Predictive modeling using point-of care lung ultrasound (P-LUS) for emergency triage of patients with acute respiratory symptoms related to COVID-19

Maj Patrick C Ng, MD, Director, En route Care Research Center
Ana Fernandez-Bustamante, MD, PhD, University of Colorado School of Medicine

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1632 Nellis, BLDG. 5406
JBSA Lackland AFB, TX 78236-7517

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Digitally signed by TAVISH.MICHELE.F.1031059280
Date: 2023.03.23 12:16:09 -05'00'

Michele F. Tavish, DAF
Program Analyst
En route Care Research Program
59MDW Office of the Chief Scientist

DEL MONACO.DIANA.V.1369906131
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Date: 2023.03.23 11:39:22 -05'00'

Diana del Monaco, Ph.D.
Acting Director, Trauma & Clinical Care
59MDW Office of the Chief Scientist

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14. ABSTRACT-

The unprecedented number of patients with COVID-19 disease (infected or presumably infected by SARS-CoV-2) seeking urgent care for acute respiratory symptoms severely disrupted the allocation of hospital personnel and resources. Progressive respiratory failure may occur rapidly (<72h) during COVID-19. It is imperative to identify safe and effective diagnostic tools to appropriately allocate scarce resources early while minimizing further viral spread. Point-of-care lung ultrasound (P-LUS) imaging is available with the portable, cost-effective Butterfly iQ probes. We tested the hypothesis that P-LUS imaging and other predictors provide effective emergency triage and early identification of hospital resources required by COVID-19 patients presenting with acute respiratory symptoms. We developed a simplified scoring system (adjusted from prior published score rubric) and tested the score inter-user agreement. We then used this scoring matric to evaluate P-LUS images obtained for clinical purposes from patients presenting with possible COVID-19-related acute respiratory symptoms to the Emergency Department (ED) at three participating sites between March 2020 and April 2021. At least three blinded ultrasound-trained investigators evaluated the images available from eligible patients and provided the worst score (from normal, 0, to most abnormal, 3) for all the P-LUS exams available for each patient. A predictive model was then developed for the need of hospital admission (vs. discharge) from the ED, including clinically relevant vital signs and laboratory values, and P-LUS findings. Reviewers had uniform agreement on the low (scores 0-1) or high (2-3) risk classification of 66.7% cases. The presence of diffuse B-lines showed the highest level of agreement among reviewers (ICC 0.906). Out of 204 patients, 75 (36.8%) were discharged home and 129 (63.2%) required a hospital admission. During the ED stay, top predictors of hospital admission included: age, oxygenation, and plasma concentrations of C-reactive protein, lymphocyte count, and procalcitonin. The highest P-LUS score (overall worst score of 2 or 3), the detection of diffuse B-lines, and the presence of pleural thickening/irregularity in the ED P-LUS images were all acceptable predictors for the need of hospital admission.

15. SUBJECT TERMS- Butterfly iQ®, lung ultrasound, point-of-care lung ultrasound on the battlefield, portable lung ultrasound

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1.0 EXECUTIVE SUMMARY

Point-of-care lung ultrasound (P-LUS) imaging is available with the portable, cost-effective Butterfly iQ probes. They can facilitate the triage of patients with COVID-19-related acute respiratory insufficiency. We tested the hypothesis that P-LUS imaging and other predictors provide effective emergency triage and early identification of hospital resources required by COVID-19 patients presenting with acute respiratory symptoms. We developed a simplified scoring system (adjusted from prior published score rubric) and confirmed an adequate inter-user level of agreement. We then used this scoring matrix to evaluate P-LUS images obtained for clinical purposes from patients presenting with possible COVID-19-related acute respiratory symptoms to the Emergency Department (ED) at three participating sites. A predictive model was then developed for the need of hospital admission (vs. discharge) from the ED, including clinically relevant vital signs and laboratory values, and P-LUS findings. Top predictors of hospital admission included: age, oxygenation, and plasma concentrations of C-reactive protein, lymphocyte count, and procalcitonin. The highest P-LUS score (overall worst score of 2 or 3), the detection of diffuse B-lines, and the presence of pleural thickening/irregularity in the ED P-LUS images were all acceptable predictors of hospital admission.

2.0 INTRODUCTION

The COVID-19 pandemic due to the SARS-CoV-2 virus has infected approximately 600M patients worldwide and caused >6M deaths since the first case was detected in China in November 2019[1-3]. While 80% of infected patients present with fever or mild upper respiratory symptoms, nearly 20% experience severe respiratory compromise requiring hospital admission (~15% of all cases), or even transfer to the Intensive Care Unit (ICU) (~5%)[2-4]. Progressive respiratory failure and hypoxemia may occur rapidly (<72h)[2,5,6]. The case-fatality rate of COVID-19 patients varies from <5% in the community to >50% in ICU patients. The predictive value of several clinical and laboratory biomarkers is being investigated to facilitate an early detection of high-risk patients.

Bilateral infiltrates can be found in the chest X-ray (CXR), and chest CT have shown ground-glass opacities and consolidative pulmonary opacities[7,8]. Although chest CT showed a 97% sensitivity for COVID-19, specificity was only 25%[9]. Furthermore, CXR and chest CT present limitations beyond radiation exposure, particularly undesirable in COVID-19, due to the risk to further expose healthcare personnel and equipment, as well as time for cleaning and decontamination. Bedside point-of-care lung ultrasound (P-LUS) is a noninvasive, quick diagnostic tool, and is effective for detecting low and high-risk COVID-19 patients. P-LUS may help increase efficiency of hospital resources allocation, improve patients' outcomes by early detection of deterioration, and reduce hospital personnel and equipment exposure. P- LUS has been shown to be extremely valuable for the evaluation of COVID-19[10,11] and ARDS[12], and for the triage of acute respiratory insufficiency for other reasons[13]. The first lung ultrasound (LUS) findings in COVID-19 patients were described shortly after the outbreak in China and include irregular or thickened pleura, subpleural consolidations, and B-lines (focal, multi-focal and confluent)[14,15]. In Italy, which was heavily affected by SARS-CoV-2, LUS has been proposed as the primary imaging modality for COVID-19 patients[16]. A group of experts have recently proposed a standardized LUS scoring assessment that is specific for patients with COVID-19[17].

For this project, we developed a simplified scoring system (adjusted from Soldati et al.'s scoring rubric[17]) for evaluating P-LUS images. After testing the inter-user level of agreement, we tested

if P-LUS imaging and other clinical and laboratory values have predictive value for the effective emergency triage and early identification of hospital resources required by COVID-19 patients presenting with acute respiratory symptoms.

3.0 METHODS, ASSUMPTIONS AND PROCEDURES

The study was approved by the Institutional Research Board at the participating sites before any study procedures or data collection was performed.

We conducted a retrospective and prospective observational pragmatic study to evaluate *previously obtained* P-LUS images from COVID-19 patients with acute respiratory symptoms, using a simplified scoring approach, adjusted from expert recommendations[17]. We aimed to develop a simplified scoring approach that would have adequate consistency among experienced US reviewers to provide meaningful predictive value for clinical risk classification of patients. We tested the hypothesis that P-LUS imaging and other predictors provide effective emergency triage and early identification of hospital resources required by COVID-19 patients presenting with acute respiratory symptoms. Specifically, we tested if this simplified scoring approach of clinically obtained P-LUS images could reliably identify low and high-risk patients and predict patient disposition from the ED (hospital admission vs. home discharge).

P-LUS images were considered as eligible if they had been obtained from any adult patient who presented to the ED seeking medical care for acute respiratory symptoms related to possible COVID-19 at the following participating sites: University of Colorado Hospital, Anschutz Medical Center (Aurora, Colorado), Denver Health Medical Center (Denver, Colorado), and Brooke Army Medical Center (Fort Sam Houston, Texas). The P-LUS exams were acquired by bedside physicians or advanced practice providers between March 2020 and April 2021. Ultrasound images were obtained using a portable ultrasound system, such as the Butterfly iQ+ (Guilford, CT) transducer in the lung setting. Images were saved as per local protocol. Educational materials were developed for recommended lung areas to be examined (*Figure 1a*) but these were not mandatory, and the clinicians performed the P-LUS exams without a specific image acquisition protocol. This is an important feature of our pragmatic study, because the majority of bedside P-LUS exams do not typically include a complete set of scanned lung areas and the highest quality of P-LUS images that are usually obtained for formal prospective ultrasound studies.

Scoring system. We first developed a simplified scoring system (adjusted from Soldati et al.'s scoring rubric[17]). We modified the proposed model by Soldati et al [26] using the scoring system of 0-3 (*Figure 1b*) which quantifies the ultrasound findings (from most normal, 0, to most abnormal, 3). A minimum of three reviewers, blinded to patients' outcomes, scored the de-identified P-LUS exams. The six image reviewers were attending physicians with training in emergency medicine, anesthesiology, and/or critical care. The inter-user level of agreement between reviewers was estimated with the intraclass correlation coefficient (ICC) with a two-way random effects model in a subset of P-LUS exams.

Predictive modeling for patient disposition (hospital admission vs. home discharge) including P-LUS scoring and other clinical and laboratory variables. We tested the hypothesis that P-LUS imaging and other predictors provide effective emergency triage and early identification of hospital resources required by COVID-19 patients presenting with acute

respiratory symptoms. For this modeling, unblinded investigators (different from the P-LUS raters), collected demographics, clinical variables (e.g., vital signs, post-ED disposition, ED/hospital/ICU length of stay as applicable, intubation, mortality), laboratory characteristics, radiology imaging performed, and P-LUS scores and individual findings from the blinded raters. Data was entered into a specific Research Electronic Data Capture System (REDCap) database at the University of Colorado provided by the Colorado Clinical and Translational Sciences Institute **(**CCTSI). Completely deidentified data was exported for analysis.

Statistical analysis. Descriptive summaries are provided as median (minimum, maximum) for continuous measures and frequency (percent) for categorical measures. P-values provided in tables use the nonparametric Mann-Whitney U-test to compare groups for continuous measures and Fisher's exact test for categorical measures. The ability to predict the outcome of interest (i.e., hospital admission) is summarized with the area under the curve (AUC) (values closer to 1 are better) and Brier score (values closer to 0 are better). For categorical measures we also describe the sensitivity and specificity, for continuous measures we utilize Youden's J statistic which maximizes the combined sensitivity and specificity to identify a threshold to calculate the sensitivity and specificity for. Agreement of P-LUS findings across cases by different raters is summarized by the intraclass correlation coefficient (ICC) for agreement based on a two-way random effects model was estimated for agreement using the average of all raters. All analyses are completed in R v4.1.0 (Vienna, Austria).

4.0 MAJOR EVENTS/MILESTONES/SUCCESS

We successfully met the following milestones:

- Development of P-LUS educational and scoring materials
- Testing and confirmation of the adequate agreement among at least three ultrasound raters of P-LUS scores and findings in a retrospective set of 93 eligible COVID-19 P-LUS exams.
- Deployment of Butterfly iQ probes to the three participating sites for their use by ED clinicians.
- Retrospective and prospective collection of clinical, laboratory and imaging data from 204 eligible patients
- P-LUS scoring and evaluation of individual P-LUS findings of the same 204 patients.
- Development of predictive model for the hospital level of care needed by COVID-19 patients presenting to the ED with acute respiratory symptoms. We identified specific P-LUS scores and findings as acceptable predictors of hospital admission.

A key aspect of this pragmatic study is the successful P-LUS scoring of real-life P-LUS exams acquired at the bedside with a portable inexpensive ultrasound probe that has applications in medical facilities from the large urban center to the far forward, austere setting.

5.0 RISK ASSESSMENT

5.1 Risk Analysis:

Medium risk was experienced during the execution of the project at BAMC. Due to the nature of how images are collected and stored within the MHS, there was a delay in

acquiring the retrospective images for scoring. Once images were obtained, data abstraction proceeded without additional delays.

5.2 Technical Challenges

The majority of P-LUS exams acquired at the bedside for triage of patients do not include a complete set of scanned lung areas or the highest quality of P-LUS images that are usually acquired for formal prospective ultrasound studies. Most publications on lung ultrasound utilize a high number and quality of P-LUS exams to develop their scores and predictive modeling. However, these high-quality comprehensive P-LUS exams are unrealistic for the triage of most patients with acute respiratory conditions. Our pragmatic study provides important information to assess the value of P-LUS with less-than-ideal P-LUS exams. Although this is obviously a limitation to generalization due to the imperfect P-LUS exams, it is critical information to determine the value of P-LUS in real-life clinical scenarios.

6.0 TRANSITION PLAN

6.1 Military Relevance

The Butterfly iQ is a portable, low-cost and low-maintenance P-LUS device capable of far-forward use to facilitate timely and effective triage of patients with acute respiratory symptoms. The implementation of our simplified scoring system showed adequate agreement in identifying low risk and high-risk COVID-19 patients during the initial triage. P-LUS is a noninvasive and rapid diagnostic technique, and its implementation and scoring has the potential to facilitate hospital resource allocation efficiency in scenarios with scarce resources. Additionally, such a system can help inform decisions for patient movement in a combat environment as well as contribute to more efficient use of the en route care patient movement system. The effectiveness in predicting patient outcomes (via early detection of deterioration) is still pending.

6.2 Transition Strategy

Acute respiratory symptoms are a significant source of potentially survivable service member fatalities on the battlefield. There is no current field technology capable of providing timely and effective lung imaging triage options. Our predictive model was to evaluate the potential for a portable ultrasound device to provide a practical, forward-deployable technology for point of care lung assessments to help inform real world clinical decisions in both the far forward, combat environment and the MTFs in garrison. The results here will continue to guide our future studies dedicated to effective triage of patients, thereby decreasing patient morbidity and mortality. The study started at KRL 3 and ended at KRL 4.

7.0 RESULTS

Scoring system testing. P-LUS exams from 93 patients were reviewed by at least 3 raters (16 patients were reviewed by 4 raters). Patients' risk was classified based on the P-LUS score as low risk (P-LUS score 0-1) or high risk (P-LUS score 2-3). A uniform (100%) agreement in risk classification was reached in 62/93 (66.7%) of patients. The levels of agreement for the most abnormal P-LUS score and individual findings are shown in *Table 1*. The presence of diffuse B-lines was the individual P-LUS finding with the highest consistency among raters.

Population characteristics. *Table 2* presents selected patient characteristics, clinical, laboratory and imaging values, including P-LUS scores and individual findings, as overall and classified based on their post-ED destination. *Table 3* summarizes similar parameters for patients based on whether they required intubation or not.

Predictors of post-ED disposition. *Tables 4 and 5* show selected summarized continuous and categorical parameters and their value in the logistic regression modeling for their independent association with post-ED hospital destination (hospital admission vs home discharge). During the ED stay, top predictors of patient's need for a hospital admission included: age >48 years, worst oxygenation (imputed PaO2/FiO2) <445, C-reactive protein plasma levels >71.8 mg/L, lymphocyte count >4.03 10^9cells/L, and procalcitonin plasma levels >0.19 ng/mL. The highest P-LUS score (overall worst score of 2 or 3), the detection of diffuse B-lines and the presence of pleural thickening/irregularity in the ED P-LUS images were acceptable predictors for the need of hospital admission (Brier score <0.25).

It was not feasible to develop a predictive model for the need of intubation due the low incidence of this respiratory support intervention in the cohort (12 out of 204 patients, 5.9%).

8.0 CONCLUSION/DISCUSSION

The Butterfly iQ is a portable, non-invasive, low-cost and low-maintenance P-LUS device capable of far-forward use to facilitate timely and effective triage of patients with acute respiratory symptoms. The deployment and learning curve of Butterfly iQ is smooth for providers with ultrasound training. The implementation of our simplified P-LUS scoring system allowed a quick assessment of existing P-LUS exams by raters with an excellent agreement in risk classification (low/high) among raters in two thirds of patients. P-LUS with the Butterfly iQ probe and our simplified scoring approach was capable of providing acceptable predictive value in the risk assessment of COVID-19 patients, specifically their need of hospital admission. A P-LUS score of 2 or 3 and the presence of diffuse B-lines or grossly abnormal pleura showed the highest predictive value for the need of hospital level of care. The presence of consolidation or air bronchogram, findings typically validated as the most abnormal lung findings, did not show as strong predictive value in our study. Perhaps this was related to the relative lower incidence of these findings in our patients.

The predictive value for the risk assessment of care setting after triage of acute respiratory insufficiency in conditions with a younger population or no access to laboratory analyses needs to be determined. The limitations of our study that prevent generalization to far-field military conditions could be the older age of our study population and the greater availability in several of our patients of laboratory results. Although we tested the potential to improve hospital resource allocation efficiency, our sample size of patients requiring intubation was insufficient to determine if P-LUS can reliably predict an early detection of deterioration of patients' clinical condition. This hypothesis will require a larger cohort of patients with P-LUS exams that were given prior to rapid progression of their respiratory condition.

However, it seems plausible that the Butterfly iQ and P-LUS score 2/3 with specific effort for identifying the presence of key P-LUS findings (diffuse B-lines, grossly abnormal pleura) can facilitate the initial triage of patients with suspected COVID-19 presenting with acute respiratory symptoms. We will perform secondary analyses to evaluate the predictive value of P-LUS scores

and individual findings for need of hospital level of care with and without other predictors (e.g., age, laboratory values or vital signs).

9.0 DELIVERABLES

- Educational materials for the triage of acute respiratory P-LUS with suggested lung areas.
- Scoring materials for the quick assessment of P-LUS exams.
- Predictive model including P-LUS and other clinical and laboratory biomarkers for timely and effective emergency triage and early identification of hospital admission required by COVID-19 patients presenting with acute respiratory symptoms.
- P-LUS score 2/3 and the presence of diffuse B-lines or grossly abnormal pleura in any lung location as the specific P-LUS findings with the highest predictive value for the triage and care destination of patients with acute respiratory symptoms suspected to COVID-19.
- SAEM 2022 – PAO#22277, Poster – "Predictive Modeling Including Point-of Care Lung Ultrasound (P-LUS) for Emergency Triage of Patients with Acute Respiratory Symptoms Related to COVID-19"
- MHSRS 2022 – PAO#22385, Oral Presentation – "Bedside Lung Ultrasound as a Prognostic Tool in Patients with Acute Respiratory Symptoms Related to COVID-19"
- Manuscript in progress

10.0 COST

The proposal was funded by the Air Force Medical Support Agency under the En Route Medical Technology Program in the amount of $567,537. All funds were expended.

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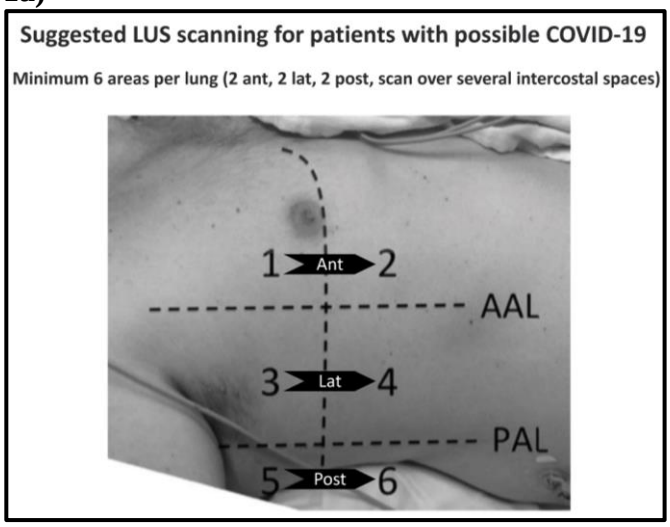
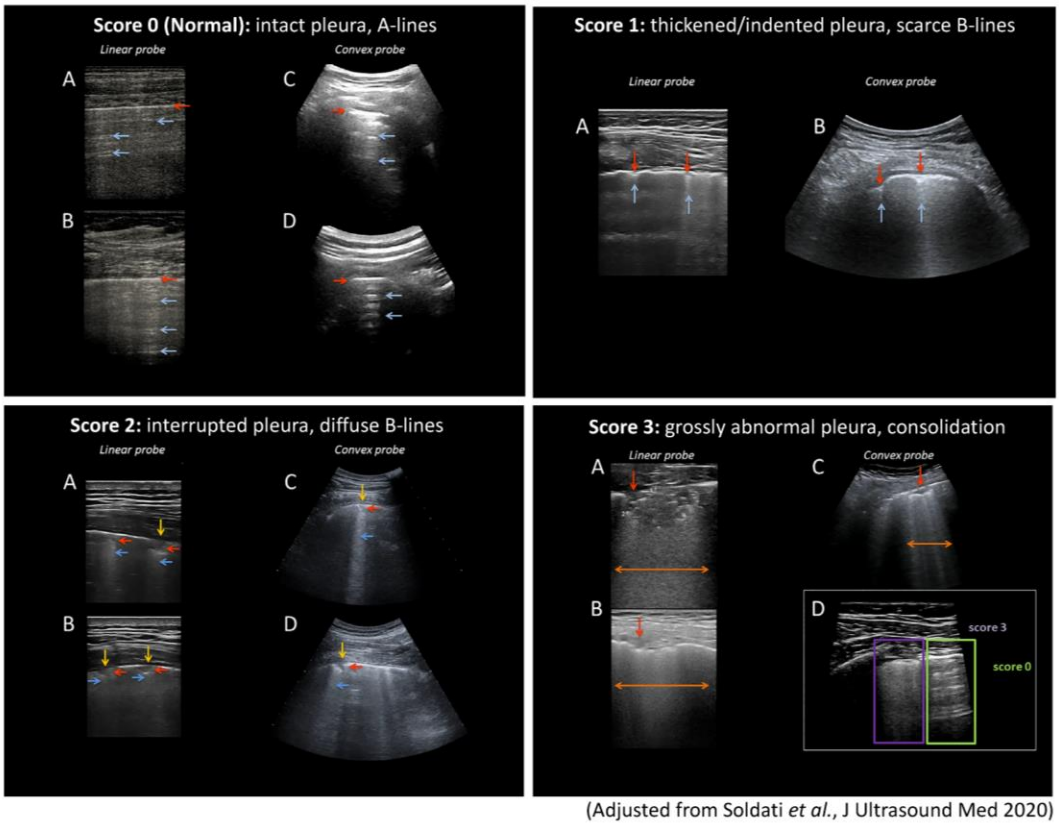
TABLES AND FIGURES

Figure 1. Materials made available for clinicians with suggested point-of-care lung ultrasound (P-LUS) scanning areas **(1a)** and with simplified scoring system for P-LUS exams by investigators **(1b).**

1a)



1b)



(Adjusted from Soldati *et al.*, J Ultrasound Med 2020)

Table 1. Level of agreement estimated by intraclass correlation coefficient with a two-way random effects model assuming the average rating of all reviewers is used in practice.

Measure	**ICC**	**95% CI**
Worst Score (0-3)	0.830	(0.772,0.875)
Presence of Normal Images	0.880	(0.846,0.909)
Presence of Isolated B-Lines	0.634	(0.531,0.721)
Presence of Diffuse B-Lines	0.906	(0.879,0.929)
Presence of Pleural Thickening/Irregularity	0.656	(0.526,0.751)
Presence of Subpleural Condensation/Thickening	0.489	(0.350,0.608)
Presence of Air Bronchograms	0.349	(0.180,0.499)
Binary Risk Classification	0.882	(0.846,0.911)

Table 2. Summary of Emergency Department visit data, overall and by post-ED destination status. (Continuous variables are presented as median (minimum, maximum) and categorical measures as frequency (percent)).

Covariate	Overall (N=204)	Hospital Admission (N=129, 63.2%)	Home Discharge (N=75, 36.8%)	p-value
Age (years)	54.0 (18.0, 96.0)	61.0 (18.0, 96.0)	38.0 (18.0, 83.0)	<0.001
Gender:				0.389
Male	118 (58.4%)	77 (60.2%)	41 (55.4%)	
Female	83 (41.1%)	51 (39.8%)	32 (43.2%)	
Other	1 (0.5%)	0 (0.0%)	1 (1.4%)	
Missing	2	1	1	
Site:				<0.001
DHMC	115 (56.4%)	47 (36.4%)	68 (90.7%)	
UCH	34 (16.7%)	27 (20.9%)	7 (9.3%)	
BAMC	55 (27.0%)	55 (42.6%)	0 (0.0%)	
Vital Signs				
Worst oxygenation (imputed PaO2/FiO2)	433.3 (73.7, 476.2)	328.6 (73.7, 466.7)	452.4 (220.4, 476.2)	<0.001
Highest respiratory rate (breaths/min)	20.0 (6.0, 84.0)	22.0 (14.0, 84.0)	18.0 (6.0, 30.0)	<0.001
Lowest mean arterial pressure (mmHg)	87.0 (41.0, 145.0)	81.0 (41.0, 145.0)	94.0 (72.0, 115.0)	<0.001
Laboratory Values				
White blood cell count (10*9/L)	7.3 (1.7, 37.7)	7.48 (1.7, 37.7)	6.4 (3.5, 13.9)	0.075
Lymphocyte count (10*9/L)	4.05 (0.44, 36.1)	5.0 (0.44, 36.1)	1.77 (0.96, 14.6)	0.156
Platelet count (10*9/L)	212.0 (12.1, 804.0)	211.0 (41.0, 804.0)	224.0 (12.1, 614.0)	0.727
C-reactive-protein (mg/L)	93.8 (2.2, 304.0)	103.1 (2.2, 304.0)	26.6 (3.2, 106.9)	0.008
IL-6 level (pg/mL)	5.0 (5.0, 5.0)	-	5.0 (5.0, 5.0)	
Ferritin	419.0 (10.5, 37280.0)	419.0 (10.5, 37280.0)	533.0 (130.3, 997.2)	0.952
Albumin	3.8 (2.3, 5.5)	3.75 (2.3, 5.5)	4.1 (3.4, 4.9)	0.016
Procalcitonin	0.28 (0.03, 46.1)	0.29 (0.03, 46.1)	0.17 (0.04, 14.5)	0.874
Creatine Kinase	61.5 (0.66, 1656.0)	61.5 (0.66, 1656.0)	-	
D-Dimer	1.12 (0.29, 5210.0)	1.13 (0.29, 3620.0)	0.67 (0.47, 5210.0)	0.945
Imaging				
Lung Ultrasound performed	126 (61.8%)	61 (47.3%)	65 (86.7%)	<0.001
P-LUS Findings:				
Normal	8 (6.3%)	1 (1.6%)	7 (10.8%)	0.063
Isolated B-lines	80 (63.5%)	50 (82.0%)	30 (46.2%)	<0.001
Diffuse B-lines	55 (43.7%)	40 (65.6%)	15 (23.1%)	<0.001
Pleural thickening/irregularity	61 (48.4%)	43 (70.5%)	18 (27.7%)	<0.001
Sub-pleural consolidation/ thickening	24 (19.0%)	16 (26.2%)	8 (12.3%)	0.068
Air bronchogram(s)	2 (1.6%)	2 (3.3%)	0 (0.0%)	0.232
P-LUS Score:				0.002
0	9 (9.8%)	1 (1.9%)	8 (21.1%)	
1	19 (20.7%)	8 (14.8%)	11 (28.9%)	

2	40 (43.5%)	27 (50.0%)	13 (34.2%)	
3	24 (26.1%)	18 (33.3%)	6 (15.8%)	
Chest X-ray performed	151 (74.4%)	114 (88.4%)	37 (50.0%)	<0.001
Other Imaging	26 (13.0%)	24 (19.0%)	2 (2.7%)	<0.001
Respiratory Treatment received:				
None	106 (52.0%)	42 (32.6%)	64 (85.3%)	<0.001
Oxygen (non-invasive)	96 (47.1%)	86 (66.7%)	10 (13.3%)	<0.001
Intubation	1 (0.5%)	1 (0.8%)	0 (0.0%)	1.000
Post-ED Destination:				<0.001
Home/Living Facility	74 (36.5%)	0 (0.0%)	75 (100.0%)	
Hospital Floor	90 (44.3%)	90 (69.8%)	0 (0.0%)	
ICU	39 (19.2%)	39 (30.2%)	0 (0.0%)	

Table 3. Summary of Emergency Department visit data, overall and by the need for intubation or not. (Continuous variables are presented as median (minimum, maximum) and categorical measures as frequency (percent)).

Covariate	Intubation (N=12, 5.9%)	No Intubation (N=192, 94.1%)
Age (years)	61.5 (48.0, 77.0)	53.0 (18.0, 96.0)
Gender:		
Male	9 (75.0%)	109 (57.4%)
Female	3 (25.0%)	80 (42.1%)
Other	0 (0.0%)	1 (0.5%)
Missing	0	2
Site:		
DHMC	6 (50.0%)	109 (56.8%)
UCH	3 (25.0%)	31 (16.1%)
BAMC	3 (25.0%)	52 (27.1%)
Vital Signs		
Worst oxygenation (imputed PaO2/FiO2) at ED	145.0 (73.7, 438.1)	433.3 (74.8, 476.2)
Worst oxygenation (imputed PaO2/FiO2) at Floor	150.0 (60.0, 900.0)	332.1 (70.5, 466.7)
Worst oxygenation (imputed PaO2/FiO2) in ICU	88.0 (47.0, 339.3)	268.6 (73.0, 461.9)
Highest respiratory rate (breaths/min)	31.0 (18.0, 48.0)	20.0 (6.0, 84.0)
Lowest mean arterial pressure (mmHg)	76.0 (41.0, 99.0)	88.0 (46.0, 145.0)
Laboratory Values		
White blood cell count (10*9/L)	9.1 (4.1, 17.2)	7.15 (1.7, 37.7)
Lymphocyte count (10*9/L)	1.1 (0.69, 13.1)	4.22 (0.44, 36.1)
Platelet count (10*9/L)	193.0 (111.0, 288.0)	215.0 (12.1, 804.0)
C-reactive-protein (mg/L)	139.5 (60.5, 267.4)	78.8 (2.2, 304.0)
IL-6 level (pg/mL)	-	5.0 (5.0, 5.0)
Ferritin	619.5 (96.0, 37280.0)	401.0 (10.5, 3248.5)
Albumin	3.85 (3.5, 4.1)	3.8 (2.3, 5.5)
Procalcitonin	1.3 (0.12, 12.2)	0.28 (0.03, 46.1)
Creatine Kinase	-	61.5 (0.66, 1656.0)
D-Dimer	1455.0 (2.06, 3620.0)	0.7 (0.29, 5210.0)
Imaging		
Lung Ultrasound performed	8 (66.7%)	118 (61.5%)
P-LUS Findings:		
Normal	0 (0.0%)	8 (6.8%)
Isolated B-lines	6 (75.0%)	74 (62.7%)
Diffuse B-lines	5 (62.5%)	50 (42.4%)
Pleural thickening/irregularity	4 (50.0%)	57 (48.3%)
Sub-pleural consolidation/ thickening	1 (12.5%)	23 (19.5%)
Air bronchogram(s)	0 (0.0%)	2 (1.7%)

P-LUS Score:		
0	0 (0.0%)	9 (10.5%)
1	0 (0.0%)	19 (22.1%)
2	5 (83.3%)	35 (40.7%)
3	1 (16.7%)	23 (26.7%)
Chest X-ray performed	11 (91.7%)	140 (73.3%)
Other Imaging	0 (0.0%)	26 (13.8%)
Respiratory Treatment received:		
None	2 (16.7%)	104 (54.2%)
Oxygen (non-invasive)	9 (75.0%)	87 (45.3%)
Intubation	1 (8.3%)	0 (0.0%)
Post-ED Destination:		
Home/Living Facility	0 (0.0%)	75 (39.0%)
Hospital Floor	5 (41.7%)	85 (44.5%)
ICU	7 (58.3%)	32 (16.8%)

Table 4. Selected continuous predictors for discharge status (hospital admission vs. home discharge) with logistic regression and summarized AUC, Brier score, optimal threshold (determined by Youden's J statistic), sensitivity, and specificity.

Predictor	Home Discharge Mean (sd)	Hospital Admission Mean (sd)	AUC	Brier Score	Optimal Thresh.	Sensit-ivity	Specif-icity
Age (years) [N=203]	39.4 (17.6)	60.0 (16.5)	0.802 (0.738, 0.867)	0.168	>47.50	0.798 (0.719, 0.864)	0.716 (0.599, 0.815)
Worst oxygenation (imputed PaO2/FiO2) [N=198]	436.3 (50.5)	319.1 (118.9)	0.850 (0.797, 0.903)	0.165	<445.24	0.815 (0.735, 0.879)	0.716 (0.599, 0.815)
Highest RR (breaths/min) [N=203]	19.2 (3.4)	25.6 (10.1)	0.780 (0.716, 0.843)	0.182	>20.50	0.628 (0.538, 0.711)	0.784 (0.673, 0.871)
Lowest MAP (mmHg) [N=130]	92.5 (10.1)	82.6 (15.6)	0.713 (0.621, 0.805)	0.186	<86.50	0.613 (0.506, 0.712)	0.811 (0.648, 0.920)
White blood cell count (10*9/L) [N=158]	7.0 (2.4)	8.8 (5.0)	0.601 (0.502, 0.700)	0.161	>8.35	0.424 (0.336, 0.516)	0.818 (0.645, 0.930)
Lymphocyte count (10*9/L) [N=105]	2.9 (3.8)	9.1 (9.5)	0.627 (0.514, 0.740)	0.096	>4.03	0.559 (0.452, 0.662)	0.917 (0.615, 0.998)
Platelet count (10*9/L) [N=157]	225.2 (100.9)	220.5 (92.1)	0.520 (0.408, 0.632)	0.162	<222.50	0.584 (0.492, 0.671)	0.531 (0.347, 0.709)
C-reactive-protein (mg/L) [N=37]	37.7 (39.3)	124.4 (86.6)	0.819 (0.659, 0.979)	0.124	>71.75	0.733 (0.541, 0.877)	0.857 (0.421, 0.996)
Albumin [N=100]	4.1 (0.4)	3.8 (0.5)	0.701 (0.554, 0.848)	0.114	<4.05	0.733 (0.626, 0.822)	0.571 (0.289, 0.823)
Procalcitonin (ng/mL) [N=39]	4.9 (8.3)	2.6 (7.9)	0.532 (0.006, 1.000)	0.071	>0.19	0.639 (0.462, 0.792)	0.667 (0.094, 0.992)
D-Dimer [N=32]	821.7 (1,939.2)	395.6 (948.8)	0.511 (0.222, 0.801)	0.166	>0.56	0.800 (0.593, 0.932)	0.429 (0.099, 0.816)
P-LUS Highest Score [N=92]	1.4 (1.0)	2.1 (0.7)	0.697 (0.591, 0.803)	0.207	>1.50	0.833 (0.707, 0.921)	0.500 (0.334, 0.666)

Table 5. Selected categorical predictors for discharge status (hospital admission vs. home discharge) with logistic regression and summarized AUC, Brier score, optimal threshold (determined by Youden's J statistic), sensitivity, and specificity.

	Home Discharge	Floor/ICU Admit	Overall		Row-Specific		
Predictor of ICU Admit	**N (Row %)**	**N (Row %)**	**AUC**	**Brier**	**AUC**	**Sens**	**Spec**
Worst ED LUS 0/1	19 (67.9%)	9 (32.1%)	0.667 (0.572, 0.762)	0.212	0.333 (0.238, 0.428)	0.167 (0.079, 0.293)	0.500 (0.334, 0.666)
Worst ED LUS 2/3	19 (29.7%)	45 (70.3%)			0.667 (0.572, 0.762)	0.833 (0.707, 0.921)	0.500 (0.334, 0.666)
No Isolated B-Lines	35 (76.1%)	11 (23.9%)	0.679 (0.601, 0.757)	0.215	0.321 (0.243, 0.399)	0.180 (0.094, 0.300)	0.462 (0.337, 0.590)
Isolated B-Lines	30 (37.5%)	50 (62.5%)			0.679 (0.601, 0.757)	0.820 (0.700, 0.906)	0.538 (0.410, 0.663)
No Diffuse B-Lines	50 (70.4%)	21 (29.6%)	0.712 (0.633, 0.792)	0.204	0.288 (0.208, 0.367)	0.344 (0.227, 0.477)	0.231 (0.135, 0.352)
Diffuse B-Lines	15 (27.3%)	40 (72.7%)			0.712 (0.633, 0.792)	0.656 (0.523, 0.773)	0.769 (0.648, 0.865)
No Pleural Thickening/Irregularity	47 (72.3%)	18 (27.7%)	0.714 (0.634, 0.794)	0.204	0.286 (0.206, 0.366)	0.295 (0.185, 0.426)	0.277 (0.173, 0.402)
Pleural Thickening/Irregularity	18 (29.5%)	43 (70.5%)			0.714 (0.634, 0.794)	0.705 (0.574, 0.815)	0.723 (0.598, 0.827)
No Sub-Pleural Consolidation/Thickening	57 (55.9%)	45 (44.1%)	0.570 (0.501, 0.638)	0.242	0.430 (0.362, 0.499)	0.738 (0.609, 0.842)	0.123 (0.055, 0.228)
Sub-Pleural Consolidation/Thickening	8 (33.3%)	16 (66.7%)			0.570 (0.501, 0.638)	0.262 (0.158, 0.391)	0.877 (0.772, 0.945)
No Air Bronchogram(s)	65 (52.4%)	59 (47.6%)	0.516 (0.494, 0.539)	0.245	0.484 (0.461, 0.506)	0.967 (0.887, 0.996)	0.000 (0.000, 0.055)
Air Bronchogram(s)	0 (0.0%)	2 (100.0%)			0.516 (0.494, 0.539)	0.033 (0.004, 0.113)	1.000 (0.945, 1.000)

12.0 List of Symbols, Abbreviations and Acronyms

AUC = Area Under the Curve
CI = Confidence Interval
COVID-19 = Coronavirus Disease -19
ED= Emergency Department
ICC = Intraclass Correlation Coefficient
MAP=Mean Arterial Pressure
P-LUS = Point-of-care Lung Ultrasound
RR=Respiratory Rate