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ORIGINAL ARTICLE

Lung Ultrasound as a Triage Tool in an Emergency Setting during the Covid-19 Outbreak: comparison with CT Findings

Monica Luiza de Alcantara, Marcos Paulo Lacerda Bernardo, Tatiana Bagrichevsky Autran, Rodolfo de Paula Lustosa, Marcelo Tayah, Lucia Antunes Chagas and Dequitier Carvalho Machado

Americas Medical City - United Health Group, Rio de Janeiro, RJ - Brazil

Abstract

Background: Lung ultrasound (LUS) can detect interstitial alveolar changes confined to the subpleural region, like those described in Covid-19.

Objetive: To evaluate how LUS findings correlate with chest computed tomography (CT) in patients admitted to the emergency department (ED) with suspicion of Covid-19.

Methods: Cross-sectional study of 20 patients (median age 43 years; interquartile range, 37–63 years; 50% male). All patients underwent LUS and chest CT on the day of ED admission. Each hemithorax was divided into 6 segments with similar landmarks, and equivalent scores (sc) of lesion severity were defined for both methods. The number of affected segments on LUS (LUSseg) was divided into tertiles (0-1, 2-5, and ≥6), and compared with number of affected segments on CT (CTseg), LUSsc, CTsc, and percentage of affected lung parenchyma through visual analysis (CTvis). ANOVA or Kruskal–Wallis test for continuous variables, chi-square test for categorical variables, and receiver operating characteristic (ROC) curve analysis to define optimal cutoff points were performed. P<0.05 was considered statistically significant.

Results: Median LUSsc, CTsc, CTseg, and CTvis were significantly different between groups. A clear separation between groups was demonstrated; patients with <2 affected segments on LUS were defined as low risk. The ROC curve showed good discriminative power to predict ≥6 affected segments on CT, with an area under the curve (AUC) of 0.97 and 0.98 for >7 LUSsc and >3 LUSseg, respectively.

Conclusion: LUS findings correlate with chest CT, and can help identify patients with normal lung or minor pulmonary involvement secondary to Covid-19. (Int J Cardiovasc Sci. 2020; 33(5):479-487)

Keywords: Lung; Ultrasonography/methods; Triage; Pandemics; COVID-19; Pulmonary Alveoli; Pleura; Tomography, X-Ray Computed/methods.

Introduction

Since late 2019, the novel coronavirus disease (Covid-19) outbreak has posed a new challenge to health organizations worldwide. Hospitals are being reformatted to provide surge capacity for the population, in an attempt to avoid a collapse of entire health systems. Triage, separating the most serious cases (requiring hospitalization) from those who can safely stay at home in self-isolation, plays a particularly important role in the management of available hospital beds in this setting. Triage protocols are based on clinical, laboratory, and imaging data, with chest computed tomography (CT) considered a sensitive tool to detect and quantify the extension of pulmonary involvement in Covid-19.[1,2] This high accuracy notwithstanding, scanners need to undergo a time-consuming high-level disinfection after each scan, slowing the workflow in overloaded emergency departments. Lung ultrasound (LUS) has been suggested as an attractive tool to rule out

Mailing Address: Monica Luiza de Alcantara
Av. Alexandre Ferreira, 350/301. Postal Code: 22470-220 Rio de Janeiro-RJ, Brazil.
E-mail: alcantaramonica@gmail.com

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Monica Luiza de Alcantara MD MSc , FESC
Coordinator of Echocardiography at Hospital Americas Medical City - RJ
alcantaramonica@gmail.com

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more extensive pulmonary involvement in patients with high clinical suspicion for Covid-19.[3,4] LUS is a ready-to-use bedside technique that relies on the visualization of artifacts that arise from the pleural line.[5]As the vast majority of interstitial syndromes involve the pleura and as most pulmonary lesions in Covid-19 are located in the subpleural region, LUS is especially suited to demonstrate those lesions.

Within this context, the aim of the present study was to evaluate whether LUS findings correlate with CT findings in patients admitted to an emergency department with clinical suspicion of Covid-19.

Methods

Patient Population and data collection

This was a cross-sectional study of 23 patients admitted to our emergency department with clinical signs and symptoms suggestive of Covid-19. The sample size was determined by convenience. All patients underwent LUS and CT on the same day. Patients were excluded if CT clearly showed evidence of non-Covid-19 pathology. The following clinical data were collected for analysis: age, gender, heart rate, respiratory rate, peripheral oxygen saturation (obtained by pulse oximetry), and duration of symptoms. Relevant symptoms suggestive of Covid-19 were fever, cough and dyspnea. Hypertension, diabetes mellitus, heart failure, chronic obstructive pulmonary disease (COPD), asthma, and obesity were considered risk factors for severe Covid-19.

Lung ultrasound

LUS was performed using a Vivid E9 XD Clear system (GE Healthcare, USA) with a 3-5 MHz convex probe. Patients were scanned in upright position whenever possible or in supine position and subsequent lateral decubitus to access posterior regions. Each hemithorax was divided in six regions: anterior, lateral and posterior with anterior and posterior axillary lines set as landmark of those regions and 4th intercostal space subdividing them in superior and inferior[6] (Figure 1a). The transducer was held perpendicular to the chest wall, with the marker pointing cephalad. Each region was carefully scanned by sliding the probe so as to cover as much pleural surface as possible. The liver and spleen were used as landmarks of transition between lung and diaphragm. Dynamic images were obtained and stored to detect typical LUS findings as described in the literature,[5] such as lung sliding, B-line movement, and subpleural and translobar consolidations. Each region was scored semiquantitatively according to increasing degrees of severity of LUS findings, as follows: 0, A-line profile (considered a normal finding); 1, >2 B-lines per intercostal space; 2, coalescent B-lines; 3, subpleural consolidation; and 4, translobar consolidation[7]. The scores of each segment were added to yield the final score (sc). The total number of abnormal segments (seg) was also added and compared with CT. Patients were divided into tertiles according to the number of affected segments on ultrasound (LUSseg): group I, 0-1 segment; group II, 2-5 segments; and group III, ≥6 segments. The presence of pleural effusion was also documented. Pleural thickening or irregularity was not considered for scoring purposes.

Computed tomography

CT was performed using a 64-slice SOMATOM Confidence® RT scanner (Pro-Siemens Healthineers, Germany). Percent lung involvement was defined through visual analysis according to the distribution of affected lung parenchyma and stratified into four categories: 0% (normal lung), less than 25% of lung affected, 25-0% of lung affected, and >50% of lung affected.[8] The number of affected segments was also evaluated using the same anatomical landmarks as for LUS (Figure 1b). A 12-segment model was used for CT instead of the traditional 5-lobe segmentation used in radiology reports, aiming to ensure comparability of analysis with LUS to define the anatomic distribution of the lesions. A cutoff value of >6 segments on CT was defined for "extensive pulmonary involvement". As in LUS, each segment was scored according to increasing severity of CT findings, as follows: 0, normal findings; 1, peripheral ground-glass opacities; 2, "crazy paving"; 3, subpleural consolidation ; and 4, translobar consolidation. Again, as in LUS, the score values of all segments were added to yield the final CTsc. The number of affected segments on CT (CTseg) was added for comparison with LUSsc (Figure 2) LUS scanning and analysis was performed by three echocardiographers experienced in LUS (MLA, MPLB, and TBA), who were blinded to CT findings. CT analysis was performed by two experienced radiologists (DCM and LAC) who, in turn, were blinded to LUS findings.

Statistical analysis

Data analyses were performed in IBM SPSS Statistics for Windows, Version 25.0 (IBM Corp., Armonk, NY, USA).

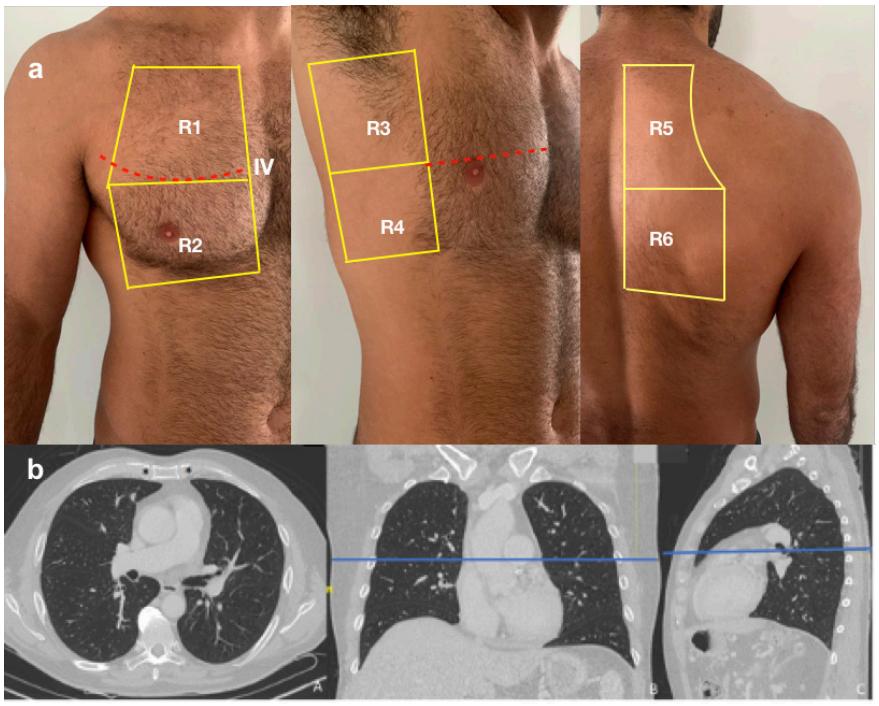
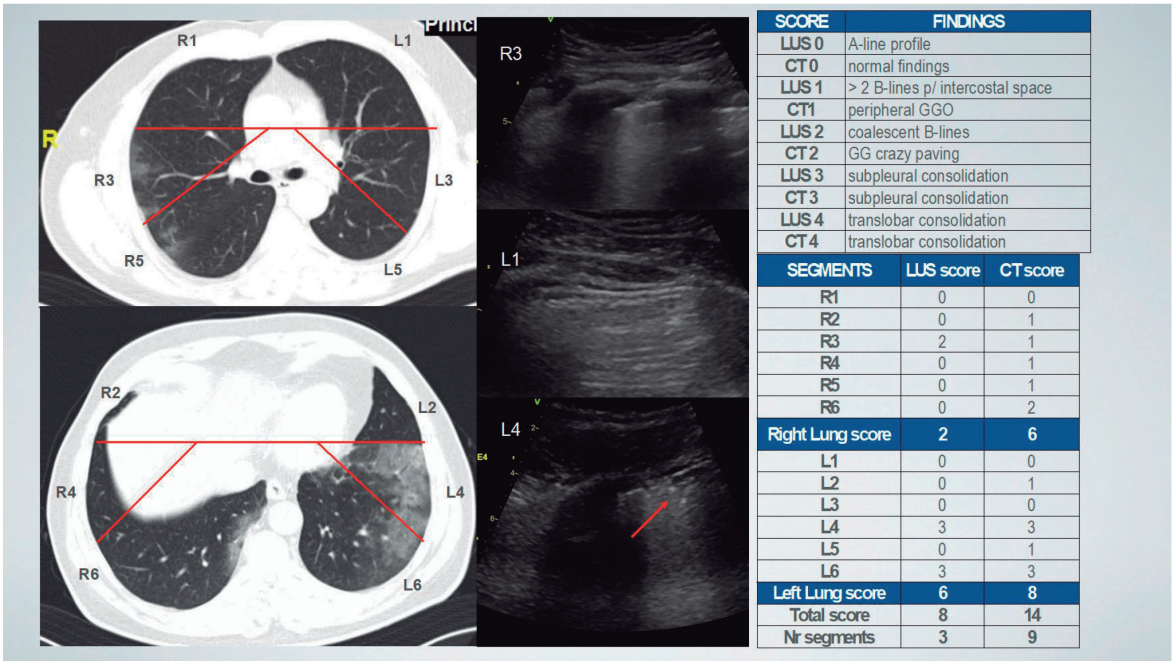


Figure 1 – Segmentation model for lung ultrasound (a) and corresponding CT (b). The anatomical landmarks are the 4th intercostal space and the anterior and posterior axillary lines.



SCORE	FINDINGS
LUS 0	A-line profile
CT 0	normal findings
LUS 1	> 2 B-lines p/ intercostal space
CT1	peripheral GGO
LUS 2	coalescent B-lines
CT 2	GG crazy paving
LUS 3	subpleural consolidation
CT 3	subpleural consolidation
LUS 4	translobar consolidation
CT 4	translobar consolidation

SEGMENTS	LUS score	CT score
R1	0	0
R2	0	1
R3	2	1
R4	0	1
R5	0	1
R6	0	2
Right Lung score	2	6
L1	0	0
L2	0	1
L3	0	0
L4	3	3
L5	0	1
L6	3	3
Left Lung score	6	8
Total score	8	14
Nr segments	3	9

Figure 2 – Example of 61 year old male patient showing CT segmentation and corresponding LUS showing subpleural in a patient with predominant peripheral ground glass opacification (GGO) and subpleural consolidation restricted to L4 and L6 as demonstrated by both methods. Left panel: CT segmentation and findings; middle panel: LUS findings in 3 segments and right panel: scoring according to findings and structured scoring table, right lung (R) and left lung (L).

Continuous data were presented as mean ± standard deviation (SD) or median and interquartile range (IQR), according to the normality of data distribution as evaluated by the Shapiro–Wilk test. Categorical data were presented as absolute and relative frequencies. Continuous variables were compared by means or medians of one-way ANOVA or Kruskal–Wallis tests, as appropriate, while categorical variables were compared with a chi-square test. Receiver operating characteristic (ROC) curve analysis and the Youden index were used to assess optimal cutoff points for LUSseg and the best LUSsc to detect ≥6 affected segments in CT. All statistical tests were two-sided, and a P-value <0.05 was considered statistically significant.

Results

Patient population

Three of 23 patients were excluded due to CT findings typical of pneumocystis infection (one patient), bilateral moderate pleural effusion secondary to heart failure (one patient), or residual changes of previously documented pneumonia (one patient). The remaining group had a median age of 43 years (IQR, 37 to 63 years) and was 50% male. The median duration of symptoms was 7 days (IQR, 6 to 8 days). Baseline clinical characteristics and differences between the groups are listed in Table 1. No difference was observed between groups except for female gender (more prevalent in group I) and lower oxygen saturation (more prevalent in group III).

Lung ultrasound and computed tomography characteristics

LUS and CT measurements based on LUSseg are shown in Table 2, Figure 3, and Figure 4. Median LUSsc, CTsc, CTseg, as well as CT visual analysis categories, were significantly different between groups. Using ROC curve analysis to predict ≥6 segments on CT (Figure 5), LUSsc and LUSseg showed good discriminative ability, with AUCs of 0.97 and 0.98 respectively. A LUSsc >7 and a LUSseg ≥3 showed similar sensitivity (81.8%) and specificity (100%) in predicting lung involvement in ≥6 CT segments.

Table 1 – Clinical characteristics of the sample, based on the number of segments affected on lung ultrasound

	Group I (0/1 segments) (n=9)	Group II (2/5 segments) (n=4)	Group III (≥6 segments) (n=7)	p-value
Age in years, median [IQR]	38 [36-48]	47 [39-58]	63 [38-74]	0.241‡
Female gender, n(%)	7 (77.8)	3 (75)	0 (0)	0.005*
Symptom duration in days, median [IQR]	7 [5-11]	8 [3-13]	7 [7-8]	0.911‡
Heart rate, bpm	88±15	86±15	94±21	0.709§
Respiration rate, bpm	18±3	20±6	24±8	0.134§
Peripheral oxygen saturation, median [IQR]	99 [98-100]	98 [93-98]	94 [91-95]	0.009‡
Fever, n (%)	7 (77.8)	3 (75)	7 (100)	0.383*
Cough, n (%)	9 (100)	3 (75)	7 (100)	0.122*
Dyspnea, n (%)	8 (88.9)	1 (25)	4 (57.1)	0.072*
Hypertension, n (%)	2 (22.2)	0 (0)	4 (57.1)	0.109*
Diabetes, n (%)	2 (22.2)	1 (25)	1 (14.3)	0.890*
Heart failure, n (%)	0 (0)	0 (0)	0 (0)	1.00*
COPD, n (%)	0 (0)	0 (0)	1 (14.3)	0.376*
Asthma, n (%)	2 (22.2)	0 (0)	0 (0)	0.257*
Obesity, n (%)	2 (22.2)	1 (25)	2 (28.6)	0.959*

*COPD: chronic obstructive pulmonary disease; IQR: interquartile range; *chi-square test; §one-way analysis of variance (ANOVA); ‡Kruskal–Wallis test.*

Table 2 – Lung ultrasound and computed tomography parameters and their relation to the number of segments affected on lung ultrasound.

	Group I (0/1 segments) (n=9)	Group II (2/5 segments) (n=4)	Group III (≥6 segments) (n=7)	p-value
Pleural effusion on lung ultrasound, n (%)	0 (0)	0 (0)	1 (14.3)	0.376*
LUS score, median [IQR]	0 [0-1]	7 [3-10]	18 [14-23]	0.002‡
Pleural effusion on CT, n (%)	0 (0)	0 (0)	1 (14.3)	0.376*
CT score, median [IQR]	0 [0-4]	13 [11-14]	27 [24-31]	<0.001‡
CT visual analysis, n (%)				0.002*
<25%	9 (100)	3 (75)	0 (0)	
25%-50%	0 (0)	1 (25)	5 (71.4)	
>50%	0 (0)	0 (0)	2 (28.6)	
CT number of segments, median [IQR]	0 [0-2]	9 [5-11]	12 [11-12]	<0.001‡

*CT: computed tomography; IQR: interquartile range; LUS: lung ultrasound. *chi-square test; ‡Kruskal–Wallis test.*

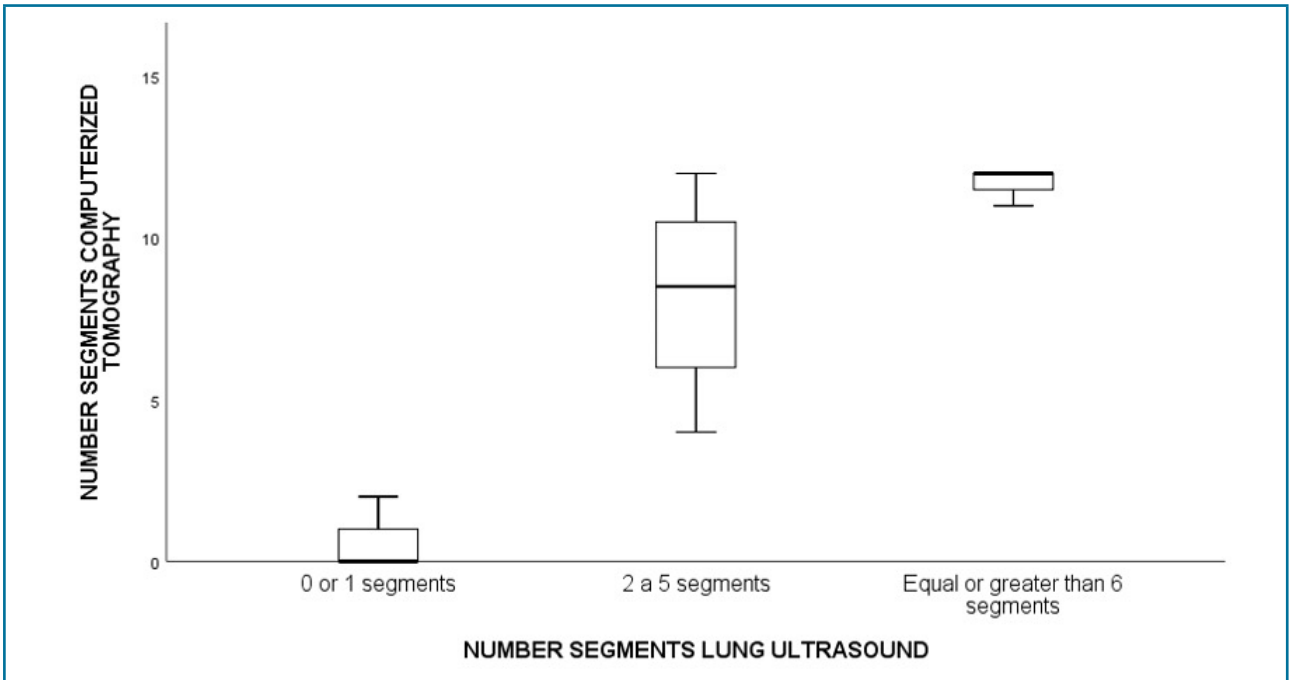


Figure 3 – Distribution of number of affected segments on lung ultrasound and computed tomography. The chart shows the median (horizontal bars), the 25th and 75th percentiles (lower and upper limits of the boxes), and lower and upper absolute values (error bars).

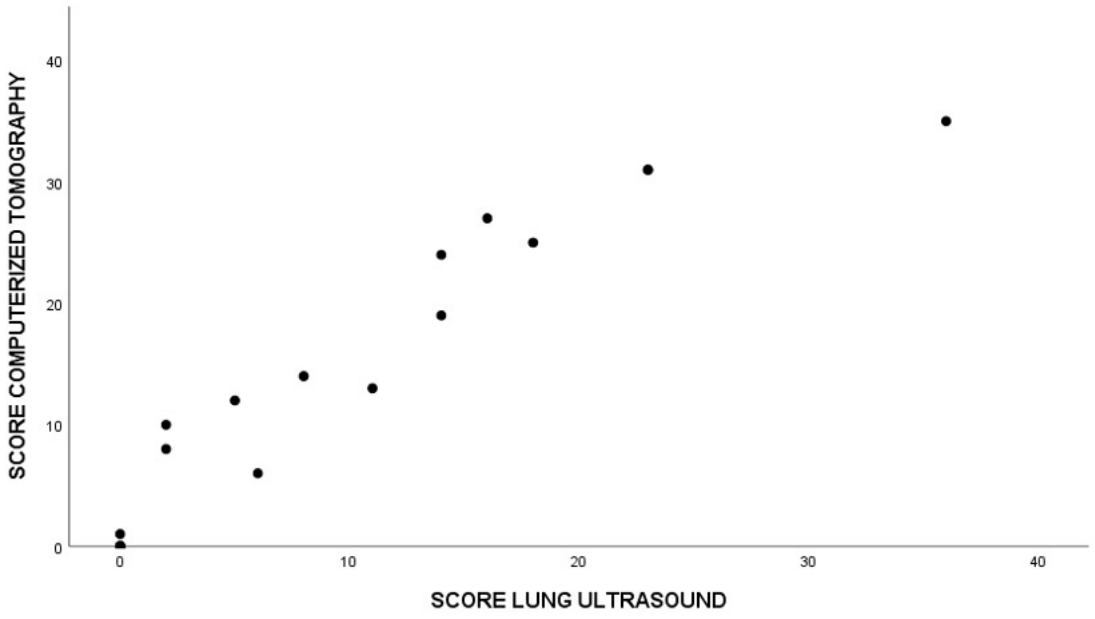


Figure 4 – Scatter-dot plot of lung ultrasound score and computed tomography score, showing proportionally ascending values according to extension of involvement.

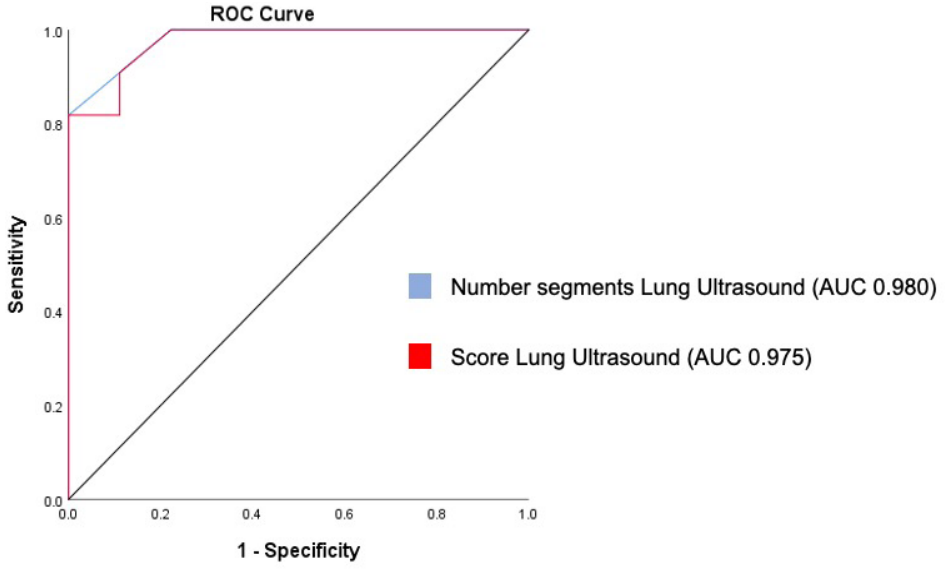


Figure 5 – Receiver operator characteristic analyses of lung ultrasound to identify ≥6 affected segments on computed tomography.

Discussion

This study provides important information about the relationship between CT and LUS findings in Covid-19. A low LUSsc and LUSseg was able to predict normal findings or minor pulmonary involvement on CT, thus classifying the patient into a low-risk group. There was a clear separation between the groups with minor pulmonary involvement (group I) and severe pulmonary involvement (group III), as shown in figure 3. On the other hand, LUS was less able to distinguish group II from group III, which might in part be explained by the sample size or by an actual lack of ability of LUS to detect those findings located deeper in the lung rather than in close relation to the subpleural space. This also explains the different scores yielded by CT and LUS. Nevertheless, as shown in figure 4, there is a linear, ascending proportion of both scores with increasing lung involvement. To better understand the limitation imposed by the physics of ultrasound, figures 6a and 6b present two identical CTsc and their LUS correlates, showing a different spatial distribution of the lesion, with CT findings in figure 6a being missed on LUS. However, this discrepancy did not change patient classification and, consequently, did not affect decision making. The presence of ≥3 abnormal segments or a score >7 on LUS showed good sensitivity and specificity in identifying more extensive involvement on chest CT.

Value of lung ultrasound to predict affected segments in chest computed tomography

LUS is an attractive tool that can be used in a variety of settings, including intensive care units and emergency departments[9]. Compared with echocardiography, LUS has a shorter learning curve for those not experienced with ultrasound imaging. The worldwide experience with Covid-19 has shown just how pivotal quick, safe decision making can be in affecting the workflow of an overwhelmed emergency department. Symptoms alone may not be good markers of disease severity, and oxygen saturation as the sole objective parameter may not be indicative of

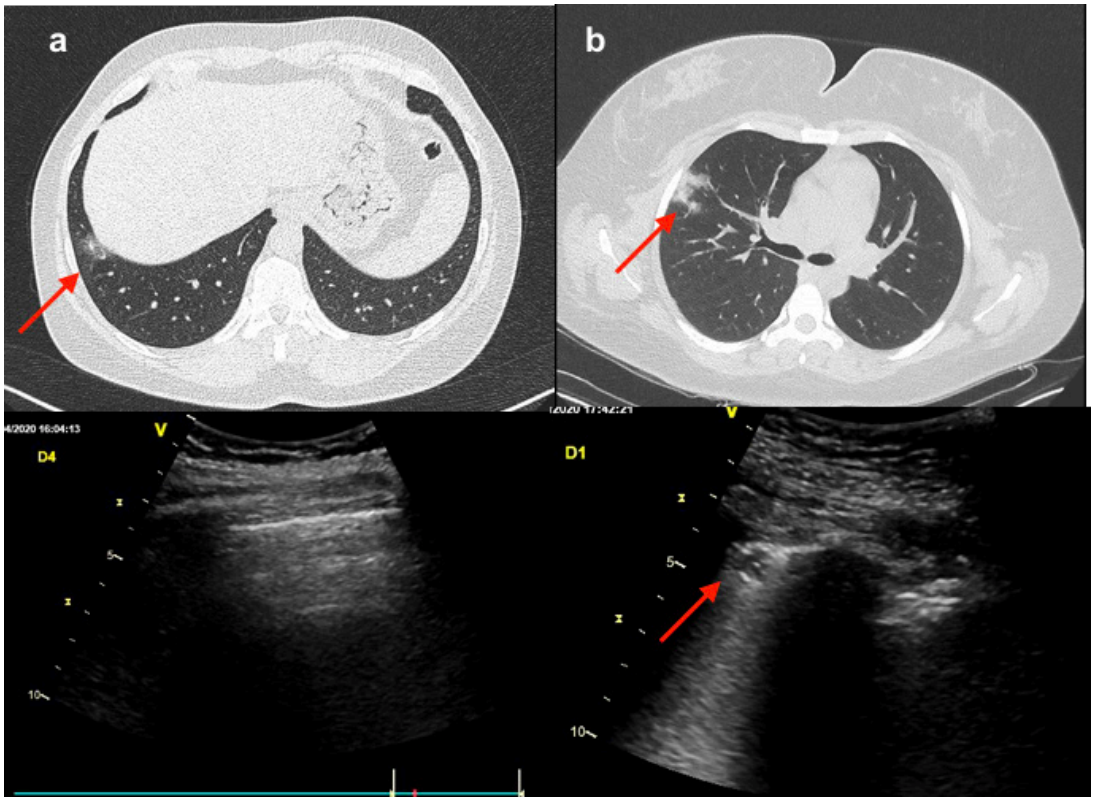


Figure 6 – Representative CT and corresponding LUS images of 2 patients with minor pulmonary involvement. Case (a) was a 42-year-old female with a deep lesion in the lung and a normal A line profile on LUS. Case (b) was a 27 year old female with subpleural consolidation, also demonstrated on LUS (red arrow), as well as coalescent B-lines

the actual anatomical picture. CT is the most sensitive imaging method to evaluate the extension and severity of pulmonary involvement[10], but the time required for disinfection[11] and patient transportation logistics mean CT will not be available for all those who need chest imaging. In this context, LUS can help identify those patients with less severe disease who can be sent home safely with instructions to self isolate, thus saving hospital beds for patients who really need them. Using LUS as a first-line imaging method in clinically stable patients who present with adequate oxygen saturation, reserving CT and other tests for those who present with two or more abnormal segments on LUS, seems a logical workflow. This strategy can potentially help hospitals and their staff cope with an extremely high patient volume scenario, reduces radiation exposure, is consistent with rational use of resources, and enhances physician confidence to discharge those patients at low risk. Further studies are needed to specifically evaluate the safety of LUS to support discharge of such patients.

This strategy has been previously described by Buonsenso et al, who suggested the use of LUS as a triage method in the emergency department[11]. Positivity for SARS-CoV-2 infection on laboratory tests was not considered in the present study, as our aim was to compare imaging methods as a triage tool for those with a high clinical likelihood of Covid-19 rather than to define the presence or absence of disease. Fang et al showed that laboratory testing has lower sensitivity when compared to CT findings,[12-14] depending on the time course of symptoms and cannot provide quick answers.

Limitations

Our study encompassed a limited sample size, and findings require reproduction in a larger population. On the other hand, LUS yielded robust data to rule out extensive pulmonary involvement in patients with suspected Covid-19, which was the main purpose of this study. A greater sample size could hypothetically refine the classification of extension and severity scores, identifying those who are considered to have less severe pulmonary involvement and can recover at home but still warrant closer surveillance, as the disease could potentially progress. LUS findings in Covid-19 are not specific for this disease, being present in other interstitial syndromes including other viral pneumonias, pneumocystis infection, hypersensitivity pneumonitis, and diffuse alveolar hemorrhage. These findings thus have to be considered in the context of the present outbreak, and laboratory testing to confirm Covid-19 is still mandatory to support long-term decision making and epidemiological data analysis.

The risk of exposure to the virus is an important issue to be considered. To mitigate this risk to acceptable low levels, patients should always wear a surgical mask and sonographers should wear full personal protective equipment (PPE) while scanning.

Conclusion

The results of this study suggest that LUS findings correlate with chest CT findings, and that can LUS therefore help identify those patients with clinical suspicion of Covid-19 infection who have unaffected lungs or minor pulmonary involvement. Further studies are needed to specifically evaluate the safety of LUS as the sole imaging triage tool for ED screening without the need for subsequent CT, allowing patients to be discharged home to recover or undergo further surveillance.

Author contributions

Conception and design: Alcantara ML, Bernardo MPL. Acquisition of data: Alcantara ML, Bernardo MPL, Autran TB. Analysis and interpretation of data: Alcantara ML, Bernardo MPL, Autran TB, CHagas LA, Machado DC. Statistical analysis: Lustosa RP. Writing of the manuscript: Alcantara ML. Critical revision of the manuscript for intellectual content: Lustosa RP.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

Sources of Funding

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Study Association

This study is not associated with any thesis or dissertation work.

Ethics approval and consent to participate

This study was approved by the Ethics Committee of *Hospital Pró-Cardíaco* under protocol number 3168.4620.0000.05533. All procedures of this study were conducted in accordance with the 1975 Helsinki Declaration, updated in 2013. Informed consent was obtained from participants included in the study.

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