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Predictive Score for Pulmonary Ultrasound and Factors Associated to Mortality and Hospitalization during the Covid-19 Pandemic

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Abstract

Pulmonary ultrasound is a non-invasive bedside resource that has showed to be useful for the assessment of patients presenting with respiratory insufficiency as well as the diagnosis of several pleural and other pulmonary pathologies. The pulmonary ultrasound score (LUS) is a semi quantitative scale that measures the loss of pulmonary aeration cause by many pathologic conditions. Our primary objective was to describe factors associated to death and hospitalization in patients aged 16 or older that were admitted to the emergency department (ED) with signs or symptoms of COVID-19 infection through the diagnosis of viral pneumonia with pulmonary ultrasound (PU). It was a cohort retrospective study through a one-year period. Emergency physicians performed lung ultrasounds and calculated LUS. Results: 672 patients suspected of COVID-19 infection with a PU finding of viral pneumonia were included. 495 patients had a positive COVID-19 PCR test, 73.6% of the population. 258 patients presented with high probability of COVID-19 pneumonia following the patterns in PU. 55% were male with a median age of 45 years old. The average LUS score at admission was 8. Global hospitalization rate was 51.5%, 7.5% were admitted to the ICU. Patients with a LUS > 10 had a mortality of 6%, and patients admitted to the ICU had a 50% mortality rate. They presented with an average LUS score at admission of 15.2. Conclusions: LUS was a good predictor of death, hospitalization to general ward or ICU of patients with COVID-19 admitted from the emergency department.

Keywords

Pulmonary Ultrasound, COVID-19, Pulmonary Ultrasound Score, Emergency

Physicians, Viral Pneumonia

1. Introduction

Pulmonary ultrasound (PU) is a non-invasive bedside (BS) resource that has shown to be useful for the assessment of patients presenting with respiratory insufficiency as well as the diagnosis of several pleural and pulmonary pathologies including acute heart failure, pleural effusion, pneumonia and pneumothorax.

Preliminary reports have been published regarding the use of pulmonary ultrasound in the evaluation of patients with SARS COV 2 infection [1]. A chest radiograph (RX) has limited diagnostic use in regards to pneumonia, with a sensitivity less than 69% - 70% and even lower than 50% in the diagnosis of pulmonary pathologies in critically ill respiratory patients [2] [3] [4].

Computed tomography (CT) is considered the gold standard for the diagnosis of viral pneumonia with a sensitivity between 97% - 100% [5] [6].

However, CT is not widely available and a number of factors have to be taken into consideration such as time, patient transportation, decontamination, radiation and the patient's hemodynamic stability.

COVID-19 symptoms vary greatly, from asymptomatic to life-threatening pneumonia. In general, symptoms begin to worsen approximately one week after the onset, and a surprising feature of COVID-19 is its rapid progression leading to respiratory insufficiency [7]. The initial use of chest radiograph to diagnose pneumonia was not enough to detect ground glass opacities, reticulations or consolidations. At the beginning of the pandemic the medical community saw the need to use multiple CT scans despite the lack of resources, excessive radiation and risky patient transportation. Slowly but surely, pulmonary ultrasound was seen as a BS resource with great accessibility and sensitivity.

Pulmonary ultrasound has been widely used in the vast majority of specialties mainly in the emergency department, Intensive Care Unit (ICU), pneumonology and kinesiology [8].

Numerous protocols regarding the evaluation of dyspnea and acute respiratory failure began to use PU and there is a lot of literature that supports its clinical utility [9].

The pulmonary ultrasound score (LUS) is a semi quantitative scale that measures the loss of pulmonary aeration caused by many pathologic conditions. It was successfully used during the H1N1 outbreak in 2009 with 94% sensitivity for viral pneumonia [10], as well as its use in the ICU to determine extubation probability [11].

2. Primary Objective

To describe factors associated to death and hospitalization in patients that were admitted to the emergency department (ED) with signs or symptoms of COVID-19

infection through the diagnosis of viral pneumonia with pulmonary ultrasound.

3. Material and Methods

Design: cohort retrospective study

Population: patients aged 16 or older that were admitted to the ED of an urban hospital level 1 with more than 12,000 annual consultations, with signs or symptoms of COVID-19 infection and a diagnosis of viral pneumonia made by pulmonary ultrasound, through a one-year period (April 1st 2020 to March 31 2021).

Inclusion criteria: cough, fever, sore throat, asthenia, ageusia, anosmia, rhinorrhea or respiratory difficulty as high chance of COVID-19 pneumonia.

Exclusion criteria: obesity with a BMI > 35, chronic pulmonary advanced pathology or absence of an acoustic window through pulmonary ultrasound. Patients with a negative PCR test for COVID-19 and patients on invasive mechanic ventilation.

The protocols were approved by the Ethics Committee. Demographic and echographic data were collected to evaluate hospitalization and inhospital death due to all causes.

Demographic data: age, sex, medical history, hospitalization, death.

Echographic data: pulmonary ultrasound (PU) was performed by medical staff (with over 500 PU done) and interpreted on site to identify signs of pneumonia (pleural irregularity, B lines, light beam, sub pleural consolidations or consolidations with air dynamic bronchogram [12]). (**Figure 1**)

Each area was assigned a score between 0 to 3 points [13].

- A lines: normal pleural line, normal reverberation artifacts of pulmonary sliding, corresponding to normal pulmonary aeration = 0 points.
- B lines: hyperechoic vertical lines that elevate from the pleural line and reach the end of the screen, blurring the A lines. They represent reverberant artefacts

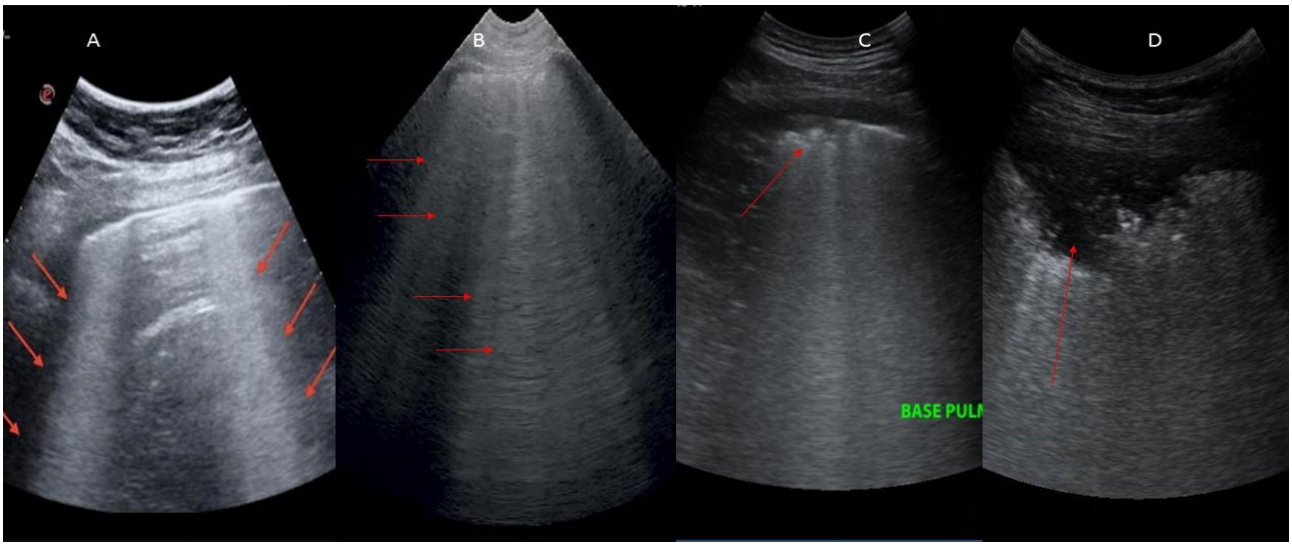

Figure 1. PU findings. (A) Light beam; (B) Coalescent B lines; (C) Subpleural consolidation; (D) Consolidation.

of edematous, interlobular or alveolar septa. They were subdivided into isolated B lines referring to moderate loss of pulmonary aeration = 1 point and coalescent B lines referring to three or more lines = 2 points.

- Pulmonary consolidation = 3 points.

Thus, the LUS score ranges from 0 (normal value) to 36 points.

As part of the protocol the patient had to be positioned either sitting up or laying down. The convex transducer with 3.5 to 5 mHz was used in the abdominal setting with a depth no more than 15 cm and with pleural focus.

The transducer is then located across and perpendicular to the ribs. 6 pulmonary segments were evaluated according to protocols already described by Via and Soldati (left, right, anterior, axillar and posterior) [13] [14]. (**Figure 2**)

Therefore the LUS score ranges from 0 meaning no signs of COVID-19 pneumonia to a maximum of 36 points which indicates severe compromise. The probability of having pneumonia is then assessed according to ultrasound data and subdivided into high, intermediate and low [12].

Study protocol:

Adult patients older than 16 who presented to the emergency department with signs or symptoms of COVID-19 infection triaged by an experienced nurse

Signs or symptoms included cough, fever, sore throat, asthenia, ageusia, anosmia, rhinorrhea, respiratory difficulty and:

1) Respiratory rate ≥ 24, crackling rails, SaO2 < 95% or

2) Age greater than 60 years old

3) Comorbidities: cardiovascular, renal or respiratory disease, diabetes, cancer or immunosuppression.

The patients that gathered the criteria above were then evaluated with pulmonary

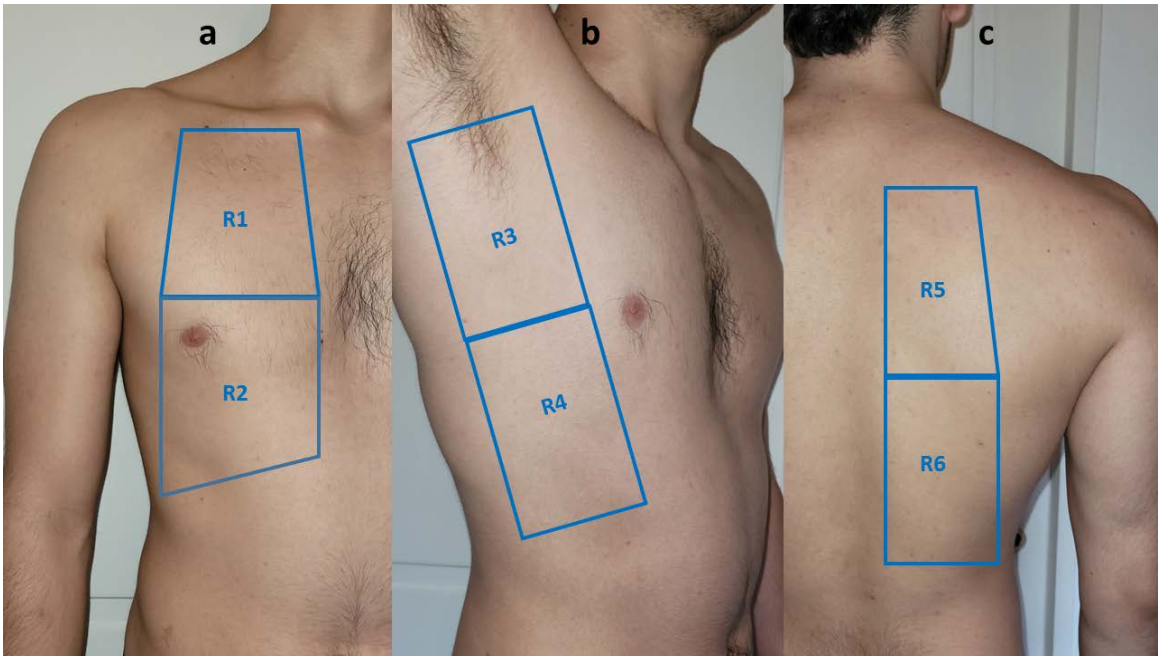

Figure 2. 6 pulmonary segments according to protocols describe by Via and Soldati: left, right, (A) Anterior; (B) Axilla; and (C) Posterior.

ultrasound and the doctor assessed the need for hospitalization in the general ward (GW), ICU or outpatient follow up according to the algorithm presented below. (Figure 3)

Sampling

Consecutive sampling of all patients that fulfilled the inclusion criteria. 600 patients to obtain a statistical power of 93% unilateral approach and 89% bilateral approach.

Statistical analysis:

The following data is presented as percentages for categorical variables and the mean ± standard deviations for continuous variables. The normality of all data was proven using the

Kolmogorov-Smirnov test. When the distribution was normal, we used to two-tail Student t-test. We performed logistic regression to explore the associations of LUS with admission to UTI, GW and mortality, presenting the raw and adjusted odds ratio with a 95% CI.

4. Results

Population

During a one-year period (April 2020 to March 2021), 672 patients suspected of COVID-19 infection with a pulmonary ultrasound finding of viral pneumonia were included. 495 patients had a positive COVID-19 PCR test, representing 73.6% of the population.

258 patients presented with high probability of COVID-19 pneumonia following

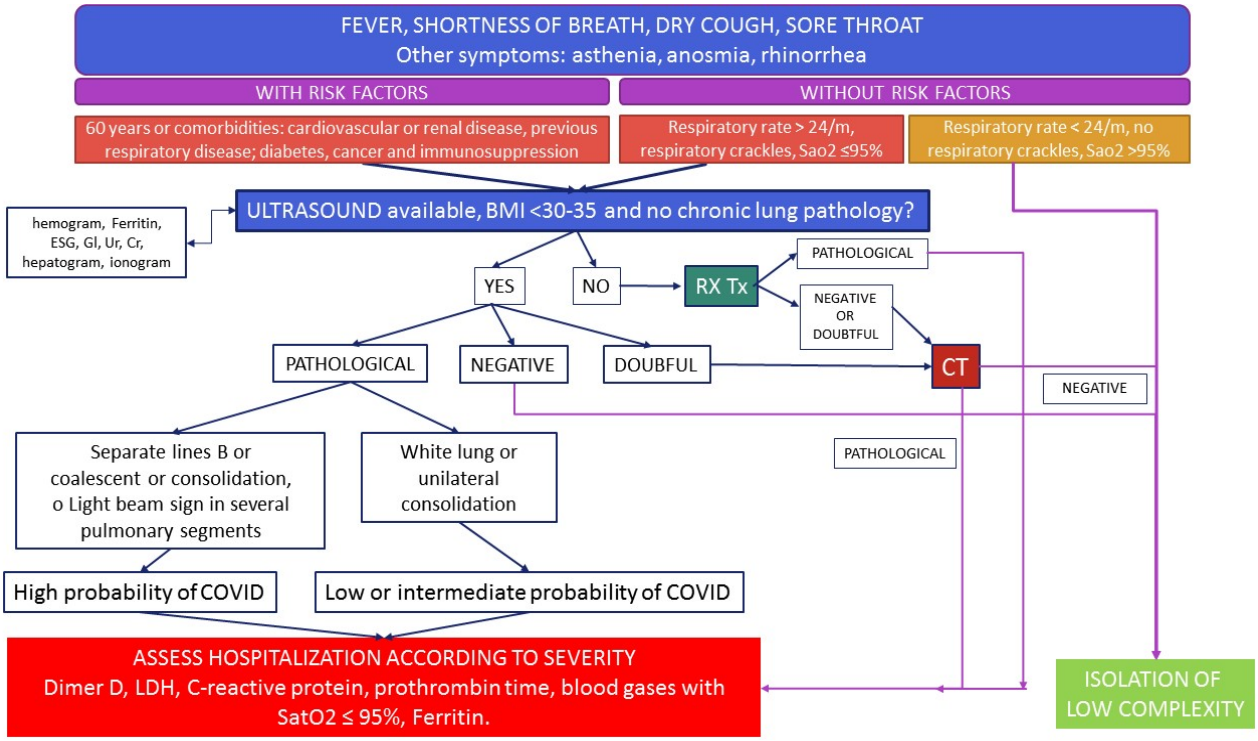

Figure 3. Evaluation algorithm of patients with suspected pulmonary infection by COVID-19.

the patterns described by Volpicelli in pulmonary ultrasound [12]. 55% were male with a median age of 45 years old. The average LUS Score at admission was of 8 points with a SD of 4 points. The main characteristics are shown in Table 1.

Main results

Global hospitalization rate was 51.5% (n= 313, CI 45% - 58%), 7% (n = 10/133, CI 4% - 14%) belonging to the ICU. Global mortality rate was 2.7% (n = 7, CI 1% - 6%). Patients with a LUS > 10 had a mortality of 6% (n = 6, CI 1% - 11%), and patients admitted to the ICU had a 50% mortality rate (n = 5, CI 12% - 88%)

Factors associated with the main results are shown in Tables 2-4.

Table 1. Main characteristic of COVID-19 patients with suspected pneumonia during the period between April 2020 and March 2021. (N-258).

Variable	%	N
Age median, in years (RIC)	45	(36 - 55)
Male sex	55%	(142)
LUS Score median (RIC)	8	(5 - 12)
Hospitalization median in days (RIC)	2	(0 - 5)
POCD	5.8%	(15)
Cancer	5.4%	(14)
Diabetes	4.3%	(11)
Pregnancy	5.4%	(14)
Other	15.2%	(39)
Obesity	15.1%	(39)
Congestive heart failure	2.3%	(6)

Table 2. Factors associated with hospitalization (ICU or GW) vs no hospitalization in COVID-19 positive patients with suspicion of pneumonia in the period between April 2020 and March 2021 (n-258).

Variable	ORc	IC	p	ORa	IC	P
LUS > 10	5.12	2.92 - 8.97	<0.001	4.9	2.7 - 8.86	<0.001
Age > 60 years old	3.20	1.58 - 6.58	0.001	2.86	1.32 - 6.19	0.007
Male sex	1.4	0.8 - 2.2	0.23			
Obesity	3.2	1.5 - 6.9	0.003	3.43	1.50 - 7.86	0.003
CHF	4.8	0.6 - 42	0.2			
POCD	1.9	0.6 - 5.9	0.2			
Cancer	2.5	0.8 - 8.0	0.14			
Diabetes	10	1.3 - 79.9	0.3			
Pregnancy	6.1	1.3 - 27.8	0.2	11.61	2.42 - 55.68	0.002
Other	1.8	0.9 - 3.7	0.09			

Table 3. Factors associated with admission to the ICU vs GW (subgroup analysis in hospitalized patients) in COVID-19 positive patients with suspected pneumonia in the period between April 2020 and March 2021 (n-258).

Variable	ORc	IC	p
LUS	1.2	1.1 - 1.4	0.002
LUS > 10	8.30	1.02 - 67.49	0.05
Age > 60	3.24	0.88 - 11.98	0.08
Male sex	3.1	0.6 - 14.9	0.17
Obesity	0.88	0.18 - 4.4	0.9
CHF	3.3	0.3 - 32.7	0.3
Cancer	1.4	0.16 - 12.4	0.76

Table 4. Factors associated with mortality in COVID-19 positive patients with suspected pneumonia in the period between April 2020 and March 2021 (n-258).

Variable	ORc	IC	p
LUS > 10	10.59	1.25 - 89	0.03
Age > 60	6.63	1.43 - 30.73	0.02
Male sex	2.1	0.4 - 10.9	0.39
Obesity	2.3	0.4 - 12.4	0.33

Factors strongly associated with higher risk of hospitalization were: LUS score greater than 10 points (5 times more, $p < 0.001$), age older than 60 years (3.2 times more, $p < 0.001$) and BMI > 30 (3.2 times more, p 0.003). In the multivariate analysis pregnant women with pneumonia had 11 times more risk of hospitalization (p 0.002). See Table 2.

Of the 143 patients with COVID-19 pneumonia that were hospitalized, 7.5% (N = 10) were admitted to the ICU. They presented with an average LUS score at admission of 15.2. LUS > 10, age > 60 years old, obesity and pregnancy were associated with hospitalization in both the univariate and multivariate analysis.

When evaluating factors associated to mortality, we found that a LUS score > 10 and age greater than 60 years old were linked to higher risk. A LUS score greater than 10 increased the risk of death by 10 (OR 10.6, CI 1.25 - 89) and an age of 60 years or older by 6 (OR 6.6, IC 1.4 - 30.7). CHF, POCD, cancer and pregnancy were tested but behaved as constants thus the OR was not calculated. See Table 4.

5. Discussion

The COVID-19 pandemic took many patients to the emergency departamento all around the world due to cough, fever and dyspnea [7].

This study describes the prognostic factors associated to death and hospitalization in patients suspected of COVID-19 infection that were submitted to pul-

monary ultrasound to diagnose viral pneumonia and admitted to the ED over a one-year period.

The LUS score was implemented as a simple tool to assess the pulmonary extent. We were able to diagnose pneumonia and measure its extent, suggesting that LUS score is useful for COVID-19 stratification and decision making.

The use of LUS score to quantify and monitor the changes in pulmonary aeration was described in adult ICU patients with respiratory distress [12] [15]. Patients infected with COVID-19 showed similar interstitial changes such as coalescent B lines, light beams and subpleural consolidations in peripheral pulmonary segments [12].

Guided by the decisions algorithm shown in **Figure 3** we were able to determine by use of pulmonary ultrasound which patients were at higher risk of having COVID-19 pneumonia and its severity according to the LUS score. The score was able to distinguish between patients that required hospitalization vs outpatient follow up. Having a LUS score > 10 meant the risk of hospitalization increased by 5 times and the associated mortality was 6%. Of all patients that were admitted with COVID-19 pneumonia, 7.5% were admitted to the ICU with an average LUS score of 15.

Two other recent studies also showed that LUS score was able to correctly assess COVID-19 patients. Brahier and Youden showed a correlation between LUS score and mortality with ABC 0.76 and 0.78 respectively [16] [17].

Similar results were found in another recent study conducted in ICU patients in the German Hospital of Buenos Aires, where they used a LUS score similar to ours [18]. Their LUS score at admission to the ICU was 20 compared to ours of 15 points, and their mortality reached 51%, similar to ours.

Some limitations to our study need to be mentioned. First, this was a study conducted in only one center in the Buenos Aires province in Argentina. Second, the level of experience necessary to detect small changes in the LUS score can limit its applicability. Last but not least, pulmonary ultrasound is operator dependent, and no intra operator tests were conducted.

We are in favor of the POCUS4-COVID19 consensus published in Critical Care 2020 [19] which suggests a) PU along with clinical evaluation is useful in the diagnosis of COVID-19 pneumonia (LQE II-B); b) when computed tomography is not available or is innapropriate, PU should be used in the diagnosis of suspected cases of COVID-19 pneumonia (LQE II-B); c) in patients with high pretest probability of COVID-19 infections and PU findings suggestive of pneumonia, a negative PCR test cannot exclude COVID-19. A positive PU increases suspicion of COVID-19 even more therefore a second PCR test should be performed (LQE II-B).

6. Conclusions

In this study, despite its limitations, the LUS was a good predictor of death, hospitalization in the general ward or ICU of patients with COVID-19 admitted to

the emergency department.

In conclusion, LUS score is easy to use tool to help doctors in the management of COVID-19 patients or other viral pneumonias.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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