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● Original Contribution

LUNG ULTRASOUND FINDINGS ARE ASSOCIATED WITH MORTALITY AND NEED FOR INTENSIVE CARE ADMISSION IN COVID-19 PATIENTS EVALUATED IN THE EMERGENCY DEPARTMENT

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Abstract—Lung ultrasound (LUS) has recently been advocated as an accurate tool to diagnose coronavirus disease 2019 (COVID-19) pneumonia. However, reports on its use are based mainly on hypothesis studies, case reports or small retrospective case series, while the prognostic role of LUS in COVID-19 patients has not yet been established. We conducted a prospective study aimed at assessing the ability of LUS to predict mortality and intensive care unit admission of COVID-19 patients evaluated in a tertiary level emergency department. Patients in our sample had a median of 6 lung areas with pathologic findings (inter-quartile range [IQR]: 6, range: 0–14), defined as a score different from 0. The median rate of lung areas involved was 71% (IQR: 64%, range: 0–100), while the median average score was 1.14 (IQR: 0.93, range: 0–3). A higher rate of pathologic lung areas and a higher average score were significantly associated with death, with an estimated difference of 40.5% (95% confidence interval [CI]: 4%–68%, $p = 0.01$) and of 0.47 (95% CI: 0.06–0.93, $p = 0.02$), respectively. Similarly, the same parameters were associated with a significantly higher risk of intensive care unit admission with estimated differences of 29% (95% CI: 8%–50%, $p = 0.008$) and 0.47 (95% CI: 0.05–0.93, $p = 0.02$), respectively. Our study indicates that LUS is able to detect COVID-19 pneumonia and to predict, during the first evaluation in the emergency department, patients at risk for intensive care unit admission and death. (E-mail: nicola.bonadia@policlinicogemelli.it) © 2020 World Federation for Ultrasound in Medicine & Biology. All rights reserved.

Key Words: Lung ultrasound, COVID-19, SARS-CoV-2, Emergency medicine, Pneumonia.

INTRODUCTION

On January 2020, a cluster of atypical pneumonia was described in Wuhan, China (Zhu et al. 2020), and subsequently found to be caused by a novel virus, belonging to the family of beta-coronavirus (Lu et al. 2020a). Since then, the virus has spread worldwide, causing more than 3 million infections and thousands of deaths. On March 11, 2020, the novel coronavirus disease 2019 (COVID-19) was declared a pandemic by the World Health

Organization (WHO 2020). COVID-19 poses several challenges for health care and economic systems of all countries: insufficient critical care availability, shortages of personal protective equipment, shortages of health care workers and high rates of infection among health care professionals (Ranney et al. 2020).

Although COVID-19 is characterized by a wide range of clinical manifestations, from asymptomatic or paucisymptomatic infections to critical disease and death, lung involvement is the mainstay of the disease (Guan et al. 2020; Weiss and Murdoch 2020). Chest X-ray, however, has low sensitivity (Guan et al. 2020), while chest computed tomography (CT) has been proven

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to have high sensitivity (Ai et al. 2020; Li and Xia 2020) and, according to some (but not all [Caruso et al. 2020]) authors, high specificity (He et al. 2020) in detecting COVID-19 pneumonia. Considering that the microbiologic isolation of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) with a nasopharyngeal swab also has low sensitivity (Tahamtan and Ardebili 2020), some authors have proposed the routine use of CT scan as a screening tool in diagnosis of COVID-19 in patients evaluated in the emergency department (ED) (Yang et al. 2020). However, this approach has a limitation: CT scan is not routinely available in most low- to middle-resource settings; therefore, such an approach would not be feasible in many countries. Because all countries are affected by the pandemic, the routine use of CT scan cannot be easily suggested. Moreover, CT scan would be available only in hospital settings. Recent evidence suggests that the diagnosis of COVID-19 in early phases of the disease would allow early treatment and containment measures. Therefore, a tool that would allow the diagnosis of pneumonia at point-of-care in every resource setting would be particularly useful. In this regard, lung ultrasound (LUS) has recently been advocated as a sensitive tool in the diagnosis of COVID-19 pneumonia, and main LUS patterns have been described (Soldati et al. 2020a, 2020b; Volpicelli and Gargani 2020; Volpicelli et al. 2020). However, information on the use of LUS is based mainly on anecdotal studies, small series or a larger study aimed at comparing LUS with CT (Lu et al. 2020b), while the prognostic role of LUS in COVID-19 patients has not yet been established.

For this reason, we performed this prospective study to evaluate the role of LUS in COVID-19 patients evaluated in a tertiary ED of a referral center for COVID-19.

METHODS

Study population

We conducted a single-center, prospective cohort study in a tertiary ED located in Rome, Italy. Our institution is a university hospital located in a metropolitan area and is currently serving as a referral center for COVID-19. In our ED, patients clinically suspected of having SARS-CoV-2 infection are admitted to a dedicated ED area.

Patients were recruited from March 1 to 31, 2020. We included symptomatic adult patients with a microbiologically confirmed infection with SARS-CoV-2. Patients were enrolled if they had a suggestive clinical presentation (dyspnea, fever, cough, coryza; for patients with a pre-existing chronic respiratory condition, worsening dyspnea or worsening respiratory failure were considered for inclusion), were 18 y or older at the time of the ED admission and were willing to participate in the study. Exclusion criteria were reduced life expectancy

(<6 mo) because of a pre-existing chronic illness according to the investigator's clinical judgment (e.g., advanced cancer, advanced dementia), inability to collaborate in the execution of LUS and lack of microbiologic confirmation of SARS-CoV-2 infection during the index hospitalization. Specifically, patients who were enrolled on the basis of clinical suspicion and for whom there was no microbiologic confirmation of SARS-CoV-2 infection by real-time reverse transcription polymerase chain reaction (RT-PCR) on a respiratory specimen (from either the upper or lower respiratory tract) were excluded from subsequent analysis. Moreover, we excluded patients who did not undergo LUS in the ED and those for whom data on the final outcome of the hospitalization were missing.

The variables collected for each patient were age; sex; clinical symptoms (fever, cough, dyspnea, other); type of ventilation required during admission (oxygen, high-flow oxygen therapy [HFOT-Optiflow], continuous positive airway pressure, non-invasive positive-pressure ventilation, invasive ventilation); electrolyte and acid-base balance (FiO_2 , pH, pO_2 , pCO_2 , HCO_3^- , lactate, P/F); and P/F class (no acute respiratory distress syndrome [ARDS), mild, moderate or severe ARDS). In addition, for each patient included in the study we collected results from the following investigations: chest X-ray; chest CT scan if performed; real-time RT-PCR for SARS-CoV2 on an oropharyngeal and nasopharyngeal swab (and bronchoalveolar lavage if performed); and laboratory tests (hemoglobin, white blood cell count, neutrophil count, lymphocyte count, platelet count, C-reactive protein, procalcitonin, fibrinogen, d-dimer, albumin, ferritin, lactate dehydrogenase). For each chest X-ray/chest CT scan, we reported whether it was positive for a unilateral or bilateral interstitial pattern, with or without pulmonary infiltrates.

Furthermore, for each patient we recorded the clinical outcome of the ED visit, defined as medical ward admission, intensive care unit (ICU) admission or discharge, and the final outcome of the hospitalization, defined as discharged or dead and need for intensive care admission during index hospitalization.

The study was approved by the ethics committee of our institution (ID No. 3146). Informed consent was obtained from each patient.

Ultrasound examination

Our LUS COVID team used a standardized approach with respect to equipment and acquisition protocol, as previously described by Soldati et al. (2020c). Soldati et al.'s approach requires division of the patient's chest into 14 areas (3 posterior, 2 lateral and 2 anterior areas on each side; Fig. 1a–d) and a single intercostal scan of each area. Then, each area is assigned a numeric

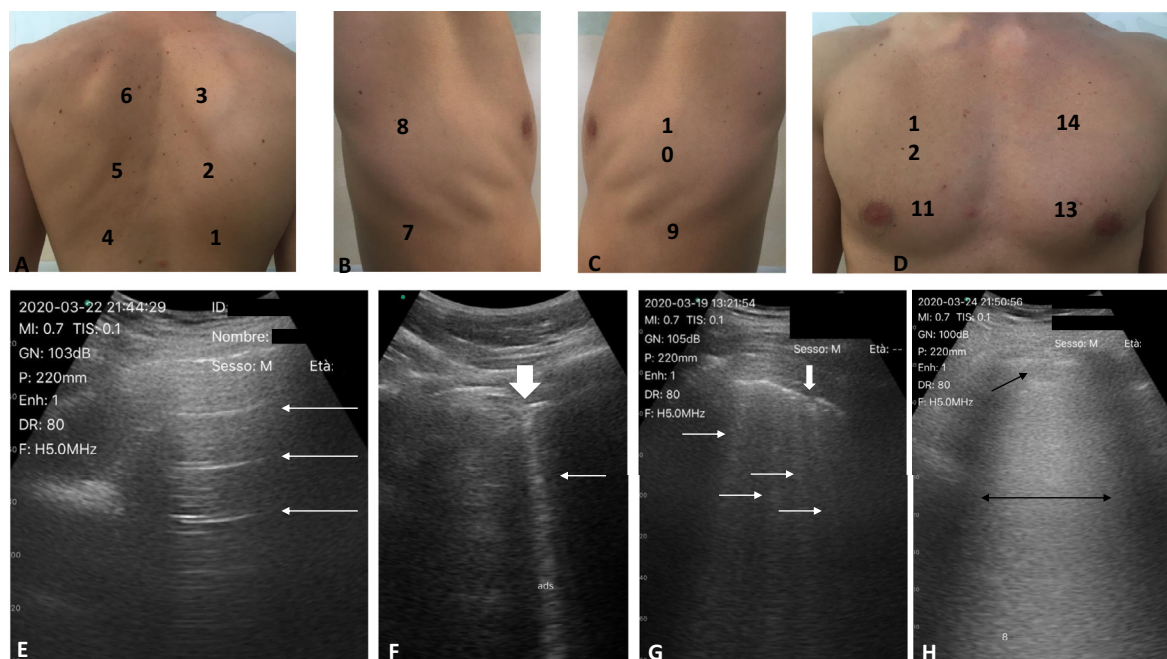


Fig. 1. Representation of lung ultrasound score for COVID-19 patients according to Soldati *et al.* (2020c). (a–d) Localization of the 14 areas evaluated with lung ultrasound. (e) Lung ultrasound score 0 (normal pattern), with clear A-lines (horizontal artifacts, *white arrows*). (f) Lung ultrasound score 1, with pleural line irregularity (*white, thick arrow*) and a single vertical artifact (B-line, *white arrow*). (g) Lung ultrasound score 2, with pleural line irregularity (*white, thick arrow*) and multiple but not confluent vertical artifacts (B-lines, *white arrow*). (h) Lung ultrasound score 3, with a subpleural consolidation (*black arrow*) and a large area of white lung (*double-head black arrow*).

score from 0–3 depending on the severity of findings (described below). No score is assigned to areas that are not accessible to examination (*e.g.*, posterior areas in patients unable to maintain a sitting position or area 13 when the cardiac window masked lung parenchyma).

All LUS assessments were performed by the authors, who, although not radiologists, are all ED staff and have at least 5 y of experience in point-of-care ultrasound at the first clinical examination in the ED. LUS was performed with a pocket device using a wireless 6-MHz convex probe (ATL s.r.l., Milan, Italy), collected in single-use plastic covers, as previously described (Buonsenso *et al.* 2020b), to reduce the risk of contamination and to facilitate sterilization procedures. For each LUS, we reported the patient's position (sitting/lying) and the type of ventilation used during the exam. Each exam was recorded, and scores awarded by each examiner underwent confirmation by at least two of the other authors. Overall, there was good concordance among the authors, particularly for extreme scores. Disagreement on single scores was resolved through collective discussion. Inter-rater reliability was established by calculation of Cohen's κ coefficient. Levels of inter-observer agreement were high ($\kappa > 0.8$) for scores 0 and 1 and good (κ between 0.6 and 0.8) for scores 2 and 3.

A total of 14 areas (3 posterior, 2 lateral and 2 anterior for each lung) were scanned per patient, registering a video of 10 seconds in each area. Scans were intercostal to cover the widest surface possible with a single scan, as COVID-19 pneumonia can be bilateral and involve any lung area. A standard sequence of evaluations were used, as described by Soldati *et al.* (2020c). In cases in which it was clinically impossible to evaluate the posterior lung areas of the patient, the operator started the exam from landmarks 7 to 14 (therefore, lateral and anterior surfaces were scanned).

We used the scoring system proposed by Soldati *et al.* (2020c) to classify the severity of lung involvement. In particular, for each area (Fig. 1e–h), we assigned the following scores: 0 = normal LUS examination; 1 = the pleural line is regular or irregular pleural line, visible non-confluent vertical artifacts; 2 = irregular pleural line, multiple confluent vertical artifacts and/or well subpleural consolidations; 3 = dense and largely extended areas of white lung with or without larger consolidations.

For each area, the score was assigned by the author performing the exam, with subsequent confirmation by at least two other authors reviewing the recorded clip. Disagreement was resolved through discussion among

all authors. Moreover, for each LUS we also registered the possible presence of single/multiple consolidations and/or pleural effusion.

For each patient, we recorded the total number of lung areas with pathological patterns, the mean score for the total area examined and the percentage of pathological area over total area examined (we included this last parameter because posterior areas were not examined in some patients in the ED because these patients could not be mobilized secondary to compromised clinical conditions).

Outcomes

The aim of this study was to investigate the usefulness of LUS in assessing the severity of COVID-19 pneumonia and to identify a potential correlation between LUS patterns and clinical outcome of the patient.

The *primary outcome* was the correlation between LUS patterns and patient mortality. The following LUS parameters were compared between surviving and deceased patients to identify predictors of mortality: mean LUS score, total number of pathologic areas at LUS examination and percentage of pathologic areas at LUS examination. Patients who were discharged home from the ED were considered discharged unless a subsequent admission to our hospital was recorded. When this occurred, we considered the LUS evaluation at the time of the first ED contact and the outcome from the last admission.

The *secondary outcomes* were to describe the LUS patterns of adult patients with COVID-19 evaluated in the ED, to correlate LUS parameters (score, total number and percentage of pathologic areas) with the need for ICU admission and invasive ventilation and to evaluate the concordance between ultrasound examination and standard chest X-ray.

Statistical analyses

Outcome of the hospital stay was considered a dichotomous variable for which only two values were possible (either death or discharge home). ICU admission was considered a dichotomous variable.

For each patient we calculated, as mentioned above, the average score as the mean of the scores in the examined areas, the absolute number of areas with a score >0 , the percentage of examined areas with a score higher than 0. These values were considered continuous variables. Normality was assessed by visual inspection of the resulting distribution of these variables. Therefore, patients were divided on the basis of final outcome of hospital stay (death/discharge), need for ICU admission (yes/no) and need for invasive ventilation (yes/no), and the above-described measures were compared in each pair of groups with the Mann–Whitney U -test for non-normal parameters and Student's t -test for normal

parameters. As none of these variables was normally distributed, comparisons were made only with the Mann–Whitney U -test. The level of significance was set at 0.05, two-sided.

Concordance between chest X-ray and LUS in the detection of overt COVID-19 pneumonia was determined by calculating Cohen's κ for cutoff values for different scores and percentages of involved area.

All statistical analyses were performed with the R programming language (R Foundation for Statistical Computing, Vienna, Austria), Version 3.6.0 (R Core Team 2019), used *via* the RStudio IDE (RStudio Team 2019, RStudio, Boston, MA, USA) and with the Tidyverse (Wickham et al. 2019) package.

RESULTS

Study population

Initially, 96 patients suspected of having COVID-19 were included in the study. Of those, 30 patients were excluded because they did not undergo LUS during the first clinical examination in the ED, and 12 were excluded because of reduced life expectancy owing to severe pre-existing comorbidities according to the evaluating physician. Of the 54 patients with suspected COVID-19 who underwent LUS during the first evaluation in the ED; 12 did not have a microbiologic confirmation of SARS-CoV-2 infection; 5 were excluded because they were still in the hospital and the final clinical outcome (dead or alive) was unknown; and 1 was excluded for being less than 18 y of age. A total of 41 patients were enrolled in the study (Fig. 2). Table 1 summarizes demographic, clinical, laboratory and imaging findings of the adult patients with COVID-19 evaluated in the ED.

Lung ultrasound findings

LUS was performed in a total of 41 patients (a total of 494 lung areas examined). In 12 patients (29.3%), their clinical condition did not allow complete evaluation of all 14 areas; the posterior regions (areas 1–6) were not evaluated. In 8 patients, area 13 was not evaluated because of a superimposed cardiac window. Additionally, 12 areas overall were not examined for technical reasons (*e.g.*, the physician had to stop the exam because of emergent clinical situations, access to a certain area was obstructed by medical devices, patient discomfort). LUS was normal in 3 patients (7.3%, all with a negative chest X-ray as well), while 38 patients (92.7%) had a pathologic pattern in at least one lung area. A score of 0 was assigned in 194 areas, a score of 1 in 147 areas, a score of 2 in 110 areas and a score of 3 in 31 areas. Figure 3a illustrates the distribution of the pathologic patterns (score: 1–3) in the 14 lung areas evaluated. Scores 1 and 2 are those most represented. All lung

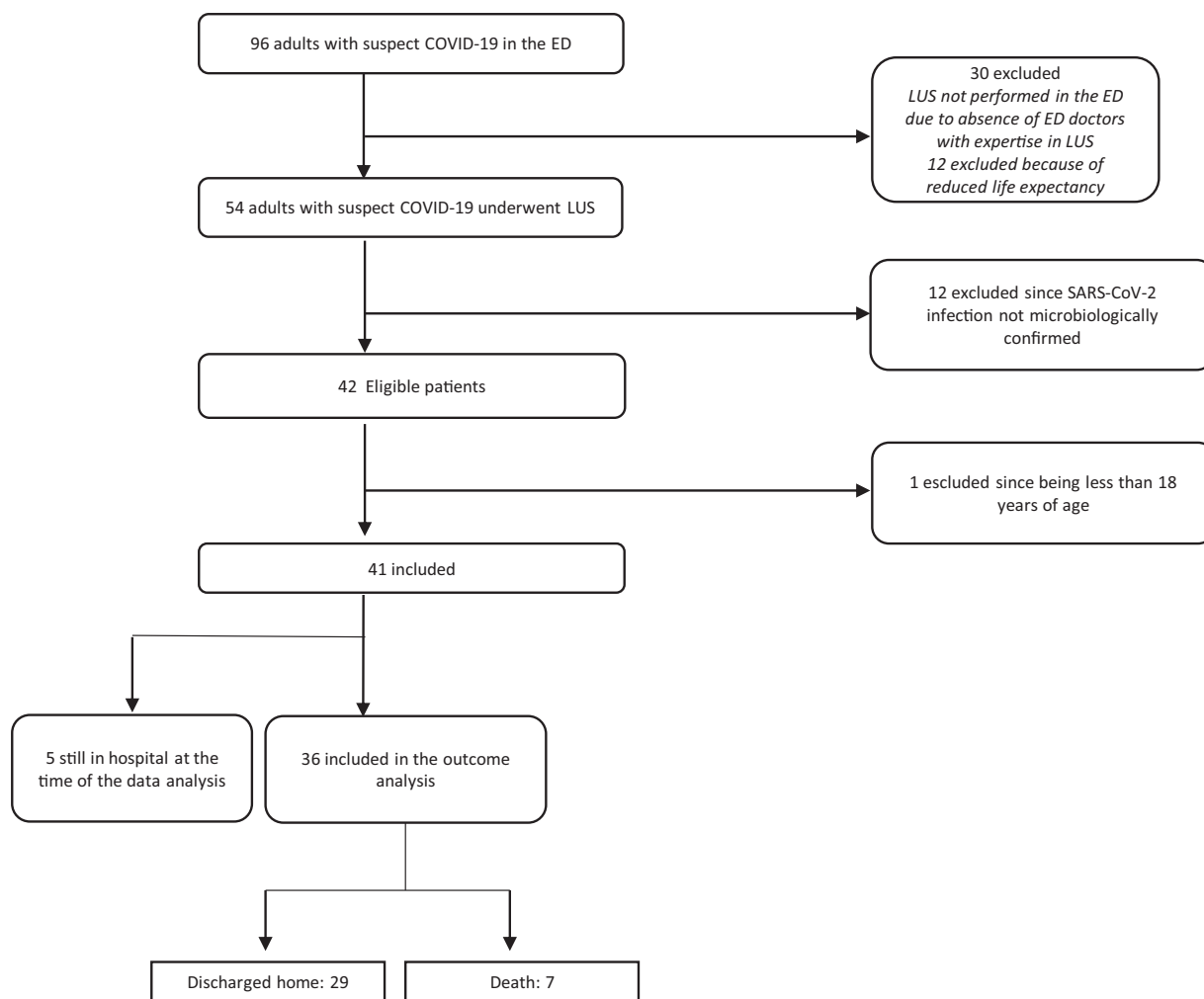


Fig. 2. Study flowchart illustrating patient selection. ED = emergency department; LUS = lung ultrasound.

areas were involved by pathologic patterns, although the lateral lung areas (areas 7 to 10) were the areas more involved by pathology (Fig. 3b).

Predictive role of LUS

Survival status. Patients in our sample had a median of 6 lung areas with pathologic findings (interquartile range [IQR]: 6, range: 0–14), defined as a score different from 0. The median percentage of lung areas involved was 71% (IQR: 64%, range: 0–100) while the median average score was 1.14 (IQR: 0.93, range: 0–3). There was a significant difference for both average score and percentage of involved lung areas between patients who died during the index hospitalization and those who were discharged home. Patients who subsequently died had 100% of areas involved (IQR: 81.5%–100%, range: 71%–100%) while those discharged had a median 50% of areas involved (IQR: 27%–81.5%, range: 0–100%),

with an estimated difference of 40.5% (95% confidence interval [CI]: 4%–68%, $p = 0.01$) (Fig. 4).

Patients who subsequently died had a median average score of 1.43 (IQR: 1.31–1.69, range: 1.14–3) compared with those who were discharged, who had a median average score of 1 (IQR: 0.27–1.4, range: 0–1.86), with an estimated difference of 0.47 (95% CI: 0.06–0.93, $p = 0.02$) (see Fig. 5). There was no significant difference between the two groups regarding the absolute number of areas with pathologic findings (see Fig. 6).

ICU admission. There was a higher rate of involved lung areas among patients admitted to the ICU anytime during hospital stay than among those who did not require ICU admission (Fig. 4). Patients admitted to the ICU had a median 93% of areas involved (IQR: 71%–100%, range: 0–100%), while patients who did not require ICU admission had a median 20% of areas involved (IQR: 0–42.5%, range: 0–50%), with an estimated difference of 29% (95%

Table 1. Characteristics of the study sample, N = 41

Characteristic	No. (%) or mean (SD)
Demographic	
Male	28 (68.3%)
Age	60 (22.7)
Fever	32 (78%)
Cough	27 (65.8%)
Dyspnea	24 (58.5%)
Positive RT-PCR for SARS-CoV-2	41 (100%)
Imaging	
Pathologic LUS examination	38 (92.7%)
Pathologic chest X-ray	34 (82.9%)
Pathologic CT scan (performed in 17 cases)	17 (100%)
Blood tests	Mean (SD)
White blood cell count	
Total	5154 (3738)
Neutrophils	3889 (3247)
Lymphocytes	926 (801)
Other blood analyses	
C-Reactive protein	98.3 (109.7)
Procalcitonin	2.7 (7.7)
Fibrinogen	518 (192.3)
D-Dimer	5604 (7460)
Albumin	33.8 (5.5)
Ferritin	213.6 (118)
Lactate dehydrogenase	368.9 (187.6)
Outcome measure	
Admission	
Discharged from emergency department	4 (9.7%)
Medical ward	21 (51.2%)
Intensive care unit	16 (39.1%)
Ventilatory support during admission	
Nothing	11 (26.8%)
Low-flow oxygen	13 (31.7%)
High-flow oxygen therapy	2 (4.9%)
Noninvasive positive-pressure ventilation	9 (21.9%)
Intubation	6 (14.6%)

CT = computed tomography; LUS = lung ultrasound; SD = standard deviation.

CI: 8%–50%, $p = 0.008$). The average score was also higher among patients who required ICU admission (Fig. 5). Patients who required a subsequent ICU admission had a median average score of 1.36 (IQR: 1.2–1.58, range: 0–3), while those who did not require ICU admission had a median average score of 1 (IQR: 0.39–1.38, range: 0–1.86), with an estimated difference of 0.47 (95% CI: 0.05–0.93, $p = 0.02$).

The absolute number of lung areas involved also significantly differed between patients who required ICU admission and those who did not (estimated difference = 4, 95% CI: 1–7, $p = 0.016$), see Figure 6.

Need for invasive ventilation. Conversely, differences in average score, percentage of involved areas or absolute number of involved areas did not reach statistical significance when compared between patients who required invasive ventilation and those who did not.

Comparison between LUS and chest X-ray. Given the absence of a strict definition of COVID-19

pneumonia at LUS examination, we evaluated concordance for various cutoff values, both for the average score and for the percentage of area involved (Fig. 7).

The best concordance was observed for a cutoff of 0.4 for score (Cohen's $\kappa = 0.72$, 95% CI: 0.4–1) and of 20% for percentage of area involved (Cohen's $\kappa = 0.53$, 95% CI: 0.14–0.93).

DISCUSSION

In recent decades, lung ultrasonography has emerged as an accurate tool for point-of-care diagnosis of many chest conditions, particularly pneumonia, pulmonary edema and pleural effusion, in several settings, including emergency and critical care. In recent years, technological advances have led to smaller devices, down to pocket size, with good image quality, particularly fit to be deployed in resource-poor settings and outside of the hospital environment. Moreover, compared with traditional radiologic techniques, LUS is particularly convenient for populations for whom exposure to ionizing radiation is a concern (*e.g.*, children and pregnant women).

In this study, we prospectively evaluated the predictive role of LUS performed during the first evaluation in the ED of patients with COVID-19. Moreover, we prospectively assessed the correlation between LUS findings and severity of disease in COVID-19 patients evaluated in a referral ED of a large COVID-19 university hospital. We found a significant correlation between ultrasound findings and severity of disease, assessed as mortality and need for ICU admission. To our knowledge, this is the first study describing the predictive role of LUS in patients with COVID-19.

First, we found that LUS is able to detect COVID-19 pneumonia in the ED; 92.7% of patients included in the analysis had a pathologic pattern in at least one lung area. Importantly, we observed that all lung areas (posterior, lateral and anterior) can be involved to different degrees of pathologic patterns, highlighting the importance of always assessing all lung areas if the patient's clinical condition allows.

Second, we assessed the predictive role of LUS in terms of mortality/survival and need for ICU admission. To quantify LUS severity, we used Soldati *et al.*'s (2020c) score. We chose this score for several reasons: it is the first score proposed and already used by several institutions in Italy and in the world, having a huge impact as assessed with altimetric data. Also, the score was validated by an Italian task force of LUS independent experts working in different settings, using a large virtual database that had so far collected 45,560 and 13,364 frames from different countries (Roy *et al.* 2020). Moreover, this score is based on simple LUS patterns



Fig. 3. Representation of the different scores at lung ultrasound in the whole population (a) and by the lung area evaluated (a).

already employed in the diagnosis of several lung conditions (pleural line characteristics, vertical artifacts, consolidations, white lung).

Interestingly, we found that the percentage of pathologic lung area on LUS and the LUS score were both able to significantly predict the final clinical outcome (death/survival) and need for ICU admission. Of note, in our study none of the patients with <70% of lung area involved by pathology or with an average score <1.1 died. Conversely,

the number of pathologic areas in each patient was not significantly associated with a specific outcome. However, this finding is probably owing to the fact that not all lung areas could be analyzed in several patients; it was impossible to have posterior areas analyzed for clinical reasons. For this reason, we included in our study the percentage of pathologic areas for each patient.

While the role of LUS as a pre-triage tool or in optimization of resources has been hypothesized (Soldati

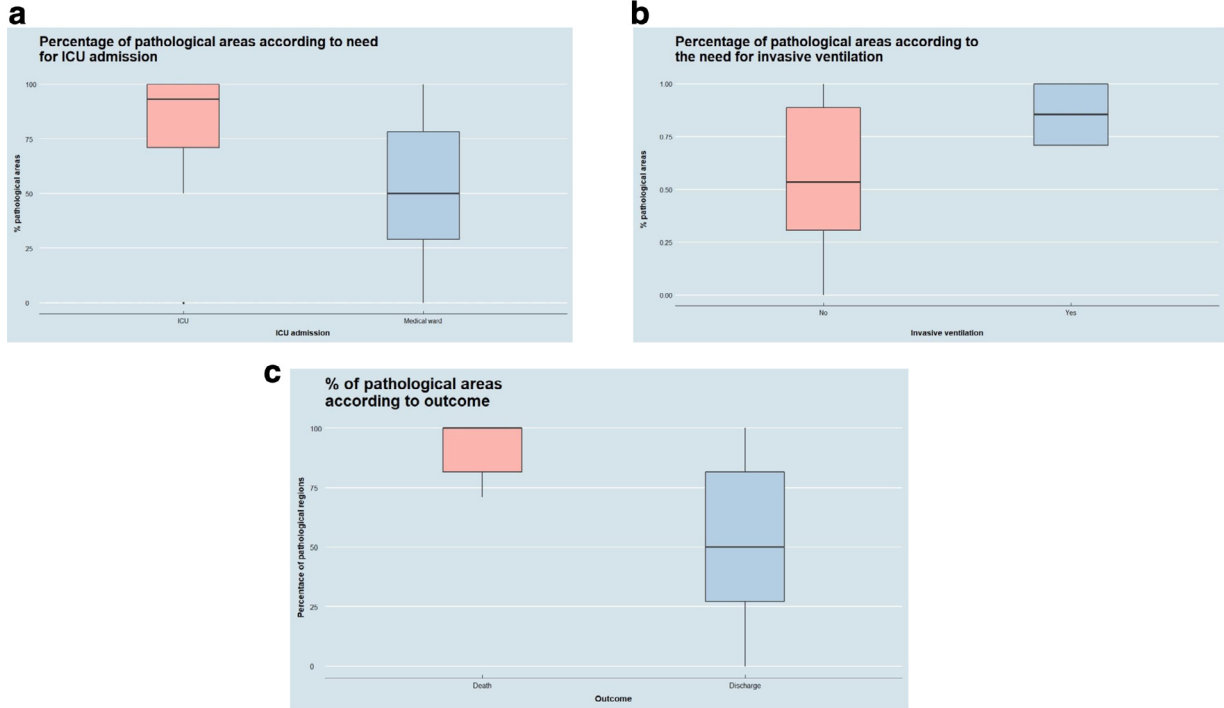


Fig. 4. Boxplot illustrating the distribution of percentages of pathologic areas with respect to the (a) need for intensive care unit (ICU) admission, (b) need for invasive ventilation and (c) outcome of index hospitalization (death, discharged) (c).

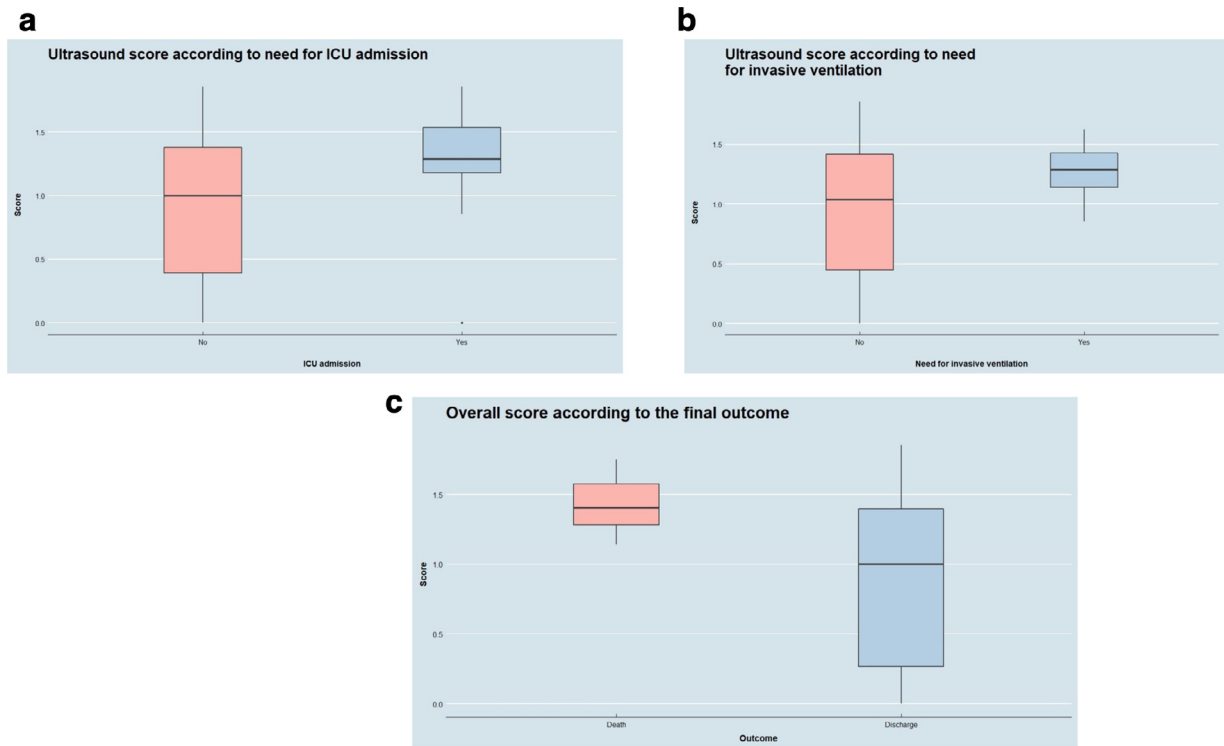


Fig. 5. Boxplot illustrating the distribution of average lung ultrasound score areas according to the need for intensive care unit (ICU) admission (a), the need for invasive ventilation (b) and the outcome of the index hospitalization (death, discharged) (c).

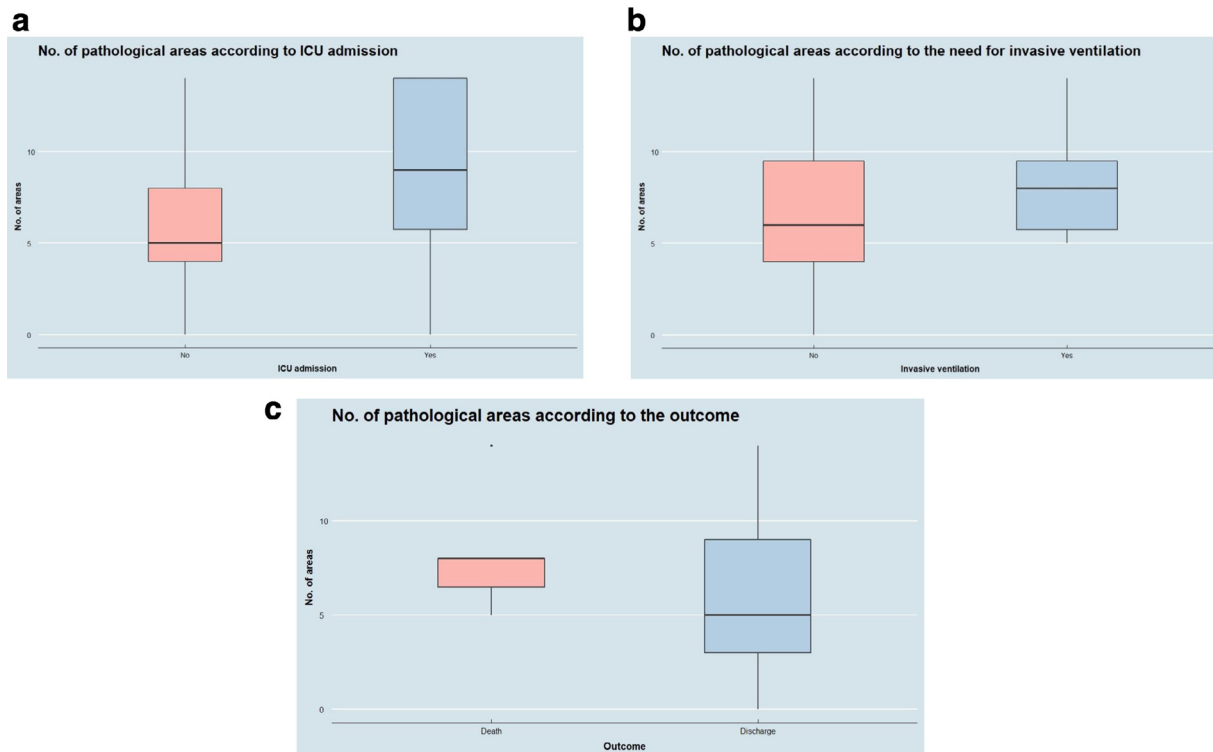


Fig. 6. Boxplot showing the distribution of absolute number of pathologic areas according to the need for intensive care unit (ICU) admission (a), the need for invasive ventilation (b) and the outcome of the index hospitalization (death, discharged) (c).

et al. 2020a, Buonsenso et al. 2020c), it has not been documented before. In fact, several authors have assessed the ability of LUS to detect COVID-19 pneumonia, but have not assessed its predictive role

(Buonsenso et al. 2020c; Huang et al. 2020; Lu et al. 2020b; Peng et al. 2020; Volpicelli and Gargani 2020). To those findings, we add that the score proposed by Soldati et al., which uses well-known and well-

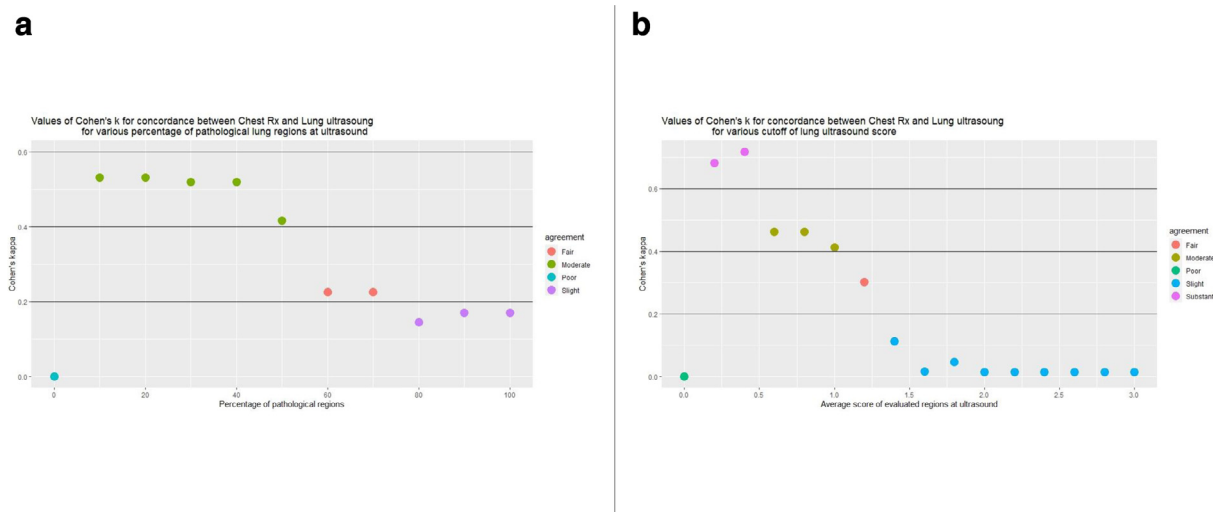


Fig. 7. Cohen's κ values for the concordance between lung ultrasound and chest X-ray using different cutoff values of the average ultrasound score (a) and the percentage of pathologic areas at lung ultrasound (b) needed to define a patient has having interstitial pneumonia. For each point, the x-axis represents the cutoff, and the y-axis represents the corresponding κ value for concordance with chest X-ray.

characterized LUS patterns and which has been analyzed on a large virtual and multicenter database (Roy et al. 2020), also has predictive ability and is associated with the need for ICU admission and outcome. Given the shortage of trained health care personnel and equipment faced by all countries in the COVID-19 pandemic, this finding may have clinical and public health implications. The use of a relatively simple diagnostic procedure such as LUS (Buonsenso et al. 2020a; De Rose et al. 2020; Moro et al. 2020), and the possibility of using it in outpatient settings or even at home with pocket devices, can help health authorities in appropriate resource allocation, early identification of patients at higher risk, identification of patients that could start early treatments at home and home/outpatient follow-up with early recognition of those with worsening LUS patterns that might benefit from hospitalization, particularly in resource-poor settings.

Third, although it was not the aim of the study, we assessed concordance between LUS and chest X-ray. Determination of the concordance between LUS and CT scan was not methodologically possible as only 17 patients (41.5%) underwent a CT scan and all were pathologic. This finding may derive from the fact that, at the peak of COVID-19, with a large number of patients hospitalized compared with available resources, CT scan was reserved only for the most severe cases. Anyway, all patients with a positive CT scan also had a positive LUS. Regarding the concordance between LUS and chest X-ray, using a cutoff LUS score of 0.4 and 20% pathologic area as a positive LUS, the concordance κ was 0.72 (good) and 0.53 (moderate) between the two methodologies.

There are several limitations to our work that should be kept in mind by the reader. First, our study was performed only on patients with microbiologically confirmed COVID-19 disease; we did not evaluate the diagnostic performance of LUS in a mixed population. However, the stated goal of our study was to evaluate LUS not as a diagnostic tool for COVID-19, but as tool to identify more severe disease and patients with a worse prognosis. Second, we had a relatively small sample, which did not allow us to evaluate whether other variables were more predictive of the outcome, thus potentially reducing the usefulness of LUS. Third, our study was performed in a referral center for COVID-19 during the peak incidence of SARS-CoV-2 infection, and thus, both selection and attention bias may have unpredictably affected our results, so that generalization of our results to other settings or other time periods should be done with caution.

On the other hand, the strengths of our study include its prospective design, the standardized ultrasound examination, the simple and standardized scoring system and the fact that our study was conducted at the early stage of hospital admission, before therapeutic interventions or subsequent worsening of the clinical picture.

CONCLUSIONS

Our study indicates that LUS, performed in the ED by emergency physicians, is able to predict at the first evaluation the overall prognosis of COVID-19 patients, recognizing those needing ICU admission and those at higher risk of death. Further studies are needed to evaluate whether LUS findings may be reliably used to prioritize hospital admissions or to guide early ICU admissions or second-level treatments (including new treatments or ventilatory support). Subsequent studies should also evaluate the usefulness of LUS in the outpatient setting.

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Conflict of Interest—All the authors vouch that they have NO affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patenting/licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

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