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REUE | Original Article

Usefulness of lung ultrasound in Emergency Department patients suspected of having COVID-19

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OBJECTIVE. To describe lung ultrasound findings in hospital emergency department patients suspected of having COVID-19.

MATERIAL AND METHODS. Lung ultrasound images were recorded between March 2020 and November 2021 along with polymerase chain reaction (PCR) and rapid antigen test results. We also recorded the findings of plain chest films and progression of disease.

RESULTS. A total of 649 ultrasound images were evaluated; 344 patients (53%) were discharged and 305 (46.99%) were hospitalized. The disease progressed and became severe in 73 patients (11.25%). The ultrasound findings suggested COVID-19 in 415 patients (63.94%), and 371 patients (71.5%) had positive PCR or antigen test results. Of the 371 patients with ultrasound findings suggestive of COVID-19 (89.39%), 147 of them (35.42%) also had a chest film suggestive of COVID-19. The most common ultrasound findings were an absence of pleural effusion (97.5%), diffuse involvement (71%), coalescing B lines (56%), subpleural consolidations (52%), 3 or more B lines in 2 or more zones (51%), 3 or more B lines bilaterally in 2 or more zones (41.62%), and consolidations (11%). These percentages were higher in the group of patients with acute respiratory failure or whose disease progressed.

CONCLUSIONS. Lung ultrasonography can be an excellent tool for detecting COVID-19 pneumonia and can help identify patients with false negative PCR tests or non-suggestive chest films.

Keywords: Ultrasonography. Emergency medicine. COVID-19. SARS-CoV-2. Lung disease. Diagnostic imaging.

Utilidad de la ecografía pulmonar en pacientes con COVID-19 en urgencias

OBJETIVO. Describir los hallazgos en la ecografía pulmonar en pacientes atendidos en un servicio de urgencias hospitalarias con clínica sospechosa de COVID-19.

MATERIAL Y MÉTODOS. Ecografías pulmonares realiazadas entre marzo de 2020 y noviembre del 2021, a pacientes con sospecha de infección por COVID-19 en urgencias de un hospital comarcal, junto con los resultados de la reacción en cadena de polimerasa (PCR) o en test de antígeno rápido (TAR), los resultados en la radiografía de tórax (RxTx), y mala evolución clínica.

RESULTADOS. Se inlcuyeron 649 ecografías. Un 53% de pacientes (344) fueron dados de alta y un 46,99% (305) ingresaron. El 11,25% (73) presentaron mala evolución. El 63,94% (415) presentaron una ecografía sugestiva de COVID-19 y un 71,48% (371) PCR/TAR positivos. De los pacientes con ecografía sugestiva de COVID-19, el 89,39% (371) tenían la PCR/TAR positiva y un 35,42% (147) la RxTx sugestiva de COVID-19. Los hallazgos ecográficos más frecuentes fueron la ausencia de derrame pleural (97,5%), la afectación difusa (71%), las líneas B (LB) coalescentes (56%), las consolidaciones subpleurales (52%), ≥ 3 LB en ≥ 2 zonas (51%), ≥ 3 LB en ≥ 2 zonas con afectación bilateral (41,62%) y las consolidaciones (11%). Estos porcentajes aumentaban en caso de insuficiencia respiratoria aguda y en situaciones de mala evolución clínica.

CONCLUSIONES. La ecografía pulmonar puede ser una herramienta excelente para detectar la neumonía por COVID-19 y puede ayudar a identificar los pacientes con PCR falsamente negativa o bien con RxTx no indicadora de infección por COVID-19.

Palabras clave: Ultrasonografía. Medicina de urgencias. COVID-19. SARS-CoV-2. Enfermedades pulmonares. Diagnóstico por imagen.

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Introduction

In December 2019, the first cases of pneumonia caused by a new coronavirus, SARS-CoV-2 or COVID-19, were identified.[1] On March 11, 2020, the World Health Organization (WHO) declared a global COVID-19 pandemic.[2]

Rapid identification of cases and severity stratification became essential, which created the need for reliable and effective diagnostic tools.

The diagnostic method of choice was the polymerase chain reaction (PCR) test or the rapid antigen test (RAT) for SARS-CoV-2 in a nasopharyngeal swab sample,[3,4] with an estimated sensitivity of around 66–80%, depending on the technique used and the stage of infection.[5]

Chest X-ray (CXR) has a sensitivity of 59–69% in hospitalized patients and 42% in outpatients.[6,7] Computed tomography (CT)[8] and lung ultrasound9 have similar sensitivity, approximately 94%.

According to the published medical literature, radiological interstitial patterns similar to other coronaviruses have been identified in COVID-19-induced pneumonia.[10,11] Feng Pan *et al.*[12] observed changes occurring on CT from the early stages of the disease—ground-glass opacities predominantly in the lower lobes, with peripheral and bilateral involvement—progressing to multilobar consolidations in more severe cases.[12,13]

Performing chest CT during the pandemic posed major limitations: risk of transmission during transport, management of hemodynamic instability in patients, time required for the examination and subsequent disinfection, cost, radiation exposure, etc.

Given the peripheral lung involvement in COVID-19, several studies have been published on the role of lung ultrasound in these clinical settings.[14-16]

Volpicelli *et al.*[17] and Galgani *et al.*[18] published a review proposing four probability categories of COVID-19-induced pneumonia according to ultrasound findings: irregular pleural line, focal, multifocal and/or coalescent B-lines (light beam), subpleural consolidations, patchy involvement (normal and pathological areas alternating), and—less frequently—lobar consolidations.[19,20]

Lung ultrasound is a rapid and sensitive tool for detecting signs of pulmonary involvement in COVID-19 and may be highly useful in triage, severity stratification, and monitoring of the aeration pattern in critically ill patients.[21,22]

Therefore, the aim of our study is to describe the characteristics of the group of patients in our emergency department with clinical suspicion of COVID-19 and the ultrasound findings of COVID-19 infection.

As secondary endpoints, we aimed to compare lung ultrasounds suggestive of COVID-19 with PCR/RAT results and CXR abnormalities and determine the relationship of these findings in patients who developed acute respiratory failure (ARF) and poor clinical outcomes during hospitalization.

Material and methods

We conducted an observational, descriptive, cross-sectional, and retrospective study between March 2020 and November 2021, including patients who presented to the emergency department of a regional hospital with symptoms of COVID-19 infection.

Inclusion criteria were patients older than 14 years with symptoms suggestive of COVID-19 infection, in whom a clinical lung ultrasound could be performed and who provided informed consent. Symptoms suggestive of COVID-19 included fever and/or dyspnea and/or odynophagia and/or headache and/or anosmia and/or ageusia and/or diarrhea or vomiting. Exclusion criteria were incomplete demographic or ultrasound data, unknown symptom onset time, and history of previous COVID-19 infection with negative PCR/RAT at the time of the emergency visit.

Sampling was non-probabilistic, by clusters, and the initially estimated sample size was 160 patients, with a 95% confidence interval (CI) and a precision of 15 percentage points. A 10% loss was estimated.

General sociodemographic variables (age, sex, visit date, triage level according to the Andorran Triage Model, smoking status, comorbidities) and clinical variables (symptoms, days of symptoms, respiratory rate, oxygen saturation, fraction of inspired oxygen, temperature, PCR/RAT result, CXR result, lung ultrasound result, patient disposition, need for ventilation) were collected.

COVID-19 pulmonary involvement on ultrasound was defined as ≥ 3 B-lines or coalescent B-lines in ≥ 2 lung fields with bilateral involvement and absence of pleural effusion.[17,18]

The scoring system of Soldati *et al.* was used to grade ultrasound findings in 12 thoracic areas: 0 points: A-lines or < 3 B-lines, 1 point: ≥ 3 B-lines, 2 points: coalescent B-lines or subpleural consolidations, 3 points: consolidations > 3 cm or involvement of > 50% of studied lung fields or ≥ 6 affected areas.[15]

CXR was considered suspicious for COVID-19 when diffuse interstitial infiltrates with bilateral involvement were present.

Since all hospitalized patients in our study required oxygen therapy because they presented with ARF,[23] such condition was considered equivalent to the need for hospital admission.[24] Poor outcome criteria included the need for non-invasive mechanical ventilation (NIV) and/or invasive mechanical ventilation (IMV) or death.

A Mindray DC40 ultrasound machine and a portable Léleman S7 probe (lung preset, convex probe, and image recording) were used. Ultrasounds were performed by emergency physicians with at least 5 hours of training in this imaging modality.[17] Thoracic areas were explored according to expert consensus,[25,26] and findings were recorded on a standardized Excel® sheet.

CXRs were performed using portable BMX-AR30 and Transportix B-D-C (TX-40HF-B-D-C) equipment in anteroposterior projection. Interpretation and reporting were carried out by radiologists who were blinded to clinical symptoms and ultrasound findings.

Data collection was performed by reviewing the health records of included patients, following prior telephone-obtained informed consent. All calls were recorded, and identity

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was verified using full name and national identity document and/or foreigner identification document. Patients/family members were provided with brief study information and then sent full documentation via email and/or postal mail.

Due to pandemic evolution, starting March 1st, 2021, written informed consent was obtained directly during the emergency visit, completed by the patient or legal representative.

The study was approved and supervised by *Hospital Josep Trueta* (Girona, Catalonia, Spain) Clinical Research Ethics Committee (CEIC). Statistical analysis of quantitative variables included descriptive measures of central tendency (mean, median, percentiles) and dispersion (standard deviation). Qualitative variables were expressed as absolute and relative frequencies.

The proportion of patients with specific characteristics was reported using point estimates with 95% confidence intervals (95% CI).

The association between ultrasound findings and positive PCR/RAT COVID-19 results, ARF, and poor outcomes was assessed using odds ratios (OR) with 95% CI. When necessary, ORs were adjusted for other study variables using logistic regression models.

Analyses were performed with STATA 17.0, using a significance level of 5%.

Results

A total of 727 lung ultrasounds were performed during the study period, with 78 patients excluded, resulting in an N of 649 cases.

The sociodemographic and clinical results are shown in Table 1.

A total of 64% of patients (416) with clinical suspicion of COVID-19 presented a lung ultrasound suggestive of COVID-19 (Figure 1).

A total of 412 patients (63.5%) showed > 50% involvement of the total explored lung area (or > 6 affected thoracic areas).

PCR/RAT tested positive in 520 patients (80%), and of these, 71.54% (372) had a suggestive ultrasound (Figure 2). A total of 57.32% had a positive PCR/RAT and a lung ultrasound suggestive of COVID. Only 3.7% (24) with a suggestive ultrasound had a negative PCR/RAT.

A total of 9.24% (60 patients) had a non-suggestive ultrasound and negative PCR/RAT.

Overall, a total of 148 patients (22.8%) had a positive PCR/RAT, but the ultrasound was not suggestive. In 45 patients (7%) PCR/RAT could not be performed; among them, 20 (3%) had a lung ultrasound suggestive of COVID-19.

Of the patients with a suggestive ultrasound, 89.4% (372) had a positive PCR/RAT, and among these, 39.52% (147) had a CXR which was consistent with COVID, 28.49% (106) had a normal CXR and 29.57% (110) had an abnormal CXR, which was not suggestive of COVID-19.

A total of 1.9% (8) had negative PCR/RAT with a CXR and an ultrasound suggestive of COVID-19. There were only 28 patients with a CXR suggestive of COVID-19 and a

Table 1. Sociodemographic and clinical variables

Variables	N = 649 n (%)	Median (SD)
Sex		
Woman	278 (42.84)	
Man	371 (57.16)	
Age		56.3 (17.32)
Smoking status		
Smoker	48 (7.40)	
Non-smoker	488 (75.19)	
Former smoker	113 (17.41)	
Comorbidities		
Yes	399 (61.01)	
No	255 (38.99)	
Type of comorbidity		
Obesity	127 (19.57)	
Hypertension	204 (31.43)	
Diabetes mellitus	87 (13.41)	
Lung disease	92 (14.18)	
Heart disease	52 (8.01)	
Stroke	14 (2.16)	
Immunosuppression	20 (3.09)	
Neoplasm	35 (5.39)	
Liver disease	11 (1.69)	
Kidney disease	27 (4.16)	
Endocrinopathy	84 (12.94)	
Dyslipidemia	51 (7.86)	
Neurological disease	7 (1.08)	
Digestive disease	7 (1.08)	
Pregnant	12 (1.85)	
COVID-19 PCR		
Not performed	45 (6.93)	
Negative	84 (12.94)	
Positive	520 (80.12)	
Days with symptoms		7.36 (5.55)
Symptoms		
Cough	440 (67.80)	
Dyspnea	275 (42.37)	
Sore throat	56 (8.63)	
Fever	479 (73.92)	
Headache	129 (19.88)	
Anosmia	77 (11.86)	
Ageusia	68 (10.48)	
Vomiting and/or diarrhea	136 (20.96)	
Respiratory rate (breaths/min)		23.44 (6.32)
SAFI (O_2 saturation/FiO_2)		442.70 (65.46)
Chest X-ray (CXR)		
Performed	607 (93.53)	
Not performed	42 (6.47)	
CXR results (N = 450)		
Suggestive of COVID-19	184 (30.31)	
Not suggestive of COVID-19	423 (69.69)	
Lung ultrasound		
Suggestive of COVID-19	416 (64.1)	
Not suggestive of COVID-19	233 (35.9)	
Disposition		
Discharged	344 (53)	
Admitted	305 (47)	
Poor outcomes		
Total	73 (11.25)	
Deaths	9 (1.39)	
IMV	15 (2.31)	
NIV or HFOT	58 (8.93)	

IMV: invasive mechanical ventilation; NIV: non-invasive mechanical ventilation; HFOT: high-flow oxygen therapy.

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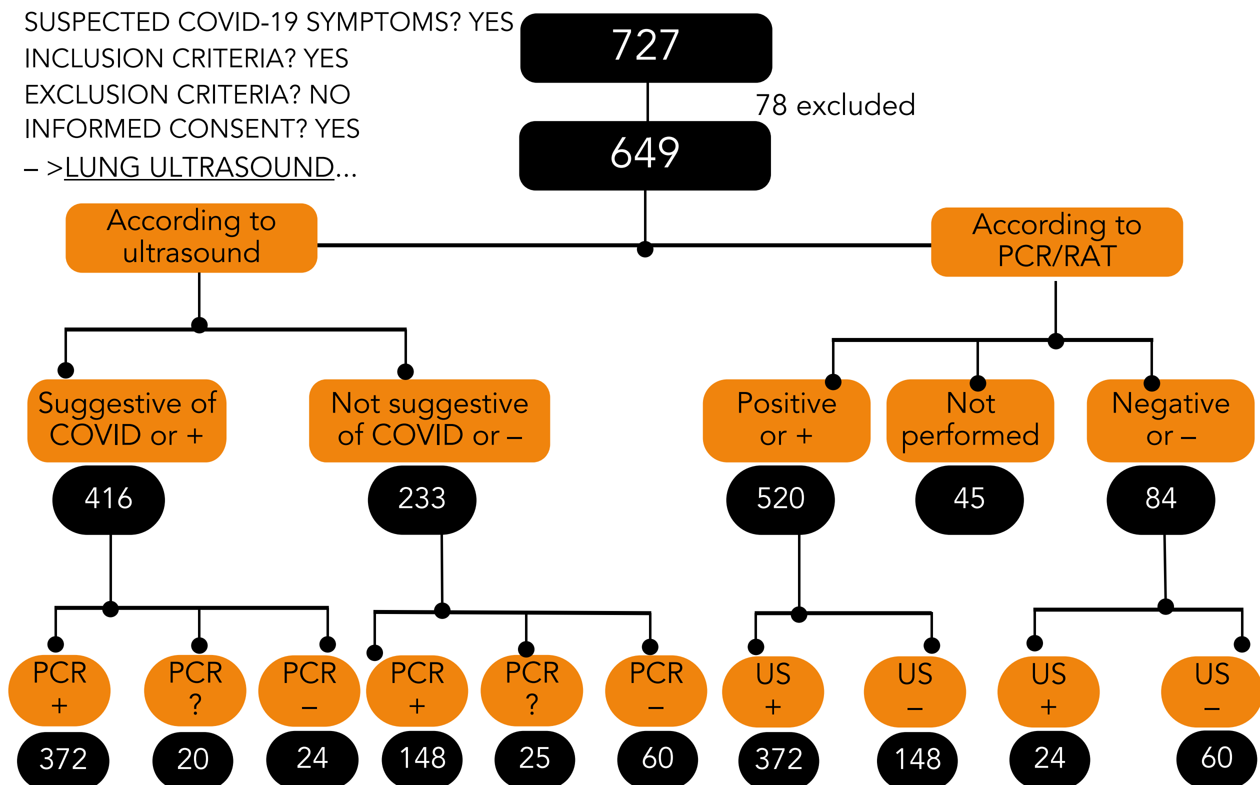

Figure 1. Flowchart of study patients.
US +: Lung ultrasound suggestive of COVID-19; US –: Non-suggestive ultrasound; PCR/RAT +: Positive PCR or rapid antigen test for COVID-19; PCR/RAT –: Negative PCR or rapid antigen test for COVID-19; PCR/RAT ?: PCR or rapid antigen test for COVID-19 not performed.

non-suggestive ultrasound, and of these 20 patients (3%) had a positive PCR/RAT (Figure 3).

The ultrasound findings in patients with positive PCR/RAT were, in order of frequency: absence of pleural effusion in 507 patients (97.5%; OR, 0.47 with 95% CI, $P < .05$), involvement of ≥ 50% or ≥ 6 areas in 368 (70.77%; OR, 2.54), coalescent B-lines in 294 (56.53%; OR = 2.13), subpleural consolidations in 271 (52.12%; OR = 1.36), ≥ 3 B-lines in ≥ 2 zones in 267 (51.35%; OR = 1.6), ≥ 3 B-lines in ≥ 2 bilateral zones in 217 (41.73%; OR = 1.75), and consolidations in any location in 42 (8.08%; OR = 0.94) (Figure 4). In the subgroup of PCR/RAT-positive patients who presented ARF (N = 257, 39.6% of the total), the observed abnormalities were: absence of pleural effusion in 246 (95.72%; OR = 0.23), involvement of ≥ 50% or ≥ 6 areas in 222 (86.38%; OR = 4.68), coalescent B-lines in 173 (67.32%; OR = 3.78), subpleural consolidations in 170 (66.15%; OR = 1.61), ≥ 3 B-lines in ≥ 2 zones in 179 (69.65%; OR = 2.27), ≥ 3 B-lines in ≥ 2 bilateral zones in 154 (59.92%; OR = 2.17), and consolidations in 30 (71.43%; OR = 3.08). Finally, in the subgroup of PCR/RAT-positive patients with a poor course of the disease during hospitalization (N = 68), the following were observed: absence of pleural effusion in 66 (97.1%; OR = 2.04), involvement of ≥ 50% or ≥ 6 areas in 62 (91.2%; OR = 4.93), coalescent B-lines in 46 (67.65%; OR = 1.72), subpleural consolidations in 44 (64.7%; OR = 1.82), ≥ 3 B-lines in ≥ 2 zones in 51 (75%; OR = 3.28), ≥ 3 B-lines in ≥ 2 bilateral zones in 48 (70.59%; OR = 4.01), and consolidations in 8 (11.76%; OR = 1.98).

The ultrasound score of findings was 16.19 (SD = 9) in the PCR/RAT-positive group, 20 (SD = 7.29) in the ARF group, and 20.81 (SD = 6.83) in the poor-course-of-the-disease group. Ultrasound was suggestive of COVID in PCR/RAT-positive patients in 371 cases (71.48%), in 221 (85.33%) with ARF, and in 61 (88.41%) with poor evolution. CXR was also suggestive of COVID in 167 (32.18%), in 138 (53.28%) with ARF, and in 43 (62.32%) with poor evolution (Figure 5).

Discussion

The results of our study show that lung ultrasound is a good tool for detecting COVID-19-induced pneumonia in patients presenting to the emergency department with suspicious symptoms during a pandemic, which is consistent with other studies.[12,14-18,20-22,24,25,27,28]

Some patients with positive PCR/RAT and a non-suggestive ultrasound were detected, probably because they were in the early days of viral infection or did not yet have pulmonary involvement.

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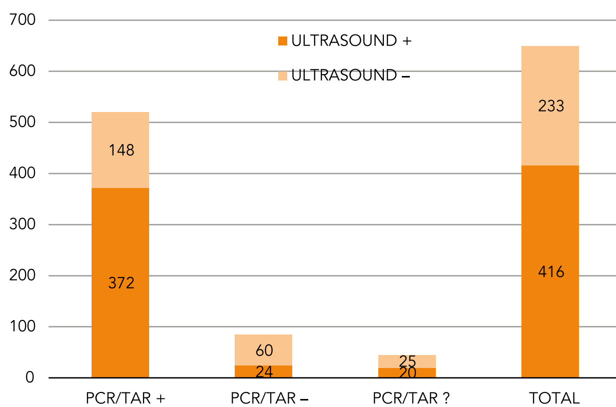

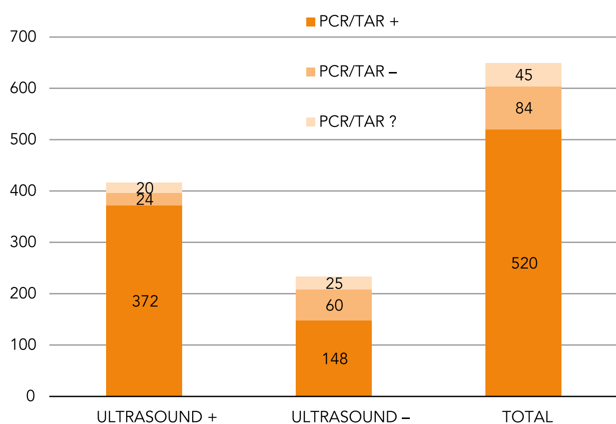

Figure 2. Patients with lung ultrasound suggestive or not suggestive of COVID-19 according to PCR/RAT results, and PCR/RAT results according to lung ultrasound findings.
Ultrasound +: Suggestive of COVID-19; Ultrasound –: Non-suggestive; PCR/RAT +: Positive; PCR/RAT –: Negative; PCR/RAT ?: Not performed.

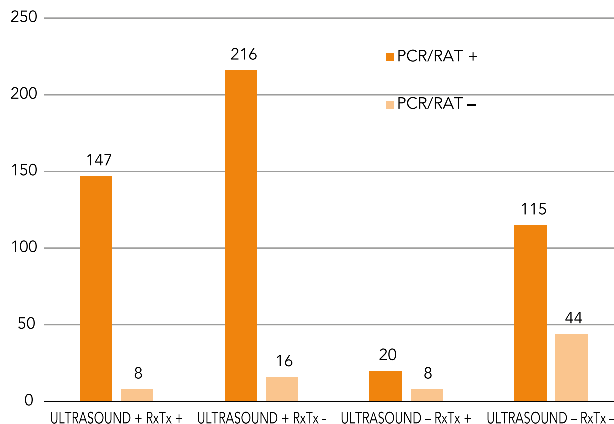

Figure 3. Lung ultrasound findings according to chest X-ray and PCR/RAT results.
Ultrasound +: Suggestive of COVID-19; Ultrasound –: Non-suggestive; PCR/RAT +: Positive; PCR/RAT –: Negative; PCR/RAT ?: Not performed; CXR +: Chest X-ray suggestive of COVID-19; CXR –: Chest X-ray not suggestive.

There were few cases with negative PCR and a suggestive ultrasound; we assume these results may be due to false-negative PCR tests or to nonspecific ultrasound patterns that can mimic COVID-19.[29]

The most frequent ultrasound findings observed in PCR/RAT-positive patients were B-lines forming an interstitial pattern with ≥ 3 B-lines in ≥ 2 fields, bilaterally and diffusely, and especially the absence of pleural effusion—results consistent with recent publications.[9,12,15,16,18,20,22,24,25,28]

These findings became more prevalent in patients with ARF and in the poor-evolution group.

In contrast, we observed a slight increase in the percentage of pleural effusion in more severe patients, which could be explained by the presence of greater comorbidity.

The specificity of lung ultrasound in COVID-19 is likely not very high, since similar findings are seen in other viral lung diseases,[29] pulmonary embolism, metastases, chronic interstitial diseases, etc. In any case, considering the context of our study, with high prevalence of COVID-19, the specificity is much higher.

Consistent with the abovementioned results, in 54% of patients with a positive COVID-19 test and a non-suggestive CXR, we detected pulmonary involvement through lung ultrasound. Therefore, lung ultrasound may help identify patients with COVID-19-induced pneumonia who have a falsely negative PCR or a non-suggestive CXR. This finding is consistent with former studies reporting high sensitivity for early detection of viral pneumonia.[16,17,19,29,30]

Only 3% of PCR/RAT-positive patients had a non-suggestive ultrasound and a suggestive CXR; however, these were patients with pre-existing chronic pulmonary or cardiac disease who did not meet ultrasound criteria for COVID-19-induced pneumonia.

Lung ultrasound should be an additional imaging modality to CXR and is very useful in early or mild pneumonia in which radiological abnormalities are not yet visible, as it is more sensitive, harmless, and rapid. In more severe patients (ARF or poor course of the disease), we observed that these differences are smaller because radiological changes become more evident.

In the design of our study objectives, comparison between ultrasound, CXR, and CT findings was not included because, during the pandemic, in our hospital (a regional healthcare center), CT was performed only in patients admitted to the intensive care unit or with suspicion of pulmonary embolism.

Another limitation of the study was the difficulty in recruiting severely ill patients (only 15 requiring IMV and 9 deaths), probably because—even if a lung ultrasound was performed—the report was verbal and not written, and the patient was quickly transferred under the care of the critical care unit.

We believe that the use of clinical lung ultrasound integrated into the initial assessment of the COVID-19 patient, together with PCR/RAT and CXR, may improve diagnostic and possibly prognostic sensitivity.

More studies are needed to establish stratification, prognosis, and monitoring of ultrasound findings in relation to the clinical course of this disease.

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PCR/RAT + and poor outcome (N 69)
PCR/RAT + with ARF (N 259)
PCR/RAT + (N 519)
95% IC $P < .05$

Consolidations
12 OR = 1.98 (0.8-4.4)
12 OR = 3.08 (1.55-6.14)
11 OR = 0.78 (0.32-1.91)

Subpleural consolidations
65 OR = 1.82 (1-3)
66 OR = 1.62 (1.09-2.38)
52 OR = 1.34 (1.02-1.76)

≥ 3LB in ≥ 2 bilateral zones
71 OR = 4.02 (2.3-7)
60 OR = 2.17 (1.4-3.35)
42 OR = 1.63 (1.2-2.2)

≥ 3LB in ≥ 2 zones
75 OR = 3.28 (1.8-5.8)
70 OR = 2.27 (1.5-3.4)
51 OR = 1.58 (1.19-2.1)

Coalescent BL
68 OR = 1.72 (1-2.9)
67 OR = 3.78 (2.46-5.83)
56 OR = 2.13 (1.57-2.88)

Involvement ≥ 50% or ≥ 6 zones
92 OR = 4.93 (2-11.6)
86 OR = 4.68 (3.1-7)
71 OR = 2.54 (1.89-3.4)

Absence of pleural effusion
81 OR = 2.04 (0.54-7.60)
95 OR = 0.23 (0.1-0.5)
98 OR = 0.47 (0.28-0.77)

0 50 100 150

Figure 4. Percentage of lung ultrasound abnormalities in PCR/RAT-positive patients according to severity level.
PCR/RAT +: Positive test; ARF: Acute respiratory failure; poor course of the disease: requirement of invasive and/or non-invasive mechanical ventilation or death; BL: B-lines; OR: odds ratio; CI: confidence interval.

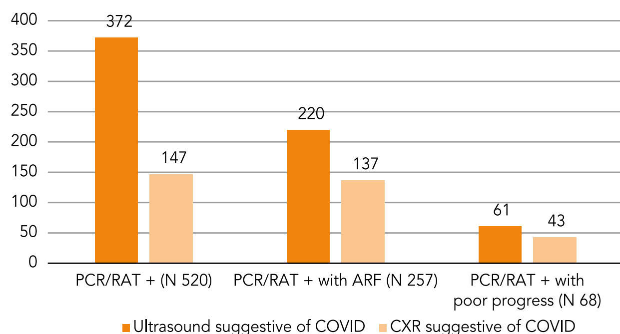

Figure 5. Differences between the results of lung ultrasound suggestive of COVID-19 and chest X-ray suggestive of COVID-19 according to the level of severity in PCR/TAR-positive patients.
PCR/RAT +: Positive test; ARF: Acute respiratory failure; poor course of the disease: requirement of invasive and/or non-invasive mechanical ventilation or death; Ultrasound suggestive of COVID: 3 B lines (BL) or coalescent BL in 2 lung fields with bilateral involvement and absence of pleural effusion; Chest X-ray suggestive of COVID: Chest X-ray with bilateral interstitial infiltrate.

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