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Clinical and Chest Radiography Features Determine Patient Outcomes In Young and Middle Age Adults with COVID-19

Danielle Toussie MD[1], Nicholas Voutsinas MD[1], Mark Finkelstein MD[1], Mario A Cedillo MD[1], Sayan Manna BS[2], Samuel Z Maron MA[2], Adam Jacobi MD[1], Michael Chung MD[1], Adam Bernheim MD[1], Corey Eber MD[1], Jose Concepcion MD[1], Zahi Fayad PhD[1], Yogesh Sean Gupta MD[1]

[1]*Department of Diagnostic, Molecular and Interventional Radiology, Icahn School of Medicine at Mount Sinai, Mount Sinai Hospital, New York, NY USA 10029*

[2]*Icahn School of Medicine at Mount Sinai, Mount Sinai Hospital, New York NY USA 10029*

Corresponding Author:
Danielle Toussie MD
Department of Diagnostic, Molecular, and Interventional Radiology
Radiology Resident PGY-5, Icahn School of Medicine at Mount Sinai
1 Gustave L. Levy Place
New York, NY 10029
Danielle.toussie@mountsinai.org

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Summary statement: On initial chest radiographs from the emergency department, lung zone severity scores predicted outcomes in young and middle age adults with COVID-19.

Key results:

- On chest x-ray divided into 3 zones per lung, a severity score was assigned based on the presence or absence of opacity in each zone (max score 6, minimum 0).
- After adjusting for demographics and co-morbidities, a chest x-ray severity score ≥2 was associated with hospital admission (OR 6.2).
- Of patients who were admitted, a CXR score ≥3 was an independent predictor of intubation (OR: 4.7).

Abbreviations for less common terms: Coronavirus disease 2019 (COVID-19); severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2); reverse transcriptase polymerase chain reaction (RT-PCR); alanine aminotransferase (ALT); estimated glomerular filtration rate (eGFR), C-reactive protein (CRP); Interleukin-6 (IL-6), emergency department (ED); body mass index (BMI), odds ratio (AOR)

Abstract:

Background: Chest radiography (CXR) has not been validated for its prognostic utility in evaluating patients with coronavirus disease 2019 (COVID-19).

Purpose: The purpose of this study was to analyze the prognostic value of a CXR severity scoring system for younger (non-elderly) patients with COVID-19 upon initial presentation to the emergency department (ED). Outcomes of interest included hospitalization, intubation, prolonged stay, sepsis, and death.

Materials & Methods: In this retrospective study, patients between the ages of 21 and 50 years who presented to EDs of an urban multicenter health system from March 10 - 26, 2020 with COVID-19 confirmation on real-time reverse transcriptase polymerase chain reaction (RT-PCR) were identified. Each patient's ED CXR was divided into 6 zones and examined for opacities by two cardiothoracic radiologists with scores collated into a total concordant lung zone severity score. Clinical and laboratory variables were collected. Multivariable logistic regression was utilized to evaluate the relationship between clinical parameters, CXR scores, and patient outcomes.

Results: The study included 338 patients: 210 males (62%), median age 39 [31-45]. After adjustment for demographics and co-morbidities, independent predictors of hospital admission (n=145, 43%) were CXR severity score ≥ 2 (OR: 6.2, 95% CI 3.5-11, p<0.001) and obesity (OR 2.4 (1.1-5.4) or morbid obesity. Of patients who were admitted, a CXR score ≥3 was an independent predictor of intubation (n=28) (OR: 4.7, 95% CI 1.8-13, p=0.002) as was hospital site. We found no significant difference in primary outcomes across race/ethnicity, those with a history of tobacco use, asthma or diabetes mellitus type II.

Conclusion: For patients aged 21-50 with COVID-19 presenting to the emergency department, a chest x-ray severity score was predictive of risk for hospital admission and intubation.

Introduction:

Coronavirus disease 2019 (COVID-19), caused by the novel severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), emerged in Wuhan, China in December 2019.[1] As of April 29th, 2020 the disease is now a global pandemic with over 3 million confirmed cases and over 250,000 deaths [2]. Chest radiography (CXR) has become the primary imaging modality used for clinical management.

Previous investigators have examined the utility of imaging for screening and prognosis.[3] The Fleischner Society issued a consensus statement exploring the application of imaging, primarily computed tomography (CT), in the evaluation, diagnosis, and risk stratification of patients.[4] Still, many radiology professional organizations, including the American College of Radiology (ACR) and the Society of Thoracic Radiology (STR), have recommended against the use of CT and two-view CXR for large-scale screening and diagnosis, stating instead that health facilities can consider portable CXR.[5] In the United States, CXR is routinely obtained in the emergency department (ED) for patients presenting with dyspnea with/without COVID-19 infection.

Early reports on CXR findings and the distribution of lung abnormalities shows a variable appearance. Though CXR has low sensitivity (~69%) for diagnosis of COVID-19, the utility of initial CXR on predicting clinical outcomes is an unmet need.[6] However, during the severe acute respiratory syndrome (SARS) coronavirus outbreak in 2003, bilateral disease and involvement of more than two zones on CXR were associated with poorer outcomes.[7–9] Similar correlations have been observed in a variety of other pneumonias.[10–12] While a recent Cochrane review of two trials suggested that routine CXR for patients with lower respiratory tract infections did not affect outcomes, the implications of using CXR to help predict outcomes in patients with COVID-19 pneumonia remains unknown.[13]

CXR interpretation can often be confounded by underlying comorbid conditions, such as heart failure or

chronic lung disease. Therefore, accurate, consistent, and predictive CXR interpretations may be more valid in the younger population. Though COVID-19 has a higher degree of morbidity and mortality in older populations, patients under 50 still comprise a sizable portion of the hospitalized population.[14]

The purpose of this study was to determine the relationship between the clinical and the initial CXR findings and the outcome variables of hospital admission and/or intubation in COVID-19 patients between the ages of 21 and 50.

Materials and Methods:

This was an IRB approved retrospective review of 338 COVID-19 patients between the ages of 21 and 50, who presented to the emergency department (ED) at Mount Sinai, a multicenter health system in New York City from March 10 - 26, 2020. The requirement for informed patient consent was waived by the ethics committee for this retrospective study.

Inclusion criteria for patients

Using the MONTAGE ™ search and Analytics platform, radiology information system (RIS) data were extracted from all CXR examinations performed during the study period. The resulting RIS dataset contained 3866 ED encounters. Patients greater than 50 or less than 21 years of age, cases with duplicate medical record numbers, unconfirmed COVID19 RT-PCR positivity, ED encounters unrelated to COVID19, unevaluable CXR, and inaccessible clinical data encounters were excluded. After exclusions, 338 patients were included for analysis (Figure 1). Subset analysis was done on the 145 of these patients who were admitted to the hospital for treatment.

Clinical data collection

Demographic variables collected included age, gender, self-reported race and ethnicity. Additional clinical variables included past medical history, body mass index (BMI), smoking history, length from symptom onset to presentation, and temperature. A temperature greater than 100.3°F was defined as febrile. Length of stay was categorized as prolonged if >10 days.

Imaging data collection

For all patients, two fellowship trained cardiothoracic radiologists (C.E. with 26 years experience and A.J with 10 years experience) scored each initial CXR independently of each other. To minimize bias, reviewers were blinded to patient histories other than COVID-19 positivity. All patients received either digital portable anteroposterior (AP) CXR (244/338 or 73.4%) or digital posteroanterior and lateral (PA/LAT) CXR (94/338 or 26.6%).

Imaging analysis

Each lung was divided into three zones. The lower zone extends from the costophrenic sulcus to inferior hilar markings, the middle zone from inferior hilar markings to superior hilar markings, and the upper zone from superior hilar markings to the apices. Each zone was given a binary score depending on if an opacity was absent (0) or present (1), which were then summed for a total score (Figure 2).

Statistical analysis

The Cohen's kappa coefficient and complete concordance were used to assess agreement in CXR

interpretation between the two radiologists. Complete concordance (CC) was defined as the percentage of identical findings among the radiologists for the various radiographic parameters. The total concordant lung zone severity score was calculated by summing zones that were in total concordance among both radiologists. Only findings that were concordant between radiologists were analyzed. Clinical features of patients were analyzed using various radiographic features as independent variables.

Continuous variables that included missing values (BMI, temperature) were imputed using predictive mean matching using models that included outcomes of interest and demographic information. Prior to imputation, data was analyzed to ensure no significant departure from the assumption of missingness at random. Sensitivity analysis was performed with multiple computed sets made available by the imputation model. The primary outcomes of interest for this study were hospital admission, patient intubation, prolonged length of stay, development of sepsis, and death. A secondary outcome of interest for clinical variables was a high CXR score. Logistic regression was utilized in order to estimate the relative effect of variables by calculating unadjusted odds ratios for categorical outcomes. Least absolute shrinkage and selection operator (LASSO) was utilized for variable selection for multivariable selection. Data with positive skewed distribution (days since symptom onset) was normalized for comparison. The area under the receiver-operating curve (ROC), sensitivity, and specificity was calculated for concordant score in relation to the outcomes of interest. Additionally, the highest value of the Youden Index was obtained to determine an appropriate cutoff for concordant score in relation to the outcomes of interest. A p-value of less than 0.05 (two-tailed) was considered statistically significant. All analysis was completed using R version 3.6.3 (R Foundation for Statistical Computing, Vienna, Austria).

Results:

A total of 338 COVID-19 positive young adults were included (median age 39 [interquartile range (IQR)31-45]; 62% male; 71 (21%) White, 30 (9%) Asian, 116 Hispanic (34%), 32 (23%) Black, unknown

43 (13%)). Fifty-one (15%) patients reported being current or former smokers and 130 (40%) were obese or morbidly obese (as defined by BMI>30). The most frequent comorbidities were hypertension 54 (16%), asthma 46 (14%), and diabetes mellitus type II 39 (12%). The median number of days from symptom onset to presentation in the ED was 4 [2-6]. All patients were followed for at least 20 days from initial ED presentation.

CXRs were scored by two radiologists with very good total lung zone concordance (0.88). Concordance scores for individuals zones were: right lower (Kappa 0.92, CC 95.9%), right middle (Kappa 0.85, CC 94.1%), right upper (Kappa 0.78, CC 97.9%), left lower (Kappa 0.87, CC 93.8%), left middle (Kappa 0.85, CC 94.1%), and left upper (Kappa 0.61, CC 96.5%).

With respect to the frequency and distribution of lung zone opacities, 170/338 (50%) patients had an initial CXR score of 0. The right lower [142 (42%)] and left lower [128 (38%)] lung zones were most frequently affected, followed by the right middle [77 (23%)] and left middle [83 (25%)] lung zones, and least by the right upper [13 (4%)] and left upper [10 (3%)] lung zones. No patients had pneumothorax or significant pleural effusion.

In the ROC curve analysis of all 338 patient's CXR scores in relation to admission, involvement of at least two lung zones was selected as a cutoff (sensitivity 96/145 (66%, 95% CI 58%-74%), specificity 153/193 (79%, 95% CI 73%-85%)) with an area under the ROC curve (AUC) of 0.77 (95% CI: 0.72-0.82, $p < 0.001$). In analyzing the subset of 145 hospitalized patients, ROC curve analysis of CXR score in relation to the outcomes of interests consistently revealed involvement of ≥ 3 lung zones as a better cutoff. For intubation: sensitivity 19/28 (68%, CI 95% 48%-84%), specificity 78/117 (67%, CI 95% 57%-75%) (AUC 0.74; CI: 0.64-0.84 $p < 0.001$). For prolonged stay: sensitivity 15/29 (52%, 95% CI 33%-71%), specificity 73/116 (63%, 95% CI 53%-72%) (AUC 0.62; CI: 0.50-0.73, $p = 0.02$). For sepsis: sensitivity 36/89 (40%, 30%-51%), specificity 34/56 (61%, 95% CI 47%-74%) (AUC 0.54; CI: 0.44-0.63 $p = 0.2$).

Secondary outcome of CXR severity score:

Demographics and clinical findings in relation to the severity of opacification on the initial CXR (score ≥ 2) are presented for all 338 patients (Table 1). Older age (40 vs 37 years; p=0.004) and male sex (73% vs 55% ; p<0.001) patients had higher CXR scores as did patients with a history of human immunodeficiency virus (HIV) infection (4% vs 1% ; p=0.4) and obesity (52%% vs 31% ; p<0.001). Patients presenting later in the disease time course (6 vs 3 days from symptom onset; p<0.001), with fever (39% vs 24% ; p=0.004) also had higher CXR scores. Interestingly, presentation to a Queens hospital site (33% vs 24% ; p=0.1) also predicted more severe lung zone opacity (CXR scores ≥2). The severity of opacities were not statistically different between races/ethnicities or among those with a history of smoking, asthma, hypertension or diabetes.

Demographics and clinical findings in relation to CXR severity score ≥3 are presented for all 145 admitted patients (Table 2). Hispanic ethnicity (50% vs 33%; p=0.03) was an independent predictor of a CXR score ≥3. There were no other demographic, clinical, or laboratory findings related to a CXR score ≥3.

Clinical outcomes:

A total of 145/338 (43%) patients were admitted. Of these, 28 (19%) were intubated, 89 (61%) developed sepsis, 29 (20%) had a prolonged stay, and 10 (7%) expired. At the time of writing, 5 (3%) were still intubated in ICUs.

CXR zonal severity scores

In adjusted analyses, the total CXR severity score was found to be significantly associated with several adverse outcomes. Incrementally increasing CXR score was found to be an independent predictor of

admission (adjusted OR: 1.9, 95% CI 1.6-2.3, p < 0.001) (Table 3). A CXR severity score ≥2 was likewise found to be an independent predictor of admission (adjusted OR: 6.2 CI 3.5-11, p < 0.001). Interestingly, 40 patients with a score of 2-4 were not admitted. Clinical predictors of need for hospitalization included age and obesity or morbid obesity. There was no significant difference in hospitalization rates amongst gender, races/ethnicities or for those with a history of smoking, asthma, diabetes mellitus, or HIV infection.

Within the admitted patients (Table 4), a CXR severity score ≥3 was found to be an independent predictor of intubation (adjusted OR: 4.7 CI 1.8-13, p = 0.002) in the adjusted models. Patients who died were found to have higher CXR scores, however there were not enough cases to achieve statistical significance (n=10). Higher CXR scores were not predictive of development of sepsis (adjusted OR: 1.1 CI 0.9-1.0, p=0.47) or prolonged length of stay (adjusted OR: 1.1 CI 0.8-1.5, p=0.25) . Clinical predictors of intubation included age and morbid obesity. Patients admitted to a hospital site in Queens, as opposed to Manhattan or Brooklyn, were more likely to be intubated. There were no differences in rates of intubation between races/ethnicities, nor those who had a history of smoking, asthma, diabetes mellitus, or HIV infection.

Discussion:

The unprecedented burden that the COVID-19 pandemic has placed upon healthcare institutions highlights the need for a simple to use robust CXR algorithm to prioritize management and predict outcomes. In this study we explore the value of initial chest radiography in evaluating young adults with COVID-19 in the emergency room setting. The severity of opacification on the initial chest radiograph was associated with need for hospitalization and need for intubation. Patients with opacities in at least two lung zones were more likely to require hospitalization and those with opacities in at least three lung zones

were more likely to require intubation. Chest radiography was not predictive of development of sepsis or prolonged stay and while most patients who died had more extensive lung opacification, too few deaths occurred for a meaningful relationship. There was no significant difference in primary outcomes across race/ethnicity, those with tobacco use or a history of asthma or diabetes mellitus type II.

Opacities in any lung zone increased the risk of hospitalization and intubation, except for opacification in the left lower lung zone, which had no correlation with intubation. The left lower lung zone is often partially obscured and suboptimally evaluated on portable CXR so true correlations may have been missed. Regardless, the lobar distribution of COVID-19 provides insight into the progression of the disease. In our cohort, the right lower lobe was the most frequently affected (42%) followed by the left lower lobe (38%). Prior studies on the frequency and distribution of CXR and CT opacities in patients with COVID-19 have demonstrated the opacities are typically bilateral, peripheral, and basilar in distribution with a similar predilection for the right lower lobe, especially early on in disease.[2,5,15] Other viral pneumonias such as SARS and H7N9 influenza infection also have demonstrated a predilection for the right lower lobe, which has been thought to be related to the anatomical structure of the right lower lobe bronchus.[16] Right lower lung zone opacification was additionally associated with prolonged length of stay in our cohort. While CXR severity score was an independent predictor of outcomes, a number of clinical risk factors were also identified in this cohort. The observation that age, male gender and higher BMI are associated with an increased risk of a higher CXR score (≥2) and need for hospitalization and intubation in this group is in accordance with several other reports, including a large-scale analysis conducted by the Centers for Disease Control and Prevention's (CDC) COVID-net database.[14,17]

Smoking was not an independent risk factor for outcomes of interest. Our results are somewhat incongruent with other reports that note smoking is associated with COVID-19 disease progression.[18] Basic science research has suggested that cigarette smoke upregulates the expression of the SARS-CoV

entry receptor in respiratory epithelium.[19] The evaluation of dose-response effect between smoking and CXR severity was in fact unachievable without available pack-year data in the patient's chart. Future studies should obtain the duration of smoking exposure in order to adequately assess smoking risk.

In a relatively healthy population, the presence of underlying medical conditions can be reasonably suggested as drivers for adverse outcomes. The CDC's analysis of 366 COVID-19 patients aged 18-49 demonstrated that the five most common underlying conditions were obesity, asthma, diabetes, hypertension, and immunosuppressive disease. In our cohort, hypertension was a significant comorbidity, increasing the risk of admission, but not intubation or other outcomes. These findings dovetail with a meta-analysis of over 46,000 patients demonstrating increased severity of disease in patients with hypertension, but not diabetes.[20] Patients with HIV infection, an often understudied population, also demonstrated higher CXR scores.

There was no difference in primary patient outcomes between races and ethnicities in our cohort. Though preliminary data from the New York City Department of Health notes that African Americans and Hispanics/Latinos may have higher death rates, studies are ongoing and data is still being collected. Despite this, the presence of disproportionately worse CXR scores and increased risk of intubation among patients presenting to our hospital site in Queens suggests the presence of a systemic disparity and warrants further investigation.

The primary limitation of this study is its retrospective nature, which may introduce observer bias in how outcome is assessed. CXR reports were available to ED physicians, which likely influenced the decision to admit, confounding and potentially overestimating the true relationship between CXR severity and

admission. While the degree of this influence is unclear, a prior study has demonstrated that ED physicians do not cite chest radiography as a major factor in influencing decisions to admit for community acquired pneumonia. [21] Furthermore, CURB-65 and Pneumonia Severity Index (PSI)—the most widely used scoring systems to guide decisions on admitting patients with CAP—exclude chest radiographs as major or minor criteria. [22] Nevertheless, validation studies are needed to thoroughly corroborate the exposure-outcome relationship between CXR severity and admission in COVID-19 patients.

A second limitation of this study is the lack of long-term follow-up beyond 20 days. As yet, only 10 deaths were observed in the entire patient cohort, but as of the time of writing eight patients were still intubated in ICUs with indeterminate outcomes. An additional limitation is its retrospective nature, which can lead to observer bias. Most of the CXRs in this study were portable, in which evaluation of the left lower lobe is limited. The study of young adult patients only pertained to the initial CXR; further studies will be needed to analyze worsening and improving opacities on follow-up CXRs in relation to outcomes and to validate these results in an older population.

Conclusion

We have validated the use of initial CXR severity scores as an independent prognostic indicator of outcomes in COVID-19 patients. These results underscore how COVID-19, despite its many non-respiratory manifestations, is primarily a respiratory illness and the lung parenchymal changes—as seen on chest radiography as opacification—are the primary driver of disease progression. Furthermore, the study identifies a number of demographic and clinical features that are strongly correlated with these outcomes. These findings allow for identification of high-risk patients while minimizing anchoring heuristics that may be present among clinicians in high-volume settings.

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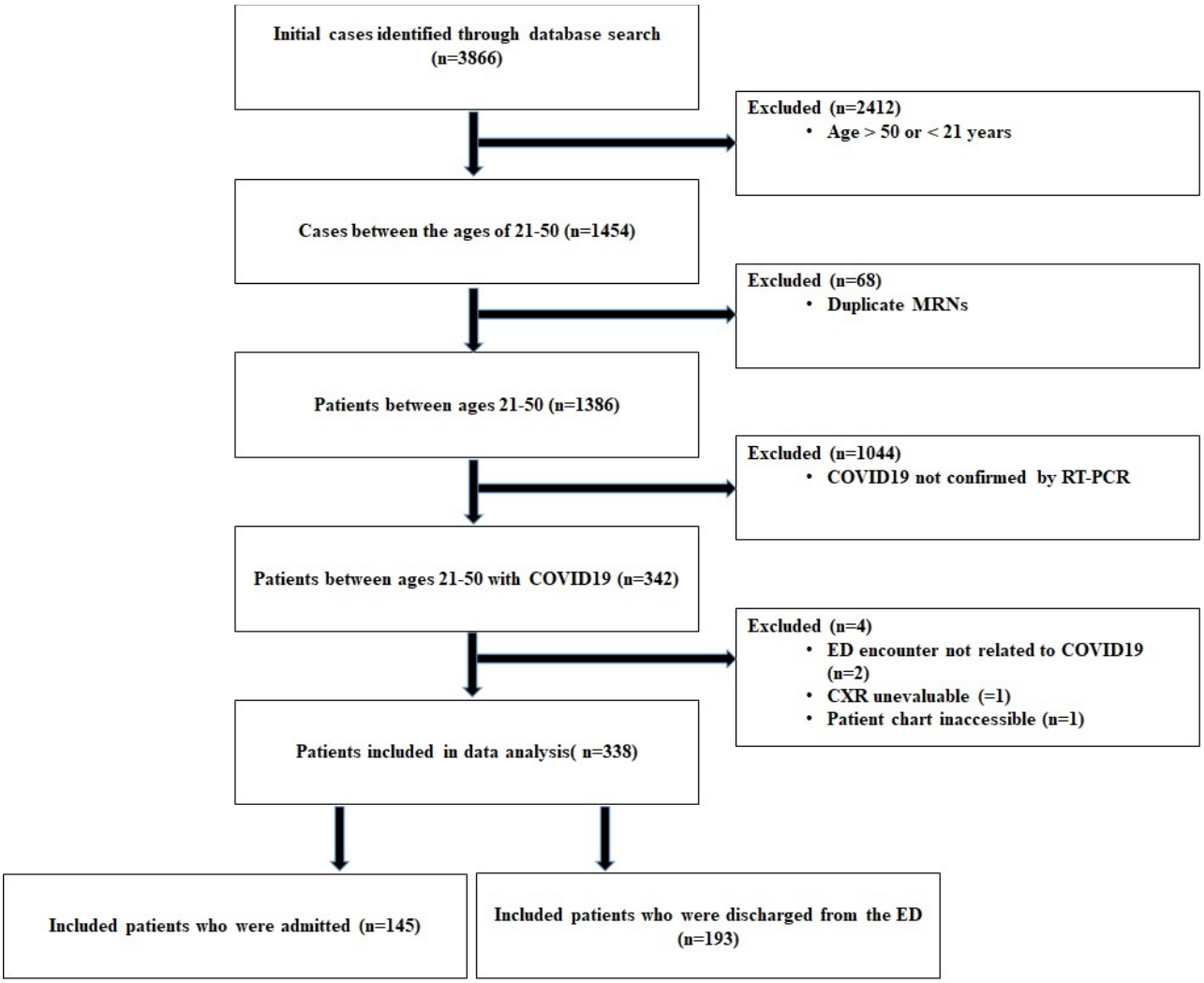

Figure 1: Flow diagram of our retrospective cohort study.

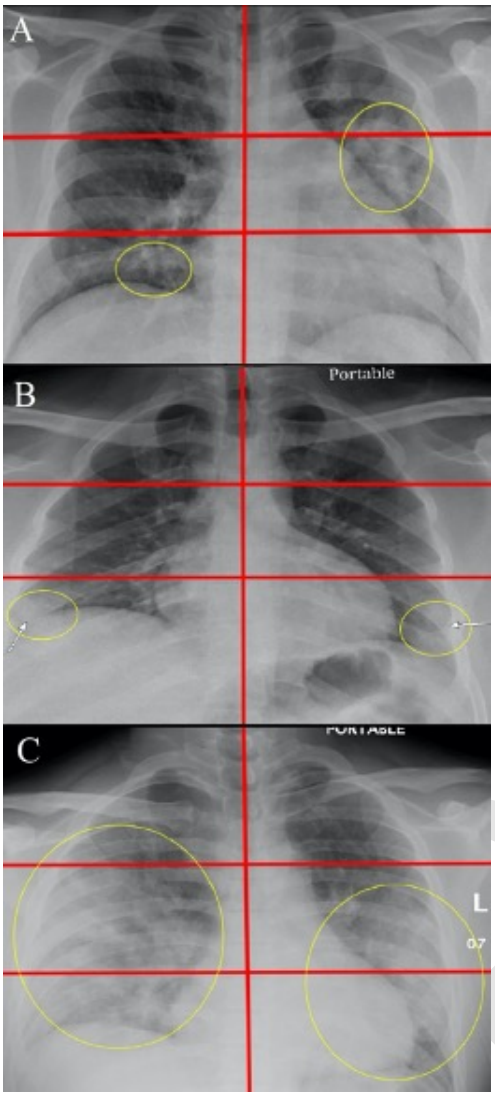

Figure 2: Examples of the chest severity score. *A*, Chest radiograph of a 26-year-old male with no past medical history other than obesity (BMI = 38) who was admitted for COVID-19 requiring oxygen supplementation via nasal cannula and initially tested negative for COVID-19 via nasopharyngeal swab, but later tested positive for antibodies to SARS-CoV2 virus. Portable CXR shows right lower lung zone, left middle lung zone, and left upper lung zone hazy opacities; total score=3. *B*, Chest radiograph of a 23-year-old male with no past medical history who tested positive for COVID-19 via RT-PCR and was subsequently discharged from the emergency department with home care and isolation precautions. Portable CXR shows right and left peripheral lower lung zone hazy opacities; total score=2. *C*, Chest radiograph in a 32-year-old overweight (BMI=30) COVID-19 positive male with a history of childhood asthma who was subsequently admitted and intubated in the ICU for 3 days. Portable CXR shows opacities in all three right lung zones and in the left middle and lower lung zones; total score=5.

TABLE 1: Patient demographics and clinical findings in relation to CXR severity score 0-1 versus 2-6 for 338 patients in the ED setting.

Variables	All patients (n = 338)	Low CXR severity score 0-1 (n=202)	High CXR severity score 2-6 (n=136)	P-value
Age median (years) [IQR]	39 [31, 45]	37 [30, 44]	40 [34, 46]	**0.004**
Sex (% male)	210 (62)	111 (55)	99 (73)	**<0.001**
Race/ethnicity (%)				0.43
White	71 (21)	47 (23)	24 (18)	
Asian	30 (9)	19 (9)	11 (8.1)	
Black	78 (23)	46 (23)	32 (24)	
Hispanic	116 (34)	62 (31)	54 (40)	
Other/unknown	43 (13)	28 (14)	15 (11)	
Hospital site (%)				**0.01**
Manhattan	143 (42)	81 (40)	62 (46)	
Brooklyn	102 (30)	73 (36)	29 (21)	
Queens	93 (28)	48 (24)	45 (33)	
Time from symptom onset (days) [IQR]	4 [2, 6]	3 [2, 6]	6 [3, 7]	**<0.001**
Smoking history (%)				0.20
Never	223 (66)	141 (70)	82 (60)	
Current or Former	51 (15)	27 (13)	24 (18)	
Unknown	64 (19)	34 (17)	30 (22)	
BMI median (kg/m2) [IQR]	29 [26, 34]	28 [25, 32]	31 [27, 36]	**<0.001**
BMI (kg/m2) (%)				**<0.001**
Normal (<25)	69 (20)	51 (25)	18 (13)	
Overweight (26-30)	111 (33)	72 (36)	39 (29)	
Obese (31-40)	100 (30)	50 (25)	50 (37)	
Morbidly obese (>40)	33 (10)	12 (6)	21 (15)	
Unknown	25 (8)	17 (8)	8 (6)	
Comorbidities (%)				
Asthma	46 (14)	29 (14)	17 (13)	0.74
Hypertension	54 (16)	27 (13)	27 (20)	0.15
Diabetes mellitus type II	39 (12)	20 (10)	19 (14)	0.33
HIV	7 (2)	1 (1)	6 (4)	**0.04**
Febrile at ED presentation (%)	101 (30)	48 (24)	53 (39)	**0.004**

Categorical variables are expressed as counts and (percentages). Continuous variables are expressed as medians with [interquartile ranges]. Significant p-values (<0.05) are bolded. Febrile is defined by temperature > 100.3°F; IQR=interquartile range; CXR=chest radiography; BMI=body mass index; HIV=human immunodeficiency virus; ED=emergency department.

Table 2: Patient demographics and clinical findings in relation to CXR severity score 0-2 versus 3-6 for 145 admitted patients.

Variables	All patients (n = 145)	Low CXR severity score 0-2 (n=87)	High CXR severity score 3-6 (n=58)	P-value
Age median (years) [IQR]	40 [33, 45]	40 [33, 45]	42 [35, 46]	0.15
Sex (% male)	104 (72)	60 (69)	44 (76)	0.47
Race/ethnicity (%)				**0.03**
White	33 (23)	25 (29)	8 (14)	
Asian	12 (8)	5 (6)	7 (12)	
Black	29 (20)	17 (20)	12 (21)	
Hispanic	58 (40)	29 (33)	29 (50)	
Other/unknown	13 (9)	11 (13)	2 (3)	
Hospital site (%)				0.94
Manhattan	70 (48)	43 (49)	27 (47)	
Brooklyn	34 (23)	20 (23)	14 (24)	
Queens	41 (28)	24 (28)	17 (29)	
Smoking history (%)				0.32
Never	94 (65)	59 (68)	35 (60)	
Current or former	29 (20)	18 (21)	11 (19)	
Unknown	22 (15)	10 (12)	12 (21)	
BMI median (kg/m2) [IQR]	31 [27, 36]	31 [26, 36]	30 [27, 37]	0.66
BMI (kg/m2) (cutoffs)				0.79
Normal (<25)	22 (15)	14 (16)	8 (14)	
Overweight (26-30)	43 (30)	24 (28)	19 (33)	
Obese (31-40)	58 (40)	37 (43)	21 (36)	
Morbidly obese (>40)	22 (15)	12 (14)	10 (17)	
Comorbidities (%)				
Asthma	24 (17)	16 (18)	8 (14)	0.62
Hypertension	32 (22)	20 (23)	12 (21)	0.90
Diabetes mellitus type II	20 (14)	12 (14)	8 (14)	1.0
HIV	5 (3)	2 (2)	3 (5)	0.64
Febrile at ED presentation (%)	60 (41)	37 (43)	23 (40)	0.86

Categorical variables are expressed as counts and percentages. Continuous variables are expressed as medians with interquartile ranges. Significant p-values (<0.05) are bolded. Febrile is defined by temperature > 100.3°F; IQR=interquartile range; CXR=chest radiography; BMI=body mass index; HIV=human immunodeficiency virus; ED=emergency department.

Table 3: The relationship between clinical factors and chest x-ray severity score for risk of hospital admission (n = 388)

Variable	Unadjusted Odds Ratio	Adjusted Odds Ratio for CXR Severity Score ≥2	Adjusted Odds Ratio for CXR Severity Score (0-6)
Age median (years)	**1.04 (1.01-1.07)**	1.02 (0.98-1.05)	1.02 (0.98-1.05)
Sex (reference male)	**2.1 (1.3-3.3)**	1.2 (0.66-2.1)	1.2 (0.66-2.2)
Race/ethnicity			
White	reference	reference	reference
Asian	0.77 (0.32-1.8)	0.68 (0.22-2.0)	0.67 (0.21-2.0)
Black	0.68 (0.35-1.3)	0.35 (0.15-0.82)	0.37 (0.15-0.85)
Hispanic	1.2 (0.64-2.1)	0.95 (0.44-2.0)	0.86 (0.39-1.9)
Other/unknown	0.50 (0.22-1.1)	0.34 (0.12-0.93)	0.36 (0.13-0.97)
Hospital site			
Manhattan	reference	reference	reference
Brooklyn	0.52 (0.31-0.88)	0.75 (0.38-1.5)	0.74 (0.37-1.5)
Queens	0.82 (0.49-1.4)	0.66 (0.33-1.3)	0.60 (0.30-1.2)
Time from symptom onset (days)	**1.12 (1.04-1.21)**	-	-
Smoking history			
Never	reference	reference	reference
Current or Former	1.8 (0.98-3.3)	1.2 (0.53-2.5)	1.2 (0.54-2.6)
Unknown	0.72 (0.40-1.3)	0.50 (0.23-1.0)	0.48 (0.22-1.0)
BMI median (kg/m2)	**1.07 (1.03-1.10)**	-	-
BMI cutoffs (kg/m2)			
Normal (<25)	reference	reference	reference
Overweight (26-30)	1.4 (0.72- 2.6)	1.5 (0.68-3.1)	1.4 (0.65-3.0)
Obese (31-40)	**3.0 (1.6- 5.6)**	**2.4 (1.1-5.4)**	**2.5 (1.1-5.4)**
Morbidly obese (>40)	**4.3 (1.8-10)**	**3.6 (1.2-11)**	**3.6 (1.2-10.9)**
Comorbidities			
Asthma	1.5 (0.83-2.9)	-	-
Hypertension	**2.2 (1.2-4.0)**	1.8 (0.88-3.9)	1.9 (0.90-4.0)
Diabetes mellitus type II	1.5 (0.75-2.86)	-	-
HIV	3.4 (0.65-18)	-	-
Febrile at ED presentation	**2.6 (1.6-4.2)**	-	-
CXR type (portable)	3.3 (1.9-5.7)	-	-
CXR by zone involvement			
RLL	**6.3 (3.9-10.1)**	-	-
RML	**5.2 (2.9-9.1)**	-	-
RUL	**All admitted**	-	-
LLL	**5.9 (3.7-9.6)**	-	-
LML	**6.7 (3.8-12)**	-	-
LUL	**All admitted**	-	-
CXR Severity Score (0-6)	**2.0 (1.7-2.4)**	-	**1.9 (1.6-2.3)**
CXR Severity Score ≥2	**7.5 (4.6-12)**	**6.2 (3.5-11)**	-

Data in parenthesis are 95% confidence intervals; CXR=chest radiography; HIV=human immunodeficiency virus; RLL=right lower lung zone; RML=right middle lung zone; RUL=right upper lung zone; LLL=left lower lung zone; LML=left middle lung zone; LUL=left upper lung zone; ED=emergency department; febrile is defined by temperature > 100.3°F.

Table 4: Risk of Intubation, and Length of Stay in Patients admitted for COVID-19 (n = 145)

	Intubation (n=28)			Prolonged Length of Stay ≥ 10 days (n=29)		
Variables	**Unadjusted Odds Ratio**	**Adjusted Odds Ratio for CXR Severity Score ≥3**	**Adjusted Odds Ratio for CXR Severity Score (0-6)**	**Unadjusted Odds Ratio**	**Adjusted Odds Ratio for CXR Severity Score ≥3**	**Adjusted Odds Ratio for CXR Severity Score (0-6)**
Age median (years)	**1.07 (1.00-1.13)**	1.06 (0.99-1.15)	1.05 (0.98-1.14)	**1.09 (1.02-1.16)**	**1.08 (1.01-1.17)**	1.08 (1.01-1.16)
Gender (reference male)	1.6 (0.58-4.2)	-	-	1.3 (0.51-3.3)	-	-
Race/ethnicity						
White	reference	-	-	reference	-	-
Asian	1.5 (0.31-7.3)	-	-	1.2 (0.26-5.8)	-	-
Black	0.94 (0.25-3.5)	-	-	0.77 (0.22-2.8)	-	-
Hispanic	1.2 (0.40-3.5)	-	-	0.87 (0.30-2.5)	-	-
Other/unknown	0.82 (0.14-4.7)	-	-	1.1 (0.24-5.12)	-	-
Hospital site						
Manhattan	reference	reference	reference	reference	-	-
Brooklyn	0.38 (0.08-1.8)	0.28 (0.04-1.3)	0.31 (0.04 to 1.5)	0.53 (0.16-1.8)	-	-
Queens	**3.8 (1.3-9.6)**	**4.1 (1.5-12.2)**	**4.4 (1.5 to 14)**	1.5 (0.59-3.6)	-	-
Smoking history						
Never	reference	-	-	reference	-	-
Current or former	1.1 (0.39-3.1)	-	-	1.1 (0.45-2.5)	-	-
Unknown	0.94 (0.28-3.1)	-	-	1.1 (0.43-3.0)	-	-
BMI median (kg/m2)	**1.07 (1.01-1.13)**	-	-	1.03 (0.98-1.09)	-	-
BMI cutoffs (kg/m2)						
Normal <25	reference	reference	reference			
Overweight 26-30	0.83 (0.18- 3.9)	1.1 (0.21-7.0)	1.3 (0.22 to 9.3)	0.80 (0.28-2.3)	-	-
Obese 31-40	1.7 (0.42- 6.5)	2.1 (0.50-12)	2.2 (0.46 to 13)	1.3 (0.48-3.6)	-	-
Morbidly obese >40	3.6 (0.81-16)	2.1 (0.50-12)	5.9 (0.97 to 45)	1.5 (0.43-5.1)	-	-
Comorbidities						
Asthma	0.81 (0.25-2.6)	-	-	0.86 (0.35-2.1)	-	-
Hypertension	0.95 (0.35-2.6)	-	-	0.65 (0.29-1.4)	-	-
Diabetes mellitus type II	0.71 (0.19-2.6)	-	-	0.94 (0.36-2.5)	-	-
HIV	2.9 (0.46-18)	-	-	2.6 (0.28-24)	-	-
Febrile at ED presentation	0.61 (0.26-1.5)	-	-	0.75 (0.66-0.86)	-	-
CXR type (% portable)	0.73 (0.24-2.2)	-	-	0.77 (0.26-2.30)	-	-
CXR by zone involvement						
RLL	**8.7 (2.0-39)**	-	-	**2.9 (1.0-8.3)**	-	-
RML	**4.6 (1.9-11)**	-	-	2.0 (0.86-4.5)	-	-
RUL	**6.2 (1.9-20)**	-	-	1.2 (0.31-4.8)	-	-
LLL	**2.8 (1.1-7.5)**	-	-	1.6 (0.66-3.7)	-	-
LML	**3.5 (1.5-8.4)**	-	-	1.8 (0.80-4.1)	-	-
LUL	**4.9 (1.3-18.2)**	-	-	1.8 (0.43-7.4)	-	-
CXR Severity Score (0-6)	**1.8 (1.3-2.4)**	-	**1.8 (1.3-2.5)**	1.3 (0.99-1.6)	-	1.1 (0.84-1.5)
CXR Severity Score ≥3	**4.2 (1.8-10)**	**4.7 (1.8-13.3)**	-	1.8 (0.80-4.1)	1.2 (0.45-2.9)	-

Data in parenthesis are 95% confidence intervals; HIV=human immunodeficiency virus; RLL=right lower lung zone; RML=right middle lung zone; RUL=right upper Lung zone; LLL=left lower lung zone; LML=left middle lung zone; LUL=left upper lung zone; ED=emergency department; febrile is defined by temperature > 100.3°F.

Supplemental Table E1: Patient demographics, clinical findings, laboratory values, and CXR scores for 338 patients in the ED setting in relation to risk for hospitalization.

		OUTCOMES		
Variables	**All patients (n = 338)**	**Patients not requiring hospitalization (n=193)**	**Patients requiring hospitalization (n=145)**	**P-value**
Age median (years) [IQR]	39 [31, 45]	37 [30, 44]	40 [33, 45]	**0.010**
Gender (% male)	210 (62)	106 (55)	104 (72)	**0.002**
Race/ethnicity (%)				0.15
White	71 (21)	38 (20)	33 (23)	
Asian	30 (9)	18 (9)	12 (8)	
Black	78 (23)	49 (25)	29 (20)	
Hispanic	116 (34)	58 (30)	58 (40)	
Other/unknown	43 (13)	30 (16)	13 (9)	
Hospital site (%)				0.05
Manhattan	143 (42)	73 (38)	70 (48)	
Brooklyn	102 (30)	68 (35)	34 (23)	
Queens	93 (28)	52 (27)	41 (28)	
Time from symptom onset (days) [IQR]	4 [2, 7]	4 [2, 6]	5 [3, 7]	**<0.001**
Smoking history (%)				0.05
Never	223 (66)	129 (67)	94 (65)	
Current or Former	51 (15)	22 (11)	29 (20)	
Unknown	64 (19)	42 (22)	22 (15)	
BMI median (kg/m2) [IQR]	29 [26, 34]	28 [25, 32]	31 [27, 36]	**<0.001**
BMI cutoffs (kg/m2) (%)				**<0.001**
Normal (<25)	69 (20)	47 (24)	22 (15)	
Overweight (26-30)	111 (33)	68 (35)	43 (30)	
Obese (31-40)	100 (30)	42 (22)	58 (40)	
Morbidly obese (>40)	33 (10)	11 (6)	22 (15)	
Unknown	25 (7)	25 (13)	0 (0)	
Comorbidities (%)				
Asthma	46 (14)	22 (11)	24 (17)	0.23
Hypertension	54 (16)	22 (11)	32 (22)	**0.01**
Diabetes mellitus type II	39 (12)	19 (10)	20 (14)	0.34
HIV	7 (2)	2 (1)	5 (3)	0.25
CXR by zone involvement (%)				
RLL	142 (42)	14 (7)	128 (94)	**<0.001**
RML	77 (23)	3 (2)	74 (54)	**<0.001**
RUL	13 (4)	1 (1)	12 (9)	**<0.001**
LLL	128 (38)	7 (4)	121 (89)	**<0.001**
LML	83 (25)	6 (3)	77 (57)	**<0.001**
LUL	10 (3)	1 (1)	9 (7)	**0.003**
CXR by total score (%)				**<0.001**
0	170 (50)	136 (71)	34 (23)	
1	32 (10)	17 (9)	15 (10)	
2	58 (17)	20 (10)	38 (26)	
3	24 (7)	10 (5)	14 (10)	
4	42 (12)	10 (5)	32 (22)	
5	7 (2)	0 (0.0)	7 (5)	
6	5 (2)	0 (0.0)	5 (3)	
CXR severity score ≥2	136 (4)	40 (21)	96 (66)	**<0.001**

Categorical variables are expressed as counts and (percentages). Continuous variables are expressed as medians with [interquartile ranges]. Significant p-values (<0.05) are bolded; RLL=right lower lung zone; RML=right middle lung zone; RUL=right upper lung zone; LLL=left lower lung zone; LML=left middle lung zone; LUL =left upper lung zone; IQR=interquartile range; CXR=chest radiography; BMI=body mass index; HIV=human immunodeficiency virus.

Supplemental Table E2: Patient demographics, clinical findings, laboratory values, and CXR scores for admitted patients in relation to outcomes of interest including intubation, sepsis, and prolonged length of stay.

		OUTCOMES							
Variables	**All patients (n = 145)**	**Not Intubated (n=117)**	**Intubated (n=28)**	**P-value**	**Not Septic (n=56)**	**Septic (n=89)**	**P-value**	**Length of stay <10 days (n=116)**	**Length of stay ≥10 days (n=29)**	**P-value**
Age median (years) [IQR]	40 [33, 45]	40 [32, 45]	43 [37, 45]	0.06	42 [32, 46]	40 [34, 44]	0.34	39 [32, 44]	44 [39, 46]	**0.011**
Gender (% male)	104 (72)	82 (70)	22 (79)	0.51	38 (68)	66 (74)	0.53	82 (71)	22 (76)	0.75
Race/ethnicity (%)				0.97			0.79			0.98
White	33 (23)	27 (23)	6 (21)		12 (21)	21 (24)		26 (22)	7 (24)	
Asian	12 (8)	9 (8)	3 (11)		5 (9)	7 (8)		9 (8)	3 (10)	
Black	29 (20)	24 (21)	5 (18)		12 (21)	17 (19)		24 (21)	5 (17)	
Hispanic	58 (40)	46 (39)	12 (43)		24 (43)	34 (38)		47 (41)	11 (38)	
Other/unknown	13 (9)	11 (9)	2 (7)		3 (5)	10 (11)		10 (9)	3 (10)	
Hospital site (%)				**<0.001**			0.71			0.27
Manhattan	70 (48)	60 (51)	10 (36)		25 (45)	45 (51)		56 (48)	14 (48)	
Brooklyn	34 (23)	32 (27)	2 (7)		15 (27)	19 (21)		30 (26)	4 (14)	
Queens	41 (28)	25 (21)	16 (57)		16 (29)	25 (28)		30 (26)	11 (38)	
Smoking history (%)				0.97			0.96			0.36
Never	94 (65)	76 (65)	18 (64)		37 (66)	57 (64)		74 (64)	20 (69)	
Current or former	29 (20)	23 (20)	6 (21)		11 (20)	18 (20)		22 (19)	7 (24)	
Unknown	22 (15)	18 (15)	4 (14)		8 (14)	14 (16)		20 (17)	2 (7)	
BMI median (kg/m2) [IQR]	31 [27, 36]	30 [26, 36]	32 [30, 40]	**0.03**	30 [27, 34]	31 [27, 38]	0.15	30 [27, 36]	31 [28, 38]	0.24
BMI cutoffs (kg/m2) (%)				0.10			0.57			0.76
Normal <25	22 (15)	19 (16)	3 (11)		9 (16)	13 (15)		18 (16)	4 (14)	
Overweight 26-30	43 (30)	38 (33)	5 (18)		20 (36)	23 (26)		36 (31)	7 (24)	
Obese 31-40	58 (40)	46 (39)	12 (43)		20 (36)	38 (43)		46 (40)	12 (41)	
Morbidly obese >40	22 (15)	14 (12)	8 (29)		7 (13)	15 (17)		16 (14)	6 (21)	
Comorbidities (%)										
Asthma	24 (17)	20 (17)	4 (14)	0.94	10 (18)	14 (16)	0.9	21 (18)	3 (10)	0.50
Hypertension	32 (22)	26 (22)	6 (21)	1.00	15 (27)	17 (19)	0.38	26 (22)	6 (21)	1.0
Diabetes Mellitus type II	20 (14)	17 (15)	3 (11)	0.83	8 (14)	12 (14)	1.00	16 (14)	4 (14)	1.0
HIV	5 (3.4)	3 (2.6)	2 (7.1)	0.54	1 (2)	4 (4.5)	0.69	3 (2.6)	2 (6.9)	0.57
CXR by zone involvement (%)										
RLL	96 (66)	70 (60)	26 (93)	**0.002**	33 (59)	63 (71)	0.20	72 (62)	24 (83)	0.06
RML	56 (39)	37 (32)	19 (68)	**0.001**	22 (39)	34 (38)	1.00	41 (35)	15 (52)	0.16
RUL	13 (9)	6 (5)	7 (25)	**0.003**	5 (9)	8 (9)	1.0	10 (9)	3 (10)	1
LLL	88 (61)	66 (56)	22 (79)	0.05	32 (57)	56 (63)	0.60	68 (59)	20 (69)	0.42
LML	63 (43)	44 (38)	19 (68)	**0.01**	24 (43)	39 (44)	1.00	47 (41)	16 (55)	0.23
LUL	10 (7)	5 (4)	5 (18)	**0.03**	3 (5)	7 (8)	0.81	7 (6)	3 (10)	0.68
CXR by total score (%)				**0.001**			0.47			0.25
0	34 (23)	32 (27)	2 (7)		18 (32)	16 (18)		30 (26)	4 (14)	
1	15 (10)	14 (12)	1 (4)		3 (5)	12 (14)		13 (11)	2 (7)	
2	38 (26)	32 (27)	6 (21)		13 (23)	25 (28)		30 (26)	8 (28)	
3	14 (10)	12 (10)	2 (7)		5 (9)	9 (10)		13 (11)	1 (3)	
4	32 (22)	22 (19)	10 (36)		12 (21)	20 (23)		21 (18)	11 (38)	
5	7 (5)	4 (3)	3 (11)		3 (5)	4 (5)		5 (4)	2 (7)	
6	5 (4)	1 (1)	4 (14)		2 (4)	3 (3)		4 (3)	1 (3)	
CXR severity score ≥3	58 (40)	39 (33)	19 (68)	**0.002**	22 (39)	36 (40)	1	43 (37)	15 (52)	0.22

Categorical variables are expressed as counts and (percentages). Continuous variables are expressed as medians with [interquartile ranges]. Significant p-values (<0.05) are bolded; RLL=right lower lung zone; RML=right middle lung zone; RUL=right upper lung zone; LLL=left lower lung zone; LML=left middle lung zone; LUL=left upper lung zone; IQR=interquartile range; CXR=chest radiography; BMI=body mass index; HIV=human immunodeficiency virus.