Sensitivity of Lung US compared to Chest CT for the screening of COVID-19: preliminary report of our experience

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Abstract

As lung ultrasound (LUS) is a noninvasive, radiation-free, repeatable and portable imaging tool suitable for a point-of-care use, several recent literature reports have emphasized its role as the ideal screening tool for SARS-CoV2 pneumonia. To evaluate the actual diagnostic accuracy of LUS for this purpose, we performed a systematic comparative study between LUS and CT scan findings in a population of 82 patients hospitalized because of COVID-19. LUS and Chest CT have been performed in all patients within 6-12 hours from the admission. The sensitivity of LUS in assessing typical CT findings was 60%. Despite LUS detected consolidations adherent to pleural surface in all cases, it was not able to detect all the consolidations assessed at CT scan (p=0.002), showing a risk to underestimate the actual disease's extent. Moreover, only 70% of pleural surface is visible by LUS. Considering that the specificity and the positive predictive value of the same LUS signs may be lowered in a normal setting of non epidemic COVID-19 and in case of pre-existing cardio-pulmonary diseases, LUS use should not be indicated for diagnosis of COVID-19. However, it may be very useful for the assessment of pleural effusion and to guide safer fluid drainage.

Introduction

Since the initial cluster of pneumonia cases in Wuhan in December 2019[1], the so-called SARS-CoV-2 has sudden spread globally and the World Health Organization (WHO) declared the novel coronavirus *disease (COVID-19)* as "a pandemic" on 11 March 2020[2].

The clinical presentation of COVID-19 varies remarkably from one patient to another, going from asymptomatic forms to life-threatening acute respiratory distress syndrome requiring admission to intensive-care-units (ICUs). The diagnosis may be challenging.

Chest X-Ray generally represents the faster, widely available first-line imaging method for symptomatic patients in the Emergency Departments. Computed Tomography (CT) has a higher sensitivity than X-ray in detecting ground glass opacities (GGOs) in the early phase of the disease[3,4,5]. However, its use for the first assessment of COVID-19 infection in epidemic areas is not an easy issue. Indeed, it implies a huge burden on Radiology Departments, the designation of dedicated CT machines and the application of severe infection control procedures[6,7].

Lung ultrasound (LUS) is a safe, noninvasive, radiation-free, repeatable, cost-effective and well-tolerated imaging tool. Moreover, it is portable and usable as immediate point-of-care method. LUS has the ability to detect any process involving subpleural pulmonary areas, if adherent to the accessible pleural surface[8]. However, about the 30% of pleural surface and the deeper lung parenchyma are not accessible to LUS due to technical limitations[9]

The typical Chest-CT findings of COVID-19 include bilateral subpleural and lower lobe located GGO opacities and/or consolidation[5], that are likely visible to LUS[10]. Frequently reported LUS findings are the

appearance of multiple, confluent or not, B-lines, a thickened and irregular pleural line and small superficial or large areas of consolidation[11,12,13]. Also minimal or rarely larger pleural space fluid effusions has been evidenced[14,15].

With COVID-19 pandemic outbreak, several literature reports have emphasized the role of LUS as an useful screening tool for Emergency Department diagnosis, pre-hospitalization triage, ICU decisions (regarding ventilator need and weaning), and treatment monitoring[10,13]. However, these works included few patients, did not indicate the equipment setting and did not consider the main comorbidities of COVID-19 patients, thus reaching premature and fascinating conclusions. In addition, despite typical LUS findings may show good sensitivity and positive predictive values in the context of COVID-19 epidemic (i.e. high “a priori” probability of disease in the presence of respiratory symptoms), the ability of LUS to rule out COVID-19 in normal condition is far from sufficient, as the same US patterns overlap with several other pleuro-pulmonary conditions[16]. At present, there is still a lack of data to establish the appropriate use of LUS in the diagnostic workup of COVID-19. A deeper knowledge of LUS sensitivity to different stages of pulmonary involvement is needed.

With this background, we performed a systematic comparison between LUS findings and the respective CT scan appearances in a COVID-19 cohort with the aim to estimate the actual diagnostic accuracy of LUS in detecting COVID-19 related abnormalities in case of typical or not CT lesions.

Participants And Methods

Participants. We performed a prospective comparative study between LUS and CT findings in a cohort of COVID-19 patients. We analyzed data of the first consecutive 82 patients hospitalized in our referral COVID-19 center in Southern Italy, “Fondazione Casa Sollievo della Sofferenza” Research Institute, located in San Giovanni Rotondo, Foggia, Italy, from March 19 and April 13, 2020.

All the evaluated patients had a confirmed diagnosis of COVID-19 by a positive RT-PCR assay for SARS-CoV-2 on nasopharyngeal swabs collected at admission. Among the 82 inpatients enrolled, 59 patients presented with persistent fever, cough and fatigue and were admitted in a COVID-19 Emergency Department, 10 presented with acute dyspnea and pneumonia and were hospitalized in a COVID-19 ward and 13 patients presented with a severe acute respiratory distress syndrome and were admitted in a COVID-19 intensive or sub-intensive care units. COVID-19 severity was assessed at admission on the basis of a series of measurable laboratory and clinical parameters, including blood C-reactive protein (CRP) values and peripheral oxygen saturation (SpO_2). A Chest-CT and lung US examination was performed in all patients concurrently, i.e. within 6-12 hours from the admission to the hospital.

Ethical approval and informed consent. The study was approved by the institutional Ethics Committee of “Fondazione Casa Sollievo della Sofferenza” Hospital and was carried out according to the principles of the Declaration of Helsinki. All the participants or their legal guardians provided informed written consent for all the procedures. There is no identifying information or image in the article.

Chest-CT. Chest-CT examinations was performed using a multi-detector CT scanner with 64 channels. The detailed parameters for CT acquisition were as follows: tube voltage, 120 kVp; tube current, standard (reference mAs, 60–120); slice thickness, 0.5 mm; reconstruction interval, 0.3-1.0 mm. All CT images were acquired at full inspiration (impossible in few severely ill patients) with the patient in the supine position and without contrast medium. Chest CT scans were interpreted by a radiologist, with 32 years of experience in thoracic imaging. All the CT examinations were reviewed by a second expert in thoracic imaging to reach a consensus.

Classification of patients according to Chest-CT findings. Given the variable CT appearance in COVID-19, the RSNA Expert Consensus Statement on Reporting Chest-CT Findings Related to COVID-19[17] has recently suggested an useful classification for reporting CT findings potentially attributable to COVID-19.

We have classified Chest-CT results in our COVID-19 population according the four categories proposed by Simpson et al[17]:

1. **Typical CT appearance:** GGOs, showing a round morphology or a “crazy paving” pattern, with or without consolidations, in a peripheral, posterior, and diffuse or lower lung zone distribution;
2. **Indeterminate CT appearance:** focal or diffuse GGOs without a clear distribution;
3. **Atypical CT appearance:** lobar or segmental consolidations, cavitations, tree-in-bud opacities with centrilobular nodules and all those alterations that are reported to be uncommon or not occurring in COVID-19 pneumonia and are more typical of other diseases;
4. **Normal CT appearance:** absence of parenchymal abnormalities attributable to infection.

Findings of those four categories were then systematically compared them with the corresponding US findings.

Lung US. Lung US examination was performed with an Esaote MyLab-25 GOLD and My-Lab Twice (Esaote-Biomedica, Genoa, Italy) using a multifrequency convex probe (3-5 MHz and 3-8 MHz) and an adequate setting for the adult thoracic study (gain: max 50%, focus pointed on the hyperechoic pleural line, activation of the tissue harmonic).

The chest was examined in each patients by exploring lung fields from the bases up to the ipsilateral apexes in the following regions: 1) Anterior: along the parasternal, mid-clavicular and anterior-axillary lines; 2) Lateral: along the mid-axillary and posterior-axillary lines; 3) Posterior: along the *mid-scapular* and para-vertebral lines. The approximate duration of the entire lung US examination was 15 minutes. The lung US examinations were performed and interpreted by 3 expert sonographers, with 10-32 years of experience in diagnostic and interventional ultrasound. The Chest-CT scan of each patient was blinded to the sonographers during the exam. Examination videoclips were recorded and later blindly re-examined by another expert sonographer with 20 years of experience in lung ultrasound in order to asses intra- and inter-operator variability. Lung US examination was focused on the detection of the following findings:

regular/irregular thickening of the pleural line; multiple (>3), coalescent or not, B-lines; presence of consolidations; presence of pleural effusions.

Statistical analysis. Numerical variables were presented as mean values ± SD; categorical variables were presented as counts and percentages. The diagnostic performance of Lung US in assessing typical COVID-19 lesions detected on Chest-CT (gold standard) was evaluated by calculating accuracy, sensitivity, specificity, positive predictive value and negative predictive value with a 95% confidence interval (CI). The number of subpleural consolidations detected on Chest-CT and LUS respectively were compared by a paired Student's t-test. A p value < 0.05 was considered as statically significant. The agreement between Chest-CT and LUS in diagnosing Typical COVID-19 lung lesion was analysed with Cohen's kappa coefficient. We considered the strength of the correlation to be very weak (0.0–0.19), weak (0.20–0.39), moderate (0.40–0.59), strong (0.60–0.79) or very strong (0.80–1.0).

Results

Demographic, clinical and laboratory characteristics. Demographic, clinical and laboratory characteristics of the 82 evaluated COVID-19 patients are shown in Table 1. In particular, 75 patients (91%) had at least one comorbidity, with hypertension (65%) and other cardiovascular diseases (43%) being the most common.

Demographic, clinical and laboratory characteristics	
Age (mean ± SD)	67.84±14.01 (20-97)
Sex, female (n, %)	33 (40%)
Sex, male (n, %)	49 (60%)
BMI, Kg/m^2 (mean ± SD)	26.92±3.58 (18.07-42.32)
Smokers, current or former (n, %)	11 (13%)
Body temperature, °C (mean ± SD)	37.31±0.81 (36.2-39.0)
CRP, mg/dL	19.08±7.75 (0.29-38.7)
$SpO_{2,}$ %	92.07±2.16 (84-97)
Comorbidities (n, %)	
Hypertension	53 (65%)
Cardiovascular Diseases	35 (43%)
Diabetes	21 (26%)
Anamnestic Neoplasm	15 (18%)
Autoimmune Disorders	11 (14%)
COPD	8 (10%)

Table 1. Demographic, clinical, laboratory, CT and LUS data of our patients at admission. Abbreviations: BMI, Body Mass Index; CRP, C-Reactive Protein

Chest-CT. Chest-CT identified COVID-19 related lung abnormalities in all patients.

A total of 12 patients (15%) showed focal and sporadic ground-glass opacities (GGOs), not reaching the pleural surface, associated with smooth interlobular and intralobular septal thickening in both lungs. This

pattern was observed in younger patients (mean age 38.75±5.17), with less severe clinical presentations (mean C-reactive protein, CRP: 10.34±5.73; mean peripheral oxygen saturation, SpO_2: 95.75±0.62).

A total of 58 patients (71%) showed bilateral, patchy or extensive, peripheral GGOs, completely or incompletely adherent to pleura, associated with smooth interlobular and intralobular septal thickening (crazy-paving pattern). Patients in this group, mean aged 71.22±10.46, had mild to moderate form of pneumonia (mean CRP: 18.28±6.59; mean peripheral oxygen saturation, SpO_2: 91.88±1.37).

The remaining 12 patients (15%) presented bilateral and peripheral dense pulmonary consolidations. The mean number of consolidations detected at Chest-CT was 4.91±2.12. In 3 of these patients there was also a mild pleural effusion. The 12 patients in this group were older (mean age 80.58±9.25) and had more severe disease (mean CRP: 31.70±2.35; mean peripheral oxygen saturation, SpO_2: 88.17±3.19), with co-morbidities including heart failure, diabetes and COPD.

Lung US. A total of 39 patients (48%) did not demonstrate any evidence of pulmonary disease on concurrent lung US. At Chest-CT, among these 39 patients, 11 (28%) presented focal and sporadic GGOs, not adherent to the pleural surface, and 28 (72%) a crazy pattern of bilateral, patchy or extensive, peripheral GGOs. Therefore, the global lung US sensitivity in detecting pulmonary lesions demonstrable at Chest-CT was 52% [CI: 0.411 to 0.636].

In only 1 patient, a focal GGO reaching the pleural surface and measuring 20 mm in diameter at Chest-CT was associated with a non-specific smooth subpleural nodulation at US, measuring approximately 9 mm.

The Chest-CT crazy pattern of bilateral, patchy or extensive, peripheral GGOs associated with smooth interlobular and intralobular septal thickening was identified at LUS in a total 30/58 patients (52%), with an echographic pattern consisting in a blurred and thickened hyperechoic pleural line, with or without associated subpleural hypoechoic lung striae, and B-lines below the pleural line **(figure 1)**.

LUS was able to identify bilateral pulmonary consolidations, with predominately ill-defined margins and mixed hyper-/hypo-echoic spot within, in all the 12 patients showing consolidation at CT. The mean number of consolidations detected at LUS was 2.18±0.30. However, in only 4/12 patients (33%) there was a good correlation between number and extension of consolidations identified at Chest-CT and those identified at US. In the other 8/12 patients (67%), some areas of consolidation identified at CT scan were not assessed on US because they were located in parts of the lung not accessible to US (i.e. retro-scapular area, subpleural mediastinal area, costo-vertebral junction regions) or because they were not completely adherent to the pleural surface **(figure 2)**. Lung US also detected small pleural effusions in 7 of these patients, showing a greater sensitivity for this finding with respect to Chest-CT [100% (CI: 0.590 to 1.00) vs 64% (CI: 0.308 to 0.891)].

Lung US accuracy in detecting Chest-CT Typical findings. To better assess the accuracy of lung US in the diagnosis of COVID-19 pneumonia, we systematically compared the CT findings, classified according the

four categories identified by the RSNA Expert Consensus Statement on Reporting Chest-CT Findings Related to COVID-19[17], with the corresponding US findings in our COVID-19 patients (Table 2).

In more details:

1. 70/82 patients (85%) in our case series demonstrated **typical CT findings.** Of these, 30/70 (43%) patients showed a non-specific sonographic pattern consisting in a blurred and thickened hyperechoic pleural line, with or without small subpleural hypoechoic lung striae, and B-lines below the pleural line and 12/70 (17%) presented bilateral pulmonary consolidations. In the remaining 28/70 patients (40%) no alterations were detected by US.
2. 12/82 patients (15%) presented **indeterminate CT findings**. At US, 1/12 patient (8%) demonstrated non-specific smooth subpleural nodulation The remaining 11/12 (92%) patients showed no US evidence of COVID-19 pneumonia.
3. None of the patients in our series demonstrated the **Atypical CT appearance.**
4. None of the patients in our series demonstrated **Normal CT appearance.**

<table>
<tr><th></th><th>CT findings</th><th colspan="2">US findings</th></tr>
<tr><td rowspan="3">Typical CT appearance (n=70)</td><td>Peripheral GGOs with a “crazy-paving” pattern (n=58)</td><td>Blurred and thickened hyperechoic pleural line + B-lines, coalescent or not +/- subpleural hypoechoic lung striae (n=30)</td><td>No alteration (n=28)</td></tr>
<tr><td rowspan="2">Peripheral pulmonary consolidations, mean number: 4.91±2.12 (n=12)</td><td rowspan="2">Bilateral pulmonary consolidations, mean number: 2.18±0.30 (n=12)</td><td>All the CT consolidations (n=4)</td></tr>
<tr><td>Only some CT consolidations (n=8)</td></tr>
<tr><td>Indeterminate CT appearance (n=12)</td><td>Focal GGOs without a clear distribuition (n=12)</td><td>Smooth subpleural hypoechoic nodulation (n=1)</td><td>No alteration (n=11)</td></tr>
</table>

Table 2. Comparison between US findings and Chest-CT findings classified in Typical and Indeterminate according to what proposed by the RSNA Expert Consensus Statement on Reporting Chest-CT Findings Related to COVID-19[17]. Abbreviations: n, number of patients; GGOs, Ground Glass Opacities.

The diagnostic accuracy of US in assessing typical CT findings was 65% [confidence interval (CI), 0.534 to 0.750], with a sensitivity of 60% [confidence interval (CI), 0.476 to 0.715], a specificity of 92% [confidence interval (CI), 0.615 to 0.998], a positive predictive value of 98% [confidence interval (CI), 0.877 to 0.999] and a negative predictive value of only 28% [confidence interval (CI), 0.150 to 0.449]. The Cohen’s kappa coefficient between Chest-CT and Lung US in diagnosing Typical COVID-19 lung lesion was weak (0.27).

The sensitivity of an echographic pattern consisting in a blurred and thickened hyperechoic pleural line with B-lines below it in detecting a CT peripheral “crazy-paving” pattern of GGOs (when reaching the pleural surface) was 52% [confidence interval (CI), 0.382 to 0.651]. US sensitivity in detecting CT subpleural consolidations was 100% [confidence interval (CI), 0.735 to 1.000]. However there was a significant statistical difference in the number of consolidations detected between US and CT (2.18±0.30 vs 4.91±2.12; p=0.002), showing US a sensitivity in detecting all the CT consolidations of only 33% [confidence interval (CI), 0.992 to 0.651].

Discussion

Generally, a *screening test* should be highly *sensitive*, allowing a large proportion of subjects affected by the disease to be correctly classified as having such disease. In our case series, Chest-CT identified COVID-19 lung abnormalities in all patients. On the contrary, the detection of COVID-19 lung abnormalities by LUS was impossible or inadequate in more than one third of cases. Therefore, LUS showed a lower global sensitivity (of about 52% in our casuistry) in detecting pulmonary lesions, compared to Chest-CT.

Indeed, with respect to CT-scan, LUS shows several technical limitations in lung parenchyma assessment. In particular, less than 70% of the pleura-pulmonary surface is visible with ultrasound[8,18]: part of the chest is US-probe-blinded, due to the overlying bone structures (i.e. ribs, scapulae); part of the lung is not adherent to pleural surface, preventing full US visibility of also big lesions due to the interposition of lung air content.

Intuitively, typical Chest-CT findings are more likely visible to LUS, being them distributed in a peripheral and posterior, diffuse or lower lung, zone. However, also the diagnostic accuracy of LUS in assessing typical CT findings in our case series was 65% (i.e. lower than that of Chest-CT), with a percent of true positive subjects (i.e. a sensitivity) of 60% and a probability of not having any typical alterations at CT scan in case of negative LUS (i.e. a negative predictive value) of only 28%. As a further confirm, the Cohen’s kappa coefficient between Chest-CT and Lung US in diagnosing Typical COVID-19 lung lesion was weak.

In particular, the sensitivity of an echographic pattern consisting in a blurred and thickened hyperechoic pleural line with B-lines below it in detecting a CT peripheral “crazy-paving” pattern of GGOs was of only 52%. Nevertheless, this artifactual US pattern is an unreliable, poor reproducible and potentially misleading diagnostic approach, due to variability among different intra- and inter-operator B-lines counting and ultrasound scan settings[19]. Indeed, the erroneous use of a medium-to-low frequency probe or excessive total gain and the lack of tissue harmonic imaging can generate a large number of such artifacts. Furthermore, the increase in the pleural line movement rate in dyspneic patients or the simple

change of positioning of the probe with respect to the curvature of the patient's chest can influence the perceptual semi-quantitative evaluation of B-lines[19].

Similar to chest-CT, LUS was able to assess subpleural consolidations in all cases (12/12). Despite this, it was possible to assess the exact number and extension of such consolidations only in a third of them. The reason for this discrepancy relies on the possibility that consolidated lung may be obscured also by a very thin layer of air in the more superficial lung or may be located in parts of the lung that are not accessible on US, such as the retro-scapular region, the mediastinal surface area or the costo-vertebral junction region. In such cases, the risk is to miss the detection of some lesions and/or underestimate the actual disease's extent **(figure 2)**.

The specificity and the positive predictive value in assessing US alterations in presence of typical CT findings were 92% and 97% respectively in our case series. This suggests that the probability of having typical CT patterns at Chest CT in a subject with positive LUS is high as well as the proportion of subjects without typical CT lesions and a negative LUS. This data, however, should be handled with care. In fact, this does not mean that LUS is highly specific in COVID-19 pneumonia. If correctly performed, LUS has a high specificity and a very high positive predictive value in assessing lesions that are adjacent to the viewable pleural surface, but, once again, it may not allow to visualize any alterations, if these are located in areas not accessible to US, such as in the case of the indeterminate Chest-CT lesions in our patients.

Nevertheless, it should be considered that the specificity and the positive predictive of the same LUS signs may be lowered in a normal setting of non epidemic COVID-19. Indeed, the sonographic findings described in our case series and in the current available literature on this topic[11,12,13,14,15] shows a considerable overlap with many other lung diseases. An irregular pleural line with increased B-lines may be visible in ARDS, heart failure, nephrotic syndrome, bacterial pneumonia, other viral pneumonia, also minimal pleural effusion, hydropneumothorax, fibrosis, pulmonary contusion, exacerbations of chronic obstructive pulmonary diseases and neoplastic lymphangitis[16]. Subpleural consolidations may be visible in other viral pneumonia, non viral pneumonia, atelectasis and lung cancer[16] and their LUS pattern - consisting in mixed hypo-echogenicity, with irregular, scarcely defined borders - is non-specific, not allows to distinguish one condition from another. Furthermore, some of these overlapping conditions may even be pre-existing in COVID-19 patients (especially in more severe cases) and LUS is often unable to discern a COVID-19 diagnosis in a population with such pre-existing cardiothoracic conditions, including chronic obstructive pulmonary disease, interstitial lung disease, cardiovascular disease and malignancies with cardiothoracic involvement[18,20].

The American College of Radiology (ACR) does not recommend the use of chest CT to screen patients for COVID-19 pneumonia, due to the high possibility of typical CT findings' overlapping with other viral and non-viral conditions[21]. Indeed, other preexisting pathologies may resemble the atypical or rare CT manifestations of this viral pneumonia[22]. Moreover, also confirmed positive patients can show negative chest CT[23]. For these reasons, it has been recommended a sparing use of CT, that has to be reserved for hospitalized, symptomatic patients with specific clinical indications. Viral testing remains the only

specific method of diagnosis, whose confirmation is required, even if radiologic findings are suggestive of COVID-19.

In our COVID-19 patients, LUS resulted falsely negative in most cases, showing much less sensitivity than Chest CT in assessing disease-related lesions. This inevitable result is conform with the physical characteristics and limitations of the pleuro-pulmonary ultrasound examination and highlights LUS inadequacy for a screening purpose[24]. Furthermore, due to the high non-specificity of US findings and the difficulty to discriminate possible pre-existing cardio-pulmonary comorbidities, the incidental detection of alterations that could be attributable to COVID-19 pneumonia should be regarded and classified with much more attention. To date, no comparative studies have been performed between COVID-19 patients and patients with other possible overlapping cardio-pulmonary diseases. Therefore, LUS is not suitable for formulating diagnostic hypotheses based on conjecturally specific clues that are, actually, not reproducible, difficult to demonstrate, confusing in case of pre-existing comorbidities and have never received unanimous consensus or solid support[24,25]. Moreover, one must ask how a method like US, which only visualizes a small part of the pulmonary parenchyma could ever enable a reliable assessment of diseases extent and severity[16,26]. With these consideration in mind, if the role of CT in COVID-19 is still debated, that of LUS is not unexpectedly even more uncertain.

Otherwise, LUS is an excellent imaging method for the study of pleural effusions, being able to detect also minimal amount of liquid. In this respect, LUS is greatly superior to other standard thoracic imaging techniques (i.e. both chest X-Ray and CT), as showed also in our report. Although pleural effusions are not a typical feature of COVID-19, ultrasound may therefore be very useful to guide pleural punctures for safer fluid drainage and for the assessment of the changes in the amount of pleural fluid over time. It would be interesting to assess, by further studies on large case series, if LUS could prove useful in the follow-up during therapy of consolidations ascertained by CT and visible by ultrasound (i.e. consolidation strictly adherent to the superficial pleura).

In conclusion, to date, with the exception for US-guided procedures and interventions, the use of LUS should not be indicated for diagnostic screening and monitoring of COVID-19 patients. As bedside US implies a prolonged exposure of operators to patients and *vice versa* (longer and closer than that of a CT examinations), any US examination in patients with COVID-19 should be limited to essential imaging procedures for the ongoing clinical management of the patient (not just lung US, but rather thyroid, carotid artery, liver, renal or any other examinations), with operators protected by all the necessary personal protective equipment (PPE) in order to avoid infection transmission. Other LUS uses in patients with COVID-19 should be justified only within the context of a controlled research study.

Declarations

- This study involved human subjects.
- The author confirmed that all appropriate ethical guidelines for the use of human subjects have been followed, any necessary IRB and/or ethics committee review has been obtained, and information

about the IRB/ethics committee is included in the manuscript.

- The author has confirmed that all necessary patient/participant consent or assent has been obtained and the appropriate institutional forms have been archived. If the IRB/ethics committee waived the requirement for patient/participant consent or assent, an explanation for the waiver is included in the text.
- The author has confirmed that a statement listing potential conflicts of interest or lack thereof is included in the text.

Author contributions

All the authors contributed to the conception and design of the study. Q.C.M.I., M.A., D.L., M.V. and M.S. contributed to acquisition and interpretation of data, to drafting the work, to write the main text of the manuscript and revising it critically. R.R., M.M.M., R.G., S.A. and F.B. contributed to acquisition and interpretation of data, including lung ultrasound and Chest CT. All authors reviewed the manuscript and approved its submitted form.

Competing interests

All the authors certify to have not any actual or potential conflict of interest to disclose, including any financial, personal or other relationships with other people or organizations that could inappropriately influence or bias the work.

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Figures

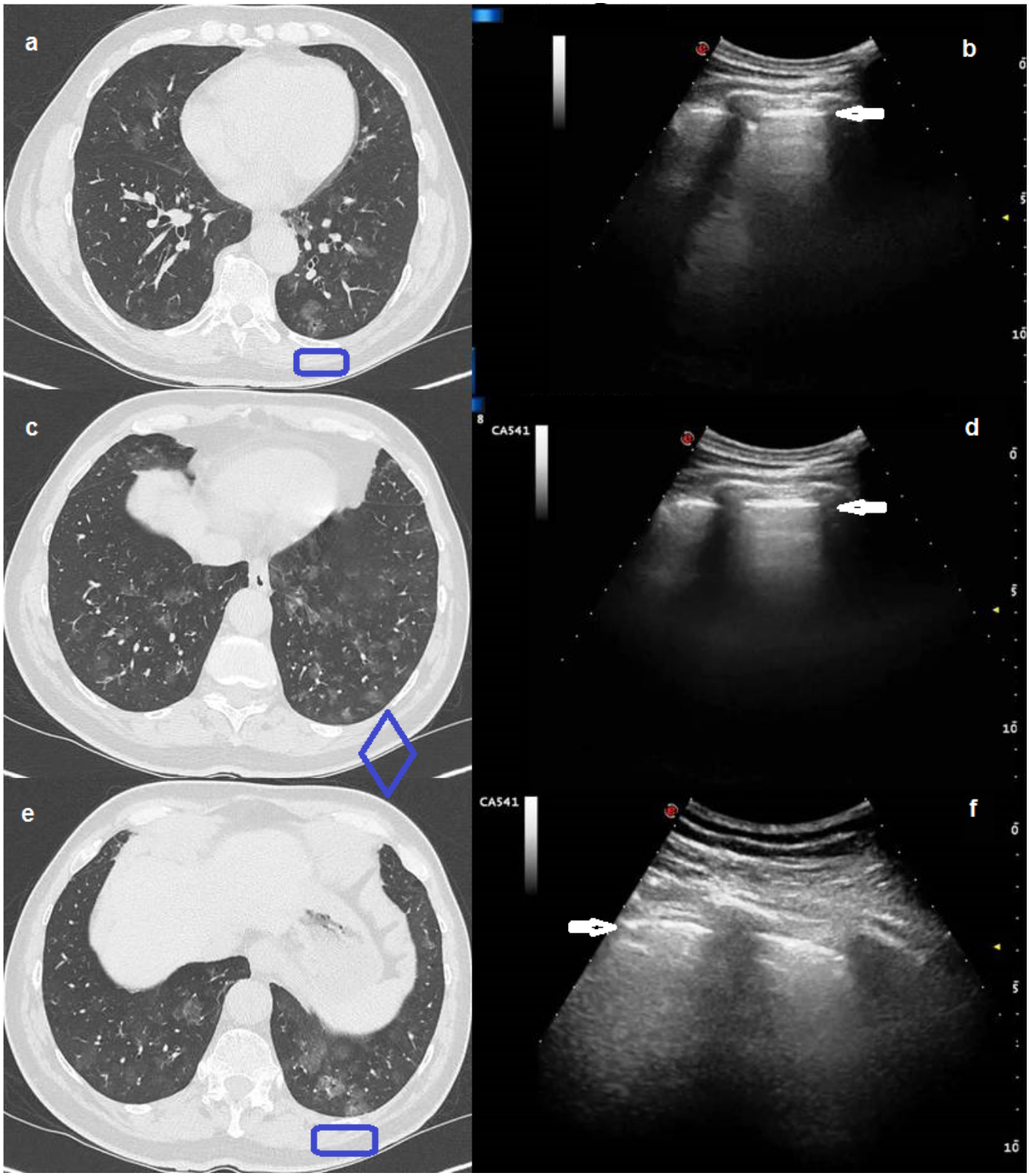

Figure 1

Figure 1. A 41-year-old male patient, presenting with a one week history of persistent and worsening dry cough and fever with fatigue. The RT-PCR assay for the SARS-COV-2 showed a positive result. CT scans in (a), (c) and (e) show a diffuse pure bilateral ground glass opacity (GGO), also peripherally distributed, but not adherent to pleural surface. Ultrasound scans in (b), (d) and (f) (corresponding to the blue boxes

in the respective (a), (c) and (e) CT scans), with a convex probe (6 MHz) and thoracic setting, do not show any pathologic pattern. The hyperechoic pleural line is highlighted by a white arrow.

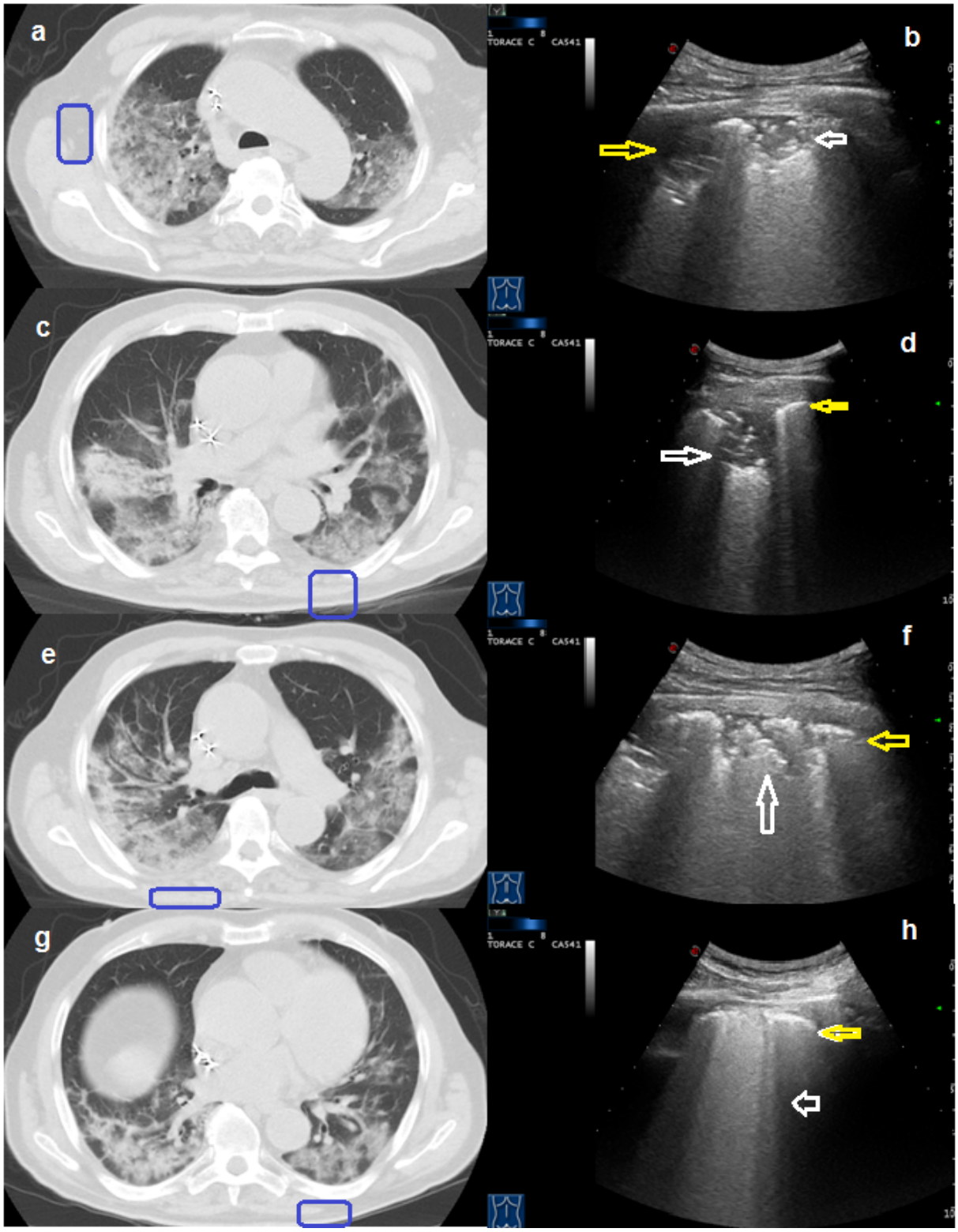

Figure 2

Figure 2. A 78-year-old male patient, presenting fever with cough for 10 days. The RT-PCR assay confirmed the suspect for COVID-19 pneumonia. CT scans in a, d, e and g show bilateral large ground-glass opacities and peripheral consolidative areas. The peripheral subpleural consolidation showed at CT

scan in (a) is in part located in the retroscapular area (blue box). In (b) the corresponding US scan with a convex probe (6 MHz) shows a mixed hypo-echoic subpleural consolidation (white arrows), that represents the non-retroscapular part of the right lung consolidation. The retroscapular part is US-probe blinded (yellow arrow). Consolidations showed at CT scan in (c) and (e) were partially adherent to the pleural surface. In (d) and (f), ultrasound scans with a convex probe (6 MHz) and thoracic setting (corresponding to the blue boxes in (c) and (e)) allow to show the adherent to the pleural surface parts of such consolidations, presenting a mixed hypo-echoic pattern. In (f) there are also small subpleural hypoechoic lung striae. Consolidations showed at CT scan in (g) are not perfectly adherent to the pleural surface. In (h) the ultrasound scan with a convex probe (6 MHz) and thoracic setting (corresponding to the blue box in (g)) allows to view only a blurred and thickened hyperechoic pleural line (yellow arrow), with B line below it (white arrows).