Radiology

ORIGINAL RESEARCH • THORACIC IMAGING

Clinical and Chest Radiography Features Determine Patient Outcomes in Young and Middle-aged Adults with COVID-19

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Conflicts of interest are listed at the end of this article.

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

Purpose: To analyze the prognostic value of a chest radiograph severity scoring system for younger (nonelderly) patients with COVID-19 at initial presentation to the emergency department (ED); outcomes of interest included hospitalization, intubation, prolonged stay, sepsis, and death.

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

Results: The study included 338 patients: 210 men (62%), with median age of 39 years (interquartile range, 31–45 years). After adjustment for demographics and comorbidities, independent predictors of hospital admission (n = 145, 43%) were chest radiograph severity score of 2 or more (odds ratio, 6.2; 95% confidence interval [CI]: 3.5, 11; $P < .001$) and obesity (odds ratio, 2.4 [95% CI: 1.1, 5.4] or morbid obesity). Among patients who were admitted, a chest radiograph score of 3 or more was an independent predictor of intubation (n = 28) (odds ratio, 4.7; 95% CI: 1.8, 13; P = .002) as was hospital site. No significant difference was found in primary outcomes across race and ethnicity or those with a history of tobacco use, asthma, or diabetes mellitus type II.

Conclusion: For patients aged 21–50 years with coronavirus disease 2019 presenting to the emergency department, a chest radiograph severity score was predictive of risk for hospital admission and intubation.

Online supplemental material is available for this article.

Coronavirus disease 2019 (COVID-19) caused by the novel severe acute respiratory syndrome coronavirus 2 emerged in Wuhan, China, in December 2019 (1). As of April 29, 2020, the disease is now a global pandemic with over 3 million confirmed cases and over 250 000 deaths (2). Chest radiography 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 CT, in the evaluation, diagnosis, and risk stratification of patients (4). Still, many radiology professional organizations, including the American College of Radiology and the Society of Thoracic Radiology, have recommended against the use of CT and two-view chest radiography for large-scale screening and diagnosis, stating instead that health facilities can consider portable chest radiography (5). In the United States, chest radiograph is routinely performed in the emergency department (ED) for patients presenting with dyspnea with or without COVID-19 infection.

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

Abbreviations

BMI = body mass index, CC = complete concordance, CI = confidence interval, COVID-19 = coronavirus disease 2019, ED = emergency department

Summary

On initial chest radiographs from the emergency department, lung zone severity scores predicted outcomes in young and middle-aged adults with coronavirus disease 2019.

Key Results

- On chest radiographic images divided into three zones per lung, a severity score was assigned based on the presence or absence of opacity in each zone (maximum score, 6; minimum score, 0).
- After adjusting for demographics and comorbidities, a chest radiograph severity score of 2 or more was associated with hospital admission (odds ratio, 6.2).
- In patients who were admitted, a chest radiograph score of 3 or more was an independent predictor of intubation (odds ratio, 4.7).

radiography to help predict outcomes in patients with COVID-19 pneumonia remain unknown.

Chest radiograph interpretation can often be confounded by underlying comorbid conditions, such as heart failure or chronic lung disease. Therefore, accurate, consistent, and predictive chest radiograph interpretations may be more valid in the younger population. Although COVID-19 has a higher degree of morbidity and mortality in older populations, patients younger than 50 years 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 chest radiography findings and the outcome variables of hospital admission and/or intubation in patients with COVID-19 between the ages of 21 and 50 years.

Materials and Methods

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

Inclusion Criteria for Patients

By using the MONTAGE search and Analytics platform, radiology information system data were extracted from all chest radiograph examinations performed during the study period. The resulting radiology information system data set contained 3866 ED encounters. Patients older than 50 years or younger than 21 years, cases with duplicate medical record numbers, unconfirmed results for COVID-19 reverse transcriptase polymerase chain reaction positivity, ED encounters unrelated to COVID-19, unevaluable chest radiographs, and inaccessible clinical data encounters were excluded. After exclusions, 338 patients were included for analysis (Fig 1). Subset analysis was performed on 145 of these patients who were admitted to the hospital for treatment.

Clinical Data Collection

Demographic variables collected included age, sex, 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 more than 10 days.

Imaging Data Collection

For all patients, two fellowship-trained cardiothoracic radiologists (C.E., with 26 years of experience; A.J., with 10 years of experience) scored each initial chest radiograph independently of each other. To minimize bias, reviewers were blinded to patient histories other than COVID-19 positivity. All patients underwent either digital portable anteroposterior chest radiography (244 of 338, 73%) or digital posteroanterior and lateral chest radiography (94 of 338, 27%).

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 the inferior hilar markings to superior hilar markings, and the upper zone from the superior hilar markings to the apices. Each zone was given a binary score depending on whether an opacity was absent (score of 0) or present (score of 1), which was then summed for a total score (Fig 2).

Statistical Analysis

The Cohen κ coefficient and complete concordance (CC) were used to assess agreement in chest radiograph interpretation between the two radiologists. 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 between both radiologists. Only findings that were concordant between radiologists were analyzed. Clinical features of patients were analyzed by using various radiographic features as independent variables.

Continuous variables that included missing values (BMI, temperature) were imputed with predictive mean matching using models that included outcomes of interest and demographic information. Prior to imputation, data were analyzed to ensure there was 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 chest radiograph score. Logistic regression was used to estimate the relative effect of variables by calculating unadjusted odds ratios for categorical outcomes. Least absolute shrinkage and selection operator was used for variable selection for multivariable selection. Data

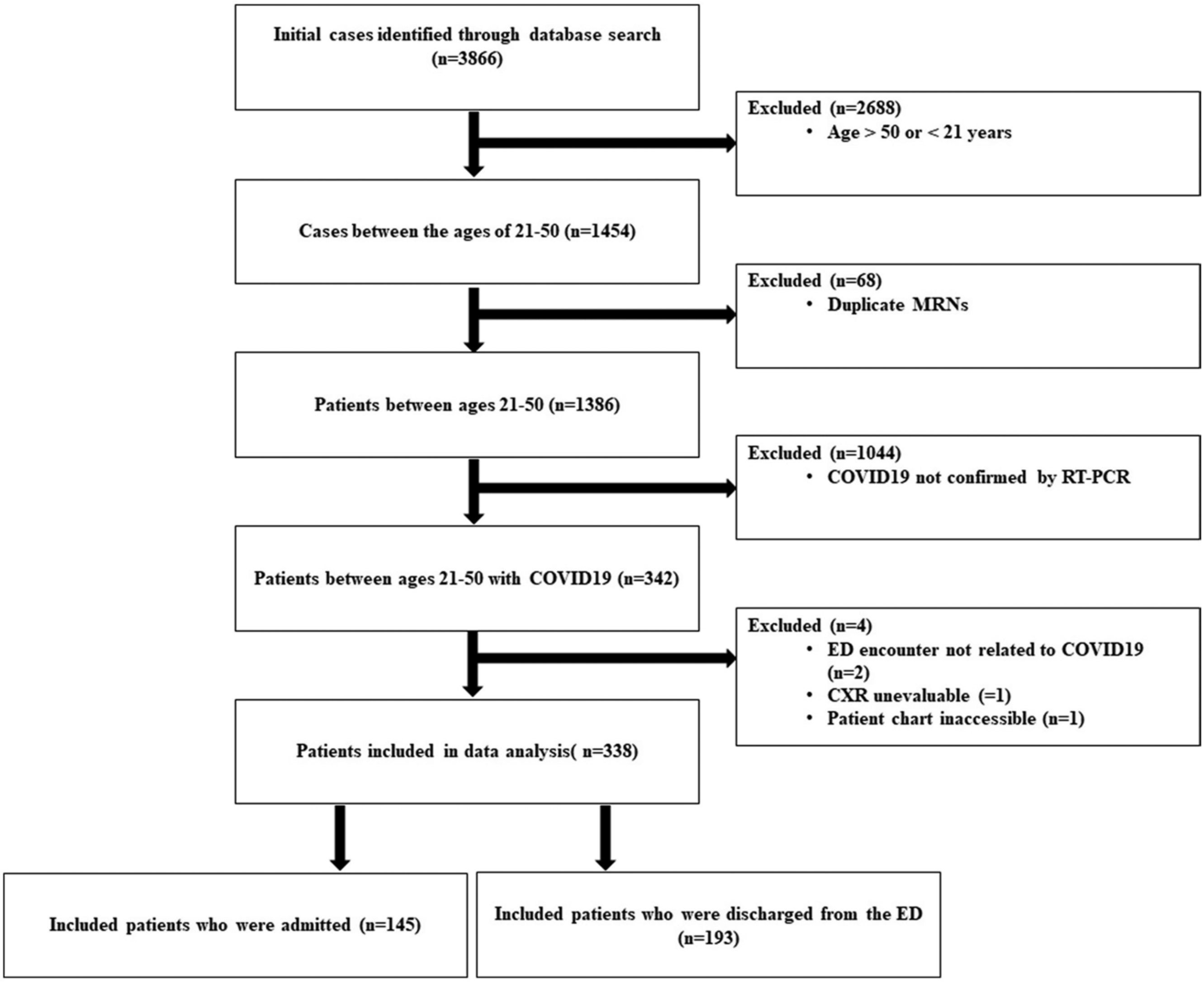

Figure 1: Flow diagram shows retrospective cohort study. COVID-19 = coronavirus disease 2019, CXR = chest radiograph, ED = emergency department, MRN = medical record number, RT-PCR = reverse transcription polymerase chain reaction.

with positive skewed distribution (days since symptom onset) were normalized for comparison. The area under the receiver operating characteristic curve, sensitivity, and specificity were 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 value of $P < .05$ (two tailed) was considered to indicate statistical significance. All analysis was completed by 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 years; interquartile range, 31–45 years; 62% were male; 71 were White [21%]; 30 were Asian [9%]; 116 were Hispanic [34%]; 32 were Black [23%]; and 43 were unknown [13%]). Fifty-one (15%) patients reported being current or former smokers, and 130 (40%) had obesity or morbid obesity (as defined by BMI >30 kg/m^2). The most frequent comorbidities were hypertension (54 of 338, 16%), asthma (46 of 338, 14%), and diabetes mellitus type II (39 of 338, 12%). The median number of days from symptom onset to presentation in the ED was 4 days (interquartile range, 2–6). All patients were followed for at least 20 days from initial ED presentation.

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

With respect to the frequency and distribution of lung zone opacities, 170 of 338 patients (50%) had an initial chest radiograph 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; the least affected were the right upper (13, 4%) and left

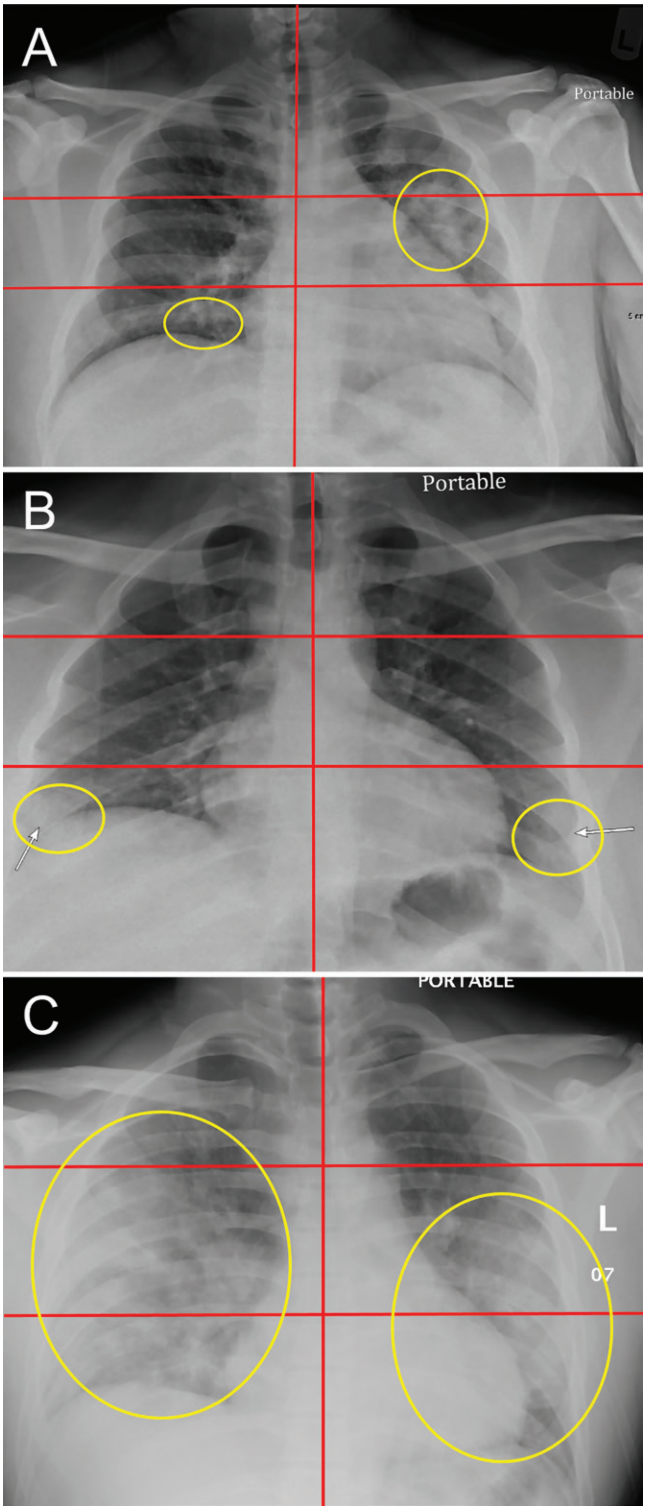

Figure 2: Images show examples of the chest severity score. Yellow circles indicate regions of the lung with visible opacities. *A,* Chest radiograph in a 26-year-old man with no past medical history other than obesity (body mass index [BMI] of 38 kg/m^2) who was admitted for coronavirus disease 2019 (COVID-19) requiring oxygen supplementation via nasal cannula. He initially tested negative for COVID-19 via nasopharyngeal swab, but later tested positive for antibodies to severe acute respiratory syndrome coronavirus 2. Portable chest radiograph shows hazy opacities in right lower lung zone, left middle lung zone, and left upper lung zone; total score of 3. *B,* Chest radiograph in a 23-year-old man with no past medical history who tested positive for COVID-19 via reverse transcription polymerase chain reaction and was subsequently discharged from emergency department with home care and isolation precautions. Portable chest radiograph shows hazy opacities (arrows) in right and left peripheral lower lung zone; total score of 2. *C,* Chest radiograph in a 32-year-old overweight (BMI of 30 kg/m^2) COVID-19–positive man with history of childhood asthma who was subsequently admitted and intubated in intensive care unit for 3 days. Portable chest radiograph shows opacities in all three right lung zones and in left middle and lower lung zones; total score of 5.

upper (10, 3%) lung zones. No patients had pneumothorax or significant pleural effusion.

In the receiver operating characteristic curve analysis of all 338 patients' chest radiograph scores in relation to admission, involvement of at least two lung zones was selected as a cutoff (sensitivity, 96 of 145 [66%; 95% confidence interval {CI}: 58%, 74%]; specificity, 153 of 193 [79%; 95% CI: 73%, 85%]) with an area under the receiver operating characteristic curve of 0.77 (95% CI: 0.72, 0.82; $P < .001$). In analyzing the subset of 145 hospitalized patients, receiver operating characteristic curve analysis of chest radiograph score in relation to the outcomes of interests consistently revealed involvement of three or more lung zones as a better cutoff. For intubation, sensitivity was 68% (19 of 28; 95% CI: 48%, 84%), specificity was 67% (78 of 117; 95% CI: 57%, 75%) (area under the receiver operating characteristic curve, 0.74; 95% CI: 0.64, 0.84; $P < .001$). For prolonged stay, sensitivity was 52% (15 of 29; 95% CI: 33%, 71%), specificity was 63% (73 of 116; 95% CI: 53%, 72%) (area under the receiver operating characteristic curve, 0.62; 95% CI: 0.50, 0.73; $P = .02$). For sepsis, sensitivity was 40% (36 of 89; 95% CI: 30%, 51%), specificity was 61% (34 of 56; 95% CI: 47%, 74%) (area under the receiver operating characteristic curve, 0.54; 95% CI: 0.44, 0.63; $P = .2$).

Secondary Outcome of Chest Radiograph Severity Score

Demographics and clinical findings in relation to the severity of opacification on the initial chest radiograph (score ≥ 2) are presented for all 338 patients (Table 1). Patients who were older (40 years vs 37 years; $P = .004$) and male (73% vs 55%; $P < .001$) had higher chest radiograph scores than did patients with a history of human immunodeficiency virus (or HIV) infection (4% vs 1%; $P = .4$) and obesity (52%% vs 31%; $P < .001$). Patients presenting later in the disease time course (6 days vs 3 days from symptom onset; $P < .001$), with fever (39% vs 24%; $P = .004$) also had higher chest radiograph scores. Interestingly, presentation to a Queens hospital site (33% vs 24%; $P = .1$) also predicted more severe lung zone opacity (chest radiograph scores ≥2). The severity of opacities was not statistically different between races and ethnicities or among those with a history of smoking, asthma, hypertension, or diabetes.

Demographics and clinical findings in relation to chest radiograph severity score of 3 or more are presented for all 145 admitted patients (Table 2). Hispanic ethnicity (50% vs 33%; $P = .03$) was an independent predictor of a chest radiograph score 3 or greater. There were no other demographic, clinical, or laboratory findings related to a chest radiograph score of 3 or greater.

Table 1: Patient Demographics and Clinical Findings of 338 Patients in ED Setting

Variable	All Patients (n = 338)	Low Chest Radiograph Severity Score 0–1 (n = 202)	High Chest Radiograph Severity Score 2–6 (n = 136)	P Value
Age (y)*	39 (31–45)	37 (30–44)	40 (34–46)	.004†
Male sex	210 (62)	111 (55)	99 (73)	<.001†
Race and ethnicity (%)				.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 or unknown	43 (13)	28 (14)	15 (11)	
Hospital site (%)				.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 (d)*	4 (2–6)	3 (2–6)	6 (3–7)	<.001†
Smoking history (%)				.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 (kg/m^2)*	29 (26–34)	28 (25–32)	31 (27–36)	<.001†
BMI (kg/m^2) (%)				<.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)	.74
Hypertension	54 (16)	27 (13)	27 (20)	.15
Diabetes mellitus type II	39 (12)	20 (10)	19 (14)	.33
Human immunodeficiency virus	7 (2)	1 (1)	6 (4)	.04†
Febrile at ED presentation (%)‡	101 (30)	48 (24)	53 (39)	.004†

Note.—Table presents demographics and clinical findings in relation to chest radiograph severity score 0–1 versus a score of 2–6 for 338 patients in the emergency department (ED) setting. Unless otherwise specified, data are numbers, with percentages in parentheses. BMI = body mass index.

* Data are medians, with interquartile ranges in parentheses.

† P values < .05 show significance.

‡ Febrile is defined by temperature over 100.3°F.

Clinical Outcomes

A total of 145 of 338 (43%) patients were admitted. Among these, 28 (19%) were intubated, 89 (61%) developed sepsis, 29 (20%) had a prolonged stay, and 10 (7%) died. At the time of writing, five (3%) were still intubated in intensive care units.

Chest Radiograph Zonal Severity Scores

In adjusted analyses, the total chest radiograph severity score was found to be significantly associated with several adverse outcomes. Incrementally increasing chest radiograph score was found to be an independent predictor of admission (adjusted odds ratio: 1.9; 95% CI: 1.6, 2.3; P < .001) (Table 3). A chest radiograph severity score of 2 or greater was likewise found to be an independent predictor of admission (adjusted odds ratio: 6.2; 95% CI: 3.5, 11; P < .001). Interestingly, 40 patients with a score between 2 and 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 among sex, races and ethnicities, or for those with a history of smoking, asthma, diabetes mellitus, or HIV infection (see Table E1 [online]).

Among the admitted patients (Table 4), a chest radiograph severity score of 3 or greater was found to be an independent predictor of intubation (adjusted OR: 4.7; 95% CI: 1.8, 13; P = .002) in the adjusted models. Patients who died were found to have higher chest radiograph scores; however, there were not enough cases to achieve statistical significance (n = 10). Higher chest radiograph scores were not predictive of development of sepsis (adjusted odds ratio: 1.1; 95% CI: 0.9, 1.0; P = .47) or prolonged length of stay (adjusted odds ratio: 1.1; 95% CI: 0.8, 1.5; P = .25). Clinical

Table 2: Patient Demographics and Clinical Findings in Relation to Chest Radiograph Severity Score 0–2 versus 3–6 for 145 Admitted Patients

Variable	All Patients (n = 145)	Low Chest Radiograph Severity Score 0–2 (n = 87)	High Chest Radiograph Severity Score 3–6 (n = 58)	P Value
Age (y)*	40 (33–45)	40 (33–45)	42 (35–46)	.15
Male sex	104 (72)	60 (69)	44 (76)	.47
Race and ethnicity (%)				.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 or unknown	13 (9)	11 (13)	2 (3)	
Hospital site (%)				.94
Manhattan	70 (48)	43 (49)	27 (47)	
Brooklyn	34 (23)	20 (23)	14 (24)	
Queens	41 (28)	24 (28)	17 (29)	
Smoking history (%)				.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 (kg/m^2)*	31 (27–36)	31 (26–36)	30 (27–37)	.66
BMI cutoffs (kg/m^2)				.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)	.62
Hypertension	32 (22)	20 (23)	12 (21)	.90
Diabetes mellitus type II	20 (14)	12 (14)	8 (14)	1.0
Human immunodeficiency virus	5 (3)	2 (2)	3 (5)	.64
Febrile at ED presentation (%)‡	60 (41)	37 (43)	23 (40)	.86

Note.—Unless otherwise specified, data are numbers, with percentages in parentheses. BMI = body mass index, ED = = emergency department.

* Data are medians, with interquartile range in parentheses.

† P values < .05 show significance.

‡ Febrile is defined by temperature over 100.3°F.

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 and ethnicities or those who had a history of smoking, asthma, diabetes mellitus, or HIV infection (see Table E2 [online]).

Discussion

The unprecedented burden that the coronavirus disease 2019 (COVID-19) pandemic has placed on health care institutions highlights the need for a simple-to-use, robust chest radiography algorithm to prioritize management and to predict outcomes. In this study, we explore the value of initial chest radiography in evaluating young adults with COVID-19 in the emergency department setting. The severity of opacification on the initial chest radiograph was associated with the need for hospitalization and the 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 although 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 and 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 chest radiography, 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

Table 3: Relationship between Clinical Factors and Chest Radiograph Severity Score for Risk of Hospital Admission (*n* = 388)

Variable	Unadjusted Odds Ratio	Adjusted Odds Ratio for Chest Radiograph Severity Score ≥2	Adjusted Odds Ratio for Chest Radiograph Severity Score (0–6)
Median age (y)	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 and 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 or 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 (d)	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/m^2)	1.07 (1.03, 1.10)*	…	…
BMI cutoffs (kg/m^2)			
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)*	…	…
Chest radiograph type, portable	3.3 (1.9, 5.7)	…	…
Chest radiograph 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*	…	…
Chest radiograph severity score (0–6)	2.0 (1.7, 2.4)*	…	1.9 (1.6, 2.3)*
Chest radiograph severity score ≥2	7.5 (4.6, 12)*	6.2 (3.5, 11)*	…

Note.—Data in parentheses are 95% confidence intervals. BMI = body mass index, ED = emergency department, HIV = human immunodeficiency virus, LLL = left lower lung zone, LML = left middle lung zone, LUL = left upper lung zone, RLL = right lower lung zone, RML = right middle lung zone, RUL = right upper lung zone.

* Significant odds ratios with *P* values <.05.

† Febrile is defined by temperature greater than 100.3°F.

studies on the frequency and distribution of chest radiograph and CT opacities in patients with COVID-19 have demonstrated that 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 severe acute respiratory syndrome and H7N9 influenza infection, also have demonstrated a predilection for the right lower lobe, which has been thought to be related to the anatomic structure of the right lower lobe bronchus (16). Right lower lung zone opacification was additionally associated with prolonged length of stay in our cohort. Although chest radiograph 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 sex, and higher body mass index are associated with an increased risk of a higher chest radiograph score (≥2) and need

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)		
Variable	Unadjusted OR	Adjusted OR for Chest Radiograph Severity Score ≥3	Adjusted OR for Chest Radiograph Severity Score (0–6)	Unadjusted OR	Adjusted OR for Chest Radiograph Severity Score ≥3	Adjusted OR for Chest Radiograph Severity Score (0–6)
Age (y)	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)
Sex (reference male)	1.6 (0.58, 4.2)	…	…	1.3 (0.51, 3.3)	…	…
Race and 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 or 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, 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, 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 (kg/m^2)	1.07 (1.01, 1.13)*	…	…	1.03 (0.98, 1.09)	…	…
BMI cutoffs (kg/m^2)					…	…
Normal (<25)	Reference	Reference	Reference			
Overweight (26–30)	0.83 (0.18, 3.9)	1.1 (0.21, 7.0)	1.3 (0.22, 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, 13)	1.3 (0.48, 3.6)	…	…
Morbidly obese (>40)	3.6 (0.81, 16)	2.1 (0.50, 12)	5.9 (0.97, 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)	…	…
Chest radiograph type (% portable)	0.73 (0.24, 2.2)	…	…	0.77 (0.26, 2.30)	…	…
Chest radiograph 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)	…	…
Chest radiograph 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)
Chest radiograph 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)	…

Note.—Data in parentheses are 95% confidence intervals. BMI = body mass index, COVID-19 = coronavirus disease 2019, ED = emergency department, HIV = human immunodeficiency virus, LLL = left lower lung zone, LML = left middle lung zone, LUL = left upper lung zone, RLL = right lower lung zone, RML = right middle lung zone, RUL = right upper lung zone.

* Significant odds ratios with *P* values <.05.

† Febrile is defined by temperature greater than 100.3°F.

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 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 severe acute respiratory syndrome coronavirus entry receptor in respiratory epithelium (19). The evaluation of dose-response effect between smoking and chest radiograph severity was in fact unachievable without available pack-year data in the patient's chart. Future studies should obtain the duration of smoking exposure 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 Centers for Disease Control and Prevention's analysis of 366 patients aged 18–49 years with COVID-19 demonstrated that the five most common underlying conditions were obesity, asthma, diabetes, hypertension, and immunosuppressive disease (14). 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 human immunodeficiency virus infection, an often-understudied population, also demonstrated higher chest radiograph scores.

There was no difference in primary patient outcomes between races and ethnicities in our cohort. Although preliminary data from the New York City Department of Health notes that African American and Hispanic or Latino patients may have higher death rates, studies are ongoing and data are still being collected. Despite this, the presence of disproportionately worse chest radiograph 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 was its retrospective nature, which may introduce observer bias in how outcome is assessed. Chest radiograph reports were available to ED physicians, which likely influenced the decision to admit, confounding and potentially overestimating the true relationship between chest radiograph severity and admission. Although the degree of this influence is unclear, a prior study (21) has demonstrated that ED physicians do not cite chest radiograph as a major factor in influencing decisions to admit for community-acquired pneumonia. Furthermore, the CURB-65 and Pneumonia Severity Index—the most widely used scoring systems to guide decisions on admitting patients with community-acquired pneumonia—excludes chest radiographs as major or minor criteria (22). Nevertheless, validation studies are needed to thoroughly corroborate the exposure-outcome relationship between chest radiograph severity and admission in patients with COVID-19.

A second limitation of this study was 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, five patients were still intubated in intensive care units with indeterminate outcomes. Most of the chest radiographs 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 chest radiograph; further studies will be needed to analyze worsening and improving opacities on follow-up chest radiographs in relation to outcomes and to validate these results in an older population.

We have validated the use of initial chest radiograph severity scores as an independent prognostic indicator of outcomes in patients with coronavirus disease 2019 (COVID-19). These results underscore how COVID-19, despite its many nonrespiratory manifestations, is primarily a respiratory illness, and that lung parenchymal changes—as seen at chest radiography as opacification—are the primary drivers 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 patients at high risk while minimizing anchoring heuristics that may be present among clinicians in high-volume settings.

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