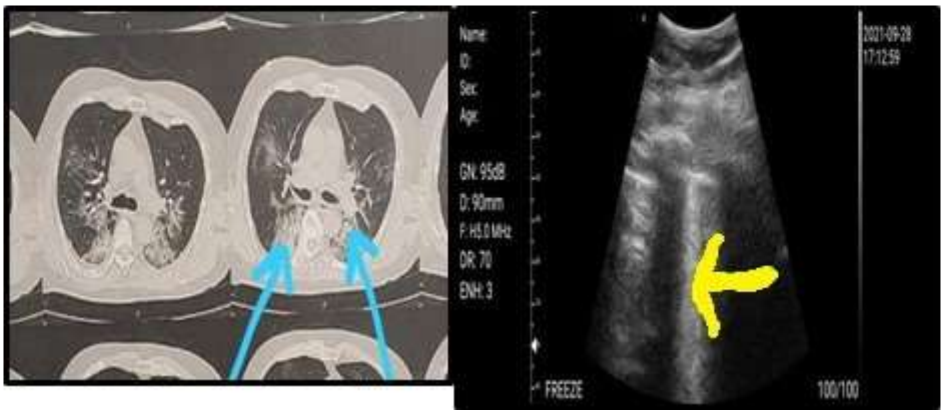

Figure 8: A case in this study: Computed tomography (CT) chest (left side) showing bilateral basal ground glass opacities (blue arrows) and lung ultrasound (right side) showing confluent B lines in right lower lobe (yellow arrow)

Role of LUS in prediction of COVID-19 pneumonia

LUS can significantly predict mild to moderate COVID-19 pneumonia (P=0.003 and AUC=0.704) with 98.04% sensitivity, 42.86 %specificity, 86.2% PPV and 85.7% NPV (Fig 9). LUS can significantly predict severe COVID-19 pneumonia (P=<0.001 and AUC=0.885) with 92.00% sensitivity, 85.00% specificity, 79.3% PPV and 94.4% NPV (Figure 10).

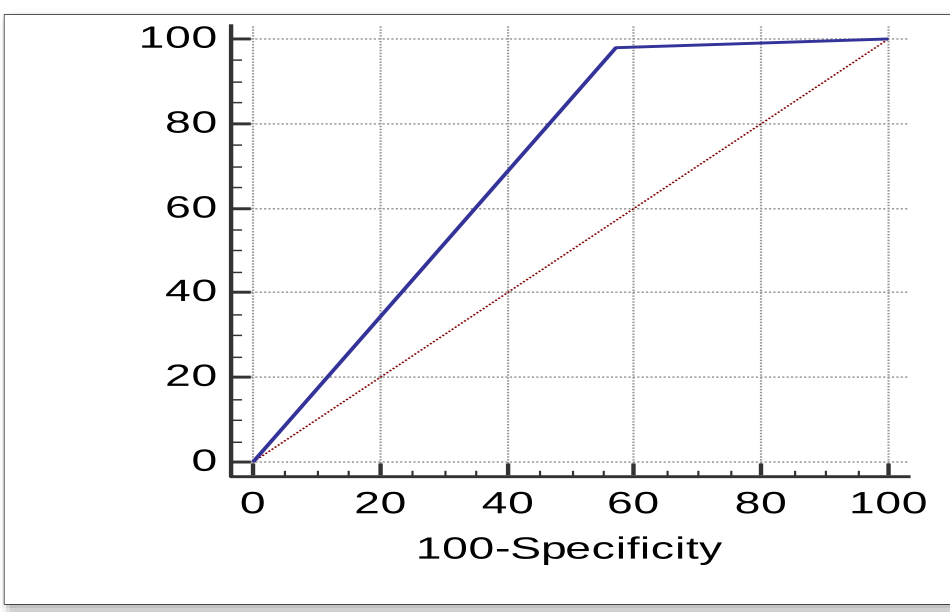

Figure 9: Receiving-operator characteristic (ROC) curve of lung ultrasound in prediction of mild to moderate COVID-19 pneumonia

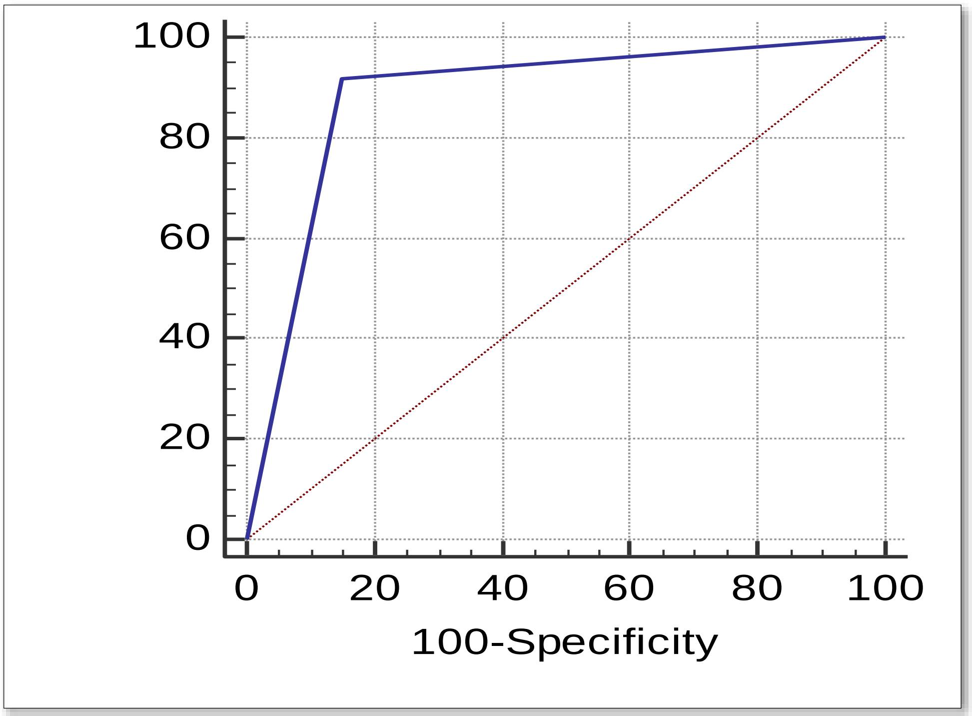

Figure 10: Receiving-operator characteristic (ROC) curve of lung ultrasound in prediction of severe COVID-19 pneumonia

4. Discussion:

The recent outbreak of SARS-CoV-2 infection has resulted in numerous patients with suspected disease waiting for a COVID-19 diagnosis. Chest imaging plays a pivotal role in the diagnostic workflow of patients with suspected virus pneumonia, notably for those with very early disease, when viral replication might not be detected by RT-PCR.

To our knowledge, few studies have investigated the concordance between CT chest and LUS in COVID-19 pneumonia. This study aimed to assess the capability of LUS to distinguish the different pulmonary patterns of COVID-19 and quantify the disease burden compared to chest CT.

In our study, 65 patients were included. The age of the studied patients ranged from 22 to 71 years with a mean value of 46.4±13.29 years. There were 45 (69.23%) males and 20 (30.77%) females. This agreed with Tung-Chen et al. [15]. They enrolled 51 patients in their study with the mean age was 61.4±17.7 years, with slight male predominance; male patients were 28 (54.9%). Another study by Casella et al. [16] agreed with our study. They enrolled 190 patients in their study with the mean age was 62 years (ranged from 49-73) with a prevalence of male sex (59%).

In our study, DM was present in 25(38.46%) patients. HTN was present in 16 (24.62%) patients. While in Tung-Chen et al. [15] DM was present in 10 patients (19.6%) whereas, HTN was present in 20 patients (39.2%).

Results of our study denoted that dyspnea, cough, fever were the most common symptoms. They represent 72.31%, 75.38 %, 70.77% of patients respectively and this result agreed with Tung-Chen et al. [15] study, they revealed that majority of patients presented with dyspnea (56.9%), and fever (45.1%).

We recorded that the time from the onset of symptoms to hospital admission ranged from 3 to 7 days with a mean value of 4.2±0.97 days. In Tung-Chen et al. [15] study, the onset of symptoms was 3.5±5.6 days and in Casella F. et al. [16] study the mean time was 8 days.

In Tung-Chun et al. [15] study, they obtained a positive rate of PCR in 23 (47.9%) patient which is a similar to our result, whereas PCR test was positive in 37 (56.92%) patients. While in Schaad et al. [17], 23% (n=30/134) only of studied patients were COVID- 19 positive.

Regarding CT chest findings, Lopes et al. [18] reported that GGOs, the crazy-paving pattern, sub pleural consolidation and parenchymal bands were observed in 30 (66.7%), 9 (20%), 3 (6.7%), and 8 (17.8%)

cases respectively. While in our study, CT chest showed GGO in 60 (92.31%) patients, Septal thickening in 33 (50.77%) patients, crazy paving in 30 (46.15%) patients, sub-pleural consolidation in 25 (38.46%) patients and effusion in 8 (12.31%) patients. We observed that a higher percentage of patients with GGO in both studies. Also, in Tung-Chen et al. [15] study GGOs were present in 37 patients (72.5%) (The higher percentage of patients), followed by septal thickening (18 patients, 35.2%).

Our study found that most patients had CO-RAD scores of 4 and 5 (41.45%) and these findings were consistent with **Kosovali et al. [19]**. They revealed that CO-RADs 5 represents most patients (50.7%).

In our study, we found that CTSS was mild in 14 (21.54%) patients, moderate in 26 (40%) patients and severe in 25 (38.46%) patients with moderate score is the most present score. While in **Tung-** Tung-Chen, et al. [15] mild 19 (37.3%), moderate 4 (7.8%) and severe 14 (27.5%) with mild score took the upper hand of studied patients.

Tung-Chen, et al. [15] reported that the most common findings on LUS were sub pleural consolidations. While in our study the presence of > 2 B- lines (isolated or confluent) are the most common finding which is like Lopes et al. [18]. Also, Du et al. [20] reported that all participants presented with an increase in B-lines. But in Sahu et al. [21] study, they found that most common findings were pleural line irregularity (70%) followed by B–profile (59%). All these studies found that the lower and posterior lung zones are the most common zones affected. Rizzetto et al. [22] reported that the mean LUS Severity Score was 12.

Regarding CTSS and LUSS, we observed correlations between scores assessed by LUS and CT chest and the studied variables. Higher scores by either technique correlated directly with age, RR, CRP, serum Ferritin and D dimer and there was a negative significant correlation with P/ F ratio and lymphocytes count (P value <0.001 for both). These are the same results as in Portale et al. [23] and Bosso et al. [24].

This study showed substantial agreement between chest CT and LUS (k=0.632, p value < 0.001). In Tung-Chen et al. [15], there was strong agreement between chest CT and LUS (k=0.842, p value < 0.001) which is similar to our results. Ökmen et al. [25] also shared similar results. There was a statistically significant positive correlation between the measured LUS and CT scores ($r = 0.857$, $p < 0.001$). Chrzan et al. [26] also agreed with our results. They revealed significant correlations between LUS and CT scores in all evaluated lung regions.

Lu et al. [6] Study suggested that agreement between lung ultrasound and chest HRCT findings vary depending on the severity of lung involvement, with diagnostic accuracy from 77% (mild involvement) to 93% (severe). And these results agreed with our study. We revealed that LUS can significantly predict severe COVID-19 pneumonia with 92% sensitivity, 85% specificity and mild to moderate COVID-19 pneumonia with 98.04% sensitivity, 42.86 %specificity.

Also, in agreement with our results, Bosso et al. [24] found that excellent ability of LUS in predicting the diagnosis of SARS-CoV-2 infection, with ROC curve of 0.92 (with a sensitivity of 73% and a specificity of 89%).

Our study suggests the usefulness and applicability of lung ultrasound as a screening tool for revealing COVID-19 features and correspondence of ultrasound and chest CT findings. The sum of chest wall areas with ultrasound score agrees with the extent of lung involvement when using CT as the reference standard. Our results suggest that lung ultrasound can substitute CT chest in predicting, screening and diagnosis of COVID-19 pneumonia.

5. Conclusions:

Lung ultrasound can substitute CT chest in predicting, screening and diagnosis of COVID-19 pneumonia.

Acknowledgments: Nil

Funding: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Financial support and sponsorship: Nil

Conflict of Interest: Nil

6. References:

1. Lai CC, Shih TP, Ko WC, et al. Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and coronavirus disease-2019 (COVID-19): The epidemic and the challenges. *Int J Antimicrob Agents*. 2020;55:105924. https://doi.org/10.1016/j.ijantimicag.2020.105924
2. Allinovi M, Parise A, Giacalone M, et al. Lung Ultrasound May Support Diagnosis and Monitoring of COVID-19 Pneumonia. *Ultrasound Med Biol*. 2020;46:2908-17. https://doi.org/10.1016/j.ultrasmedbio.2020.07.018
3. Orlandi M, Lepri G, Bruni C, et al. The systemic sclerosis patient in the COVID-19 era: the challenging crossroad between immunosuppression, differential

diagnosis and long-term psychological distress. *Clin Rheumatol*. 2020;39:2043-7. https://doi.org/10.1007/s10067-020-05193-2

4. Ramdani H, Allali N, Chat L, et al. Covid-19 imaging: A narrative review. *Ann Med Surg (Lond)*. 2021;69:102489. https://doi.org/10.1016/j.amsu.2021.102489
5. Lepri G, Orlandi M, Lazzeri C, et al. The emerging role of lung ultrasound in COVID-19 pneumonia. *Eur J Rheumatol*. 2020;7:S129-s33. https://doi.org/10.5152/eurjrheum.2020.2063
6. Lu W, Zhang S, Chen B, et al. A Clinical Study of Noninvasive Assessment of Lung Lesions in Patients with Coronavirus Disease-19 (COVID-19) by Bedside Ultrasound. *Ultraschall Med*. 2020;41:300-7. https://doi.org/10.1055/a-1154-8795
7. Brahier T, Meuwly JY, Pantet O, et al. Lung Ultrasonography for Risk Stratification in Patients with Coronavirus Disease 2019 (COVID-19): A Prospective Observational Cohort Study. *Clin Infect Dis*. 2021;73:e4189-e96. https://doi.org/10.1093/cid/ciaa1408
8. Ragnoli B, Malerba M. Focus on the Potential Role of Lung Ultrasound in COVID-19 Pandemic: What More to Do? *Int J Environ Res Public Health*. 2020;17. https://doi.org/10.3390/ijerph17228398
9. Bikdeli B, Madhavan MV, Jimenez D, et al. COVID-19 and Thrombotic or Thromboembolic Disease: Implications for Prevention, Antithrombotic Therapy, and Follow-Up: JACC State-of-the-Art Review. *J Am Coll Cardiol*. 2020;75:2950-73. https://doi.org/10.1016/j.jacc.2020.04.031
10. Yang R, Li X, Liu H, et al. Chest CT Severity Score: An Imaging Tool for Assessing Severe COVID-19. *Radiol Cardiothorac Imaging*. 2020;2:e200047. https://doi.org/10.1148/ryct.2020200047
11. Prokop M, van Everdingen W, van Rees Vellinga T, et al. CO-RADS: A Categorical CT Assessment Scheme for Patients Suspected of Having COVID-19-Definition and Evaluation. *Radiology*. 2020;296:E97-e104. https://doi.org/10.1148/radiol.2020201473
12. Wangüemert Pérez AL, Figueira Gonçalves JM, Hernández Pérez JM, et al. Prognostic value of lung ultrasound and its link with inflammatory biomarkers in patients with SARS-CoV-2 infection. *Respir Med Res*. 2021;79:100809.

https://doi.org/10.1016/j.resmer.2020.100809

13. Acar H, Yamanoğlu A, Arıkan C, et al. Effectiveness of the CLUE protocol in COVID-19 triage. *Cukurova Medical Journal*. 2022;47:722-8.
14. McHugh ML. Interrater reliability: the kappa statistic. *Biochem Med (Zagreb)*. 2012;22:276-82.
15. Tung-Chen Y, Martí de Gracia M, Díez-Tascón A, et al. Correlation between Chest Computed Tomography and Lung Ultrasonography in Patients with Coronavirus Disease 2019 (COVID-19). *Ultrasound Med Biol*. 2020;46:2918-26. https://doi.org/10.1016/j.ultrasmedbio.2020.07.003
16. Casella F, Barchiesi M, Leidi F, et al. Lung ultrasonography: A prognostic tool in non-ICU hospitalized patients with COVID-19 pneumonia. *Eur J Intern Med*. 2021;85:34-40. https://doi.org/10.1016/j.ejim.2020.12.012
17. Schaad S, Brahier T, Hartley MA, et al. Point-of-care lung ultrasonography for early identification of mild COVID-19: a prospective cohort of outpatients in a Swiss screening center. *BMJ Open*. 2022;12:e060181. https://doi.org/10.1136/bmjopen-2021-060181
18. Lopes AJ, Mafort TT, da Costa CH, et al. Comparison Between Lung Ultrasound and Computed Tomographic Findings in Patients With COVID-19 Pneumonia. *J Ultrasound Med*. 2021;40:1391-9. https://doi.org/10.1002/jum.15521
19. Kosovalı BD, Çıvgın EY, Özkan E, et al. Clinical severity and mortality predictors in COVID-19 intensive care patients: CTSS and CO-RADS. *Turkish Journal of Clinics and Laboratory*. 2022;13:116-23.
20. Du G, Wang Y, Chen Z, et al. Lung ultrasound correlates with radiographic severity and pattern in COVID-19 pneumonia: a preliminary study. *Ann Palliat Med*. 2021;10:8147-54. https://doi.org/10.21037/apm-21-1731
21. Sahu AK, Mathew R, Bhoi S, et al. Lung sonographic findings in COVID-19 patients. *Am J Emerg Med*. 2021;45:324-8. https://doi.org/10.1016/j.ajem.2020.08.080
22. Rizzetto F, Perillo N, Artioli D, et al. Correlation between lung ultrasound and chest CT patterns with estimation of pulmonary burden in COVID-19 patients. *Eur J Radiol*. 2021;138:109650.

https://doi.org/10.1016/j.ejrad.2021.109650

23. Portale G, Ciolina F, Arcari L, et al. Lung Ultrasound in COVID-19: Clinical Correlates and Comparison with Chest Computed Tomography. *SN Compr Clin Med*. 2021;3:2075-81. https://doi.org/10.1007/s42399-021-00986-1
24. Bosso G, Allegorico E, Pagano A, et al. Lung ultrasound as diagnostic tool for SARS-CoV-2 infection. *Intern Emerg Med*. 2021;16:471-6. https://doi.org/10.1007/s11739-020-02512-y
25. Ökmen K, Yıldız DK, Soyaslan E. Comparison of lung ultrasonography findings with chest computed tomography results in coronavirus (COVID-19) pneumonia. *J Med Ultrason (2001)*. 2021;48:245-52. https://doi.org/10.1007/s10396-021-01081-7
26. Chrzan R, Polok K, Antczak J, et al. The value of lung ultrasound in COVID-19 pneumonia, verified by high resolution computed tomography assessed by artificial intelligence. *BMC Infect Dis*. 2023;23:195. https://doi.org/10.1186/s12879-023-08173-4