COVID-19

Clinical Course and Factors Associated With Hospitalization and Critical Illness Among COVID-19 Patients in Chicago, Illinois

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ABSTRACT

Background: SARS-CoV-2 is a global pandemic associated with significant morbidity and mortality. However, information from United States cohorts is limited. Understanding predictors of admission and critical illness in these patients is essential to guide prevention and risk stratification strategies.

Methods: This was a retrospective, registry-based cohort study including all patients presenting to Rush University Medical Center in Chicago, Illinois, with COVID-19 from March 4, 2020 to June 21, 2020. Demographic, clinical, laboratory, and treatment data were obtained from the registry and compared between hospitalized and nonhospitalized patients as well as those with critical illness. We used logistic regression modeling to explore risk factors associated with hospitalization and critical illness.

Results: A total of 8,673 COVID-19 patients were included in the study, of whom 1,483 (17.1%) were admitted to the hospital and 528 (6.1%) were admitted to the intensive care unit. Risk factors for hospital admission included advanced age, male sex (odds ratio [OR] = 1.69, 95% confidence interval [CI] = 1.44 to 1.98), Hispanic/Latino ethnicity (OR = 1.52, 95% CI = 1.18 to 1.92), hypertension (OR = 1.77, 95% CI = 1.46 to 2.16), diabetes mellitus (OR = 1.84, 95% CI = 1.53 to 2.22), prior CVA (OR = 3.20, 95% CI = 1.99 to 5.14), coronary artery disease (OR = 1.45, 95% CI = 1.03 to 2.06), heart failure (OR = 1.79, 95% CI = 1.23 to 2.61), chronic kidney disease (OR = 2.60, 95% CI = 1.77 to 3.83), end-stage renal disease (OR = 2.22, 95% CI = 1.12 to 4.41), cirrhosis (OR = 2.03, 95% CI = 1.42 to 2.91), fever (OR = 1.43, 95% CI = 1.19 to 1.71), and dyspnea (OR = 4.53, 95% CI = 3.75 to 5.47). Factors associated with critical illness included male sex (OR = 1.45, 95% CI = 1.12 to 1.88), congestive heart failure (OR = 1.45, 95% CI = 1.00 to 2.12), obstructive sleep apnea (OR = 1.58, 95% CI = 1.07 to 2.33), blood-borne cancer (OR = 3.53, 95% CI = 1.26 to 9.86), leukocytosis (OR = 1.53, 95% CI = 1.15 to 2.17), elevated neutrophil-to-lymphocyte ratio (OR = 1.61, 95% CI = 1.20 to 2.17), hypoalbuminemia (OR = 1.80, 95% CI = 1.39 to 2.32), elevated AST (OR = 1.66, 95% CI = 1.20 to 2.29), elevated lactate (OR = 1.95, 95% CI = 1.40 to 2.73), elevated D-Dimer (OR = 1.44, 95% CI = 1.05 to 1.97), and elevated troponin (OR = 3.65, 95% CI = 2.03 to 6.57).

Conclusion: There are a number of factors associated with hospitalization and critical illness. Clinicians should consider these factors when evaluating patients with COVID-19.

In December 2019, a cluster of cases with pneumonia of unknown etiology was identified in Wuhan City, Hubei province, China. In January 2020, a novel coronavirus, now designated as severe acute respiratory

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syndrome coronavirus 2 (SARS-CoV-2), was identified as the cause of coronavirus disease 2019 (COVID-19).[1] Despite containment efforts, SARS-CoV-2 spread rapidly to other countries. The first case in the United States was identified in mid-January 2020 and it has now been reported in all 50 states.[2,3] The disease was declared a global pandemic on March 11, 2020, and spread of SARS-CoV-2 has been confirmed in over 200 countries resulting in over 12.1 million cases and 550,000 deaths.[1]

Large cities in the United States, including Chicago, Illinois, have been profoundly affected by this pandemic, with over 50,000 COVID-19 confirmed cases and 2,600 deaths among Chicago residents.[4] However, information from large cohorts within the United States remains limited and it is unclear if data from other countries are generalizable to local community dynamics and outcomes.

Observational studies have identified several medical comorbidities potentially associated with adverse clinical outcomes, including older age,[5–11] male sex,[8,12,13] cardiovascular disease,[6,10,13–15] diabetes mellitus,[6,7,13,15] and chronic respiratory disease.[10,13–15] The importance of these comorbidities has not yet been fully elucidated due to small observational cohort sizes, inadequate adjustment for confounding factors, and likely underreporting.[16]

COVID-19 is associated with significant morbidity and mortality. However, only a subset of patients become critically ill. Therefore, it is important to identify the clinical and demographic features that predict admission and critical illness among this population using large data sets to enhance our understanding of this rapidly expanding disease. Understanding the morbidity and mortality in patients with COVID-19 is essential to guide prevention and risk stratification strategies for this population.

The primary goal of this study was to present the clinical and demographic features of patients who presented to a major academic institution in Chicago, Illinois, with laboratory-confirmed COVID-19 infection as of June 21, 2020. As a secondary outcome, we sought to identify risk factors associated with hospitalization and critical illness.

METHODS

Study Design and Participants

We conducted a retrospective case–control study to evaluate the risk factors for severe COVID-19 infection. This study was conducted at Rush University Medical Center, a 664-bed urban tertiary care hospital in Chicago, Illinois, with an annual emergency department volume of 70,000 patients per year. We collected our first samples for testing on January 23, 2020, and the first patient to test positive with SARS-CoV-2 was seen at Rush University Medical Center on March 4, 2020. During this time period, we tested patients with symptoms concerning for COVID-19. From March 26 to May 21, we also screened all admissions for COVID-19 regardless of symptoms. All patients who were tested for SARS-CoV-2 were designated as a person under investigation (PUI) in the electronic health record (EHR). Patients screened as PUIs were captured in the Epic EHR (Epic Systems, Verona, WI) as a part of normal clinical workflows. These indicators subsequently were filtered to an enterprise data warehouse (EDW). All patients with diagnosed COVID-19, regardless of age, were included through June 21, 2020. We excluded patients who were transferred from other inpatient hospitals (n = 71), because these reflected a different patient cohort. These patients presented to the Rush University Medical Center intensive care unit (ICU) several days into their illness course and were often already intubated, thereby limiting the ability to use this population to predict admission or critical illness.

For patients considered as PUIs, a data mart was developed using detailed demographics, diagnoses, symptoms, comorbidities, treatments, laboratory results, and outcomes data. These data were filtered from the EDW comprising clinical and administrative data derived from the clinical EHR and associated information technology systems, including registration and intake surveys, laboratory, radiology, and billing information systems. This single-source EDW supports all clinical, research, and operational needs and contains administrative data for more than 10 years and clinical data back to 2007. All data were deidentified before sharing. The local institutional review board evaluated this project and approved it with a waiver of informed consent.

Laboratory Procedures

All patients were confirmed to have SARS-CoV-2 infection using a molecular amplification assay and nasopharyngeal, midturbinate, or nasal swab samples that were collected by trained clinical staff members. Testing was done at Illinois Department of Public Health Laboratory using the CDC-developed assay or in the clinical microbiology laboratory at Rush University Medical Center using a laboratory-modified

version of the CDC assay, the real-time SARS-CoV-2 assay on a real-time system (*m*2000 or the ID NOW COVID-19, Abbott Laboratories, Abbott Park, IL). The assay used depended on the date and location of testing.

Outcomes

Our primary outcome was to provide a descriptive summary of the clinical and demographics features of patients who presented to our institution with COVID-19 over a greater than 3-month period. As a secondary outcome, we sought to identify risk factors associated with inpatient hospitalization and critical illness. Inpatient hospitalization was defined as any patient requiring admission to the hospital. For patients with more than one hospitalization (n = 376), only the most recent hospitalization was utilized. Critical illness was defined as a patient requiring ICU admission.

Predictors

We obtained the following information from the EDW for analysis: age, sex, race, ethnicity, tobacco use (current and former), marital status, recent international travel, asthma, chronic obstructive pulmonary disease (COPD), hypertension, hyperlipidemia, diabetes mellitus, prior ischemic or hemorrhagic cerebrovascular accident (CVA), coronary artery disease (CAD), congestive heart failure (CHF), chronic kidney disease (not requiring dialysis), end-stage renal disease (ESRD) requiring dialysis, cirrhosis, obstructive sleep apnea (OSA), blood-borne cancer (e.g., leukemia, lymphoma), solid organ cancer, human immunodeficiency virus (HIV) infection, solid organ transplantation, body mass index (BMI), vital signs on arrival (e.g., temperature, heart rate, oxygenation saturation, respiratory rate, systolic and diastolic blood pressure), symptoms (i.e., anosmia, abdominal pain, bruising/bleeding, conjunctivitis, cough, diarrhea, dyspnea, fever, headache, joint pain, myalgias, rash, sore throat, vomiting, weakness), and laboratory testing (complete blood count, absolute neutrophil count [ANC], absolute lymphocyte count [ALC], creatinine, total bilirubin, albumin, aspartate aminotransferase [AST], alanine aminotransferase [ALT], lactate dehydrogenase [LDH], lactic acid, D-dimer, C-reactive protein, ferritin, creatinine kinase, troponin, brain-type natriuretic peptide (BNP), pregnancy test). We also collected hospitalization outcome data on coinfections (e.g., positive influenza test, positive respiratory syncytial virus [RSV] test), complications (e.g., cardiac dysrhythmias, positive blood culture, positive sputum culture, subsequent bacterial pneumonia, acute respiratory distress syndrome [ARDS], rhabdomyolysis), and interventions performed (e.g., high-flow nasal cannula, continuous and bilevel positive airway pressure ventilation, prone positioning, inhaled pulmonary vasodilators, extracorporeal membrane oxygenation, vasopressors, steroids, lopinavir/ritonavir, hydroxychloroquine, remdesivir, tocilizumab). All predictor variables were obtained at the time of their initial presentation. We also collected the following outcome data: hospital length of stay, ICU length of stay, number of patients who were intubated, and days of mechanical ventilation. Length of stay and days on mechanical ventilation were determined only for patients who were discharged or died.

Statistical Analysis

Categorical data were presented as percentage frequencies, with continuous data presented as median and interquartile range (IQR). All data obtained from the EDW were evaluated for anomalies by a clinical data analyst. Categorical variables were analyzed using chi-square or Fisher exact test, as appropriate. Continuous variables were analyzed by Student's t-test or Mann–Whitney U-test, as appropriate. Variables found to be significant at the $p \leq 0.10$ level were included in a multivariable logistic regression model. Two-tailed tests were used. Two logistic regression models were created. The first used inpatient hospitalization as the primary outcome and various cofactors as independent variables. The second used critical illness (defined as requiring ICU admission) as the primary outcome and various cofactors as independent variables. A plot of the standard deviance results demonstrated no extreme outliers in either model. A plot of leverage found two observations with high leverage in the admission model and no extreme influential points in the critical illness model. Removal of both observations in the admission model did not significantly influence the findings. There was no evidence of multicollinearity with a variance inflation factor < 4. There were no continuous covariates in the model. Goodness of fit was assessed for both models using a c-statistic and Hosmer-Lemeshow test. For the admission model, the c-statistic was 0.92 and the Hosmer-Lemeshow test had a $p = 0.111$. For the critical care model, the c-statistic was 0.75 and the Hosmer-Lemeshow test had a $p = 0.204$. Findings from the multivariable logistic analyses were presented as odds ratios (ORs)

Table 1
COVID-19 Patient Demographics, Clinical Symptoms, and Test Results

	Total Patients (N = 8,673)	Not Hospitalized (n = 7,190)	Hospitalized (n = 1,483)
Age (years)	41 (29–54)	38 (27–50)	56 (44–68)
Age group (years)			
0–18	432 (5.0)	404 (5.6)	28 (1.9)
19–44	4,528 (52.2)	4,161 (57.9)	367 (24.7)
45–54	1,657 (19.1)	1,359 (18.9)	298 (20.1)
55–64	1,176 (13.6)	869 (12.1)	307 (20.7)
65–74	552 (6.4)	289 (4.0)	263 (17.7)
75 or older	328 (3.8)	108 (1.5)	220 (14.8)
Sex			
Female	4,625 (53.3)	3,935 (54.7)	691 (46.6)
Male	4,045 (46.6)	3,253 (45.2)	792 (53.4)
Not specified	2 (0.0)	2 (0.0)	0 (0.0)
Race			
White	1,797 (20.7)	1,425 (20.0)	362 (24.4)
African American	2,301 (26.5)	1,747 (24.3)	554 (37.4)
Asian	119 (1.4)	100 (1.4)	19 (1.3)
Other	2,661 (30.7)	2,229 (31.0)	432 (29.1)
Unknown	1,795 (20.7)	1,679 (23.4)	116 (7.8)
Ethnicity			
Hispanic or Latino	4,281 (49.4)	3,624 (50.4)	657 (44.3)
Not Hispanic or Latino	3,785 (43.6)	2,975 (41.4)	810 (54.6)
Unknown	607 (7.0)	591 (8.2)	16 (1.1)
Tobacco use			
Former	838 (9.7)	506 (7.0)	323 (21.8)
Current	406 (4.7)	329 (4.6)	77 (5.2)
Never	7,429 (85.7)	6,355 (88.4)	1,074 (72.4)
Marital status			
Single	4,365 (50.3)	3,723 (51.8)	642 (43.3)
Married	2,766 (31.9)	2,172 (30.2)	594 (40.1)
Domestic partner	32 (0.4)	172 (2.4)	5 (0.3)
Legally separated	62 (0.7)	45 (0.6)	17 (1.1)
Divorced	243 (2.8)	172 (2.4)	71 (4.8)
Widowed	180 (2.1)	87 (1.2)	93 (6.3)
Other	33 (0.4)	23 (0.3)	10 (0.7)
Unknown	992 (11.4)	941 (13.1)	51 (3.4)
Recent international travel			
Yes	36 (0.4)	30 (0.4)	6 (0.4)
No	5,780 (66.6)	4,442 (61.8)	1,338 (90.2)
Unknown	2,587 (32.9)	2,718 (37.8)	139 (9.4)
Known COVID-19 contact			
Yes	2,313 (26.7)	1,891 (26.3)	422 (28.5)
No/unsure	3,275 (37.8)	2,398 (33.4)	877 (59.1)
Unknown	3,085 (35.6)	2,901 (40.3)	184 (12.4)
Comorbidities			
Asthma	736 (8.5)	546 (7.6)	190 (12.8)
COPD	117 (1.3)	33 (0.5)	84 (5.7)
Hypertension	1,917 (22.1)	1,020 (14.2)	897 (60.5)
Hyperlipidemia	1,242 (14.3)	650 (9.0)	592 (39.9)
Diabetes mellitus	1,269 (14.6)	635 (8.8)	634 (42.8)

(Continued)

Table 1 (continued)

	Total Patients (N = 8,673)	Not Hospitalized (n = 7,190)	Hospitalized (n = 1,483)
Prior CVA	158 (1.8)	37 (0.5)	121 (8.2)
Coronary artery disease	318 (3.7)	89 (1.2)	229 (15.4)
Congestive heart failure	280 (3.2)	62 (0.9)	218 (14.7)
Chronic kidney disease	380 (4.4)	74 (1.0)	306 (20.6)
Current ESRD	124 (1.4)	18 (0.3)	106 (7.1)
Cirrhosis	207 (2.4)	100 (1.4)	107 (7.2)
Obstructive sleep apnea	288 (3.3)	134 (1.9)	154 (10.4)
Blood-borne cancer	38 (0.4)	20 (0.3)	18 (1.2)
Solid organ cancer	506 (5.8)	316 (4.4)	190 (12.8)
HIV	32 (0.4)	22 (0.3)	10 (0.7)
Solid organ transplant	65 (0.7)	20 (0.3)	45 (3.0)
BMI	27.2 (23.1–32.0)	27.1 (23.0–31.6)	27.5 (23.4–32.6)
<30	2,490 (28.7)	1,613 (22.4)	877 (58.3)
30–40	1,026 (11.8)	637 (8.9)	389 (26.2)
>40	264 (3.0)	146 (2.0)	118 (8.0)
Unknown	4,893 (56.4)	4,794 (66.7)	99 (6.7)
Vital signs on arrival*			
Temperature ≥ 100.4° F	529 (12.2)	193 (6.7)	336 (22.7)
Heart rate (beats/min)			
>100	1,361 (31.2)	727 (25.3)	634 (42.8)
<60	78 (1.8)	57 (2.0)	21 (1.4)
Pulse ox			
<94%	556 (13.3)	42 (1.6)	504 (34.1)
<90%	258 (6.2)	4 (0.1)	254 (17.2)
Respiratory rate ≥ 20	1,711 (40.8)	808 (29.7)	903 (61.0)
sBP	129 (118–142)	130 (118–142)	128 (115–143)
dBP	78 (69–87)	79 (70–87)	74 (65–85)
Symptoms*			
Anosmia	884 (19.4)	780 (22.6)	104 (9.4)
Abdominal pain	171 (3.7)	122 (3.5)	49 (4.4)
Bruising/bleeding	28 (0.6)	18 (0.5)	10 (0.9)
Conjunctivitis	43 (0.9)	38 (1.1)	5 (0.4)
Cough	3,282 (71.9)	2,482 (71.9)	800 (71.9)
Diarrhea	282 (6.2)	231 (6.7)	51 (4.6)
Dyspnea	1,946 (42.7)	1,184 (34.3)	762 (68.5)
Fever (subjective)	2,186 (47.9)	1,586 (46.0)	600 (54.0)
Headache	361 (7.9)	318 (9.2)	43 (3.9)
Joint pain	254 (5.6)	204 (5.9)	50 (4.5)
Myalgias	1,299 (28.5)	1,053 (30.5)	246 (22.1)
Rash	55 (1.2)	45 (1.3)	10 (0.9)
Sore throat	963 (21.1)	836 (24.2)	127 (11.4)
Vomiting	115 (2.5)	86 (2.5)	29 (2.6)
Weakness	554 (12.1)	448 (13.0)	106 (9.5)
Initial labs†			
WBC	6.6 (5.1–8.9)	6.0 (4.7–7.6)	7.3 (5.4–9.9)
≥10	416 (17.8)	77 (8.2)	339 (24.1)
≤4	253 (10.8)	109 (11.7)	144 (10.2)
ANC	4.6 (3.2–7.0)	3.7 (2.7–5.5)	5.3 (3.7–7.7)
ALC	1.3 (0.9–1.8)	1.6 (1.1–2.3)	1.1 (0.8–1.5)

(Continued)

Table 1 (continued)

	Total Patients (*N* = 8,673)	Not Hospitalized (*n* = 7,190)	Hospitalized (*n* = 1,483)
ALC ≤ 1.5	1,535 (65.7)	427 (45.7)	1,108 (79.1)
Median ANC/ALC	3.8 (2.2–6.4)	2.4 (1.6–3.8)	5.0 (3.2–8.5)
ANC/ALC ≥ 6	662 (28.4)	93 (10.0)	569 (40.6)
Total Bilirubin	0.5 (0.4–0.7)	0.4 (0.3–0.6)	0.6 (0.4–0.8)
Total Bilirubin> 1.3	100 (4.7)	18 (2.3)	82 (6.2)
Albumin	3.6 (3.2–4.0)	3.9 (3.6–4.2)	3.4 (3.1–3.8)
Albumin < 3.5	895 (42.2)	115 (14.5)	780 (58.8)
AST	33 (22–52)	24 (19–35)	40 (27–62)
AST > 40	798 (37.7)	141 (17.8)	657 (49.5)
Median ALT	28 (17–46)	24 (16–38)	32 (19–52)
ALT > 40	633 (30.0)	167 (21.2)	466 (35.3)
LDH	381 (284–519)	237 (194–317)	399 (301–539)
LDH ≥ 245	635 (82.7)	30 (44.1)	605 (86.4)
Lactate	1.5 (1.1–2.0)	1.3 (1.1–1.5)	1.6 (1.2–2.1)
Lactate ≥ 2	275 (27.7)	16 (13.1)	259 (29.7)
D-dimer	0.79 (0.48–1.69)	0.48 (0.29–0.85)	0.90 (0.53–2.19)
D-dimer > 0.49	363 (73.6)	40 (46.5)	323 (79.4)
C-reactive protein	100 (47–187)	25 (10–53)	108 (53–195)
C-reactive protein > 8	671 (96.8)	38 (77.6)	633 (98.3)
Ferritin	665 (247–1,572)	123 (43–231)	795 (341–1,701)
Ferritin > 300 (men) or 150 (women)	586 (75.3)	23 (27.4)	563 (81.1)
Hemoglobin	13.2 (12.0–14.4)	13.2 (12.2–14.4)	13.2 (11.7–14.5)
Creatinine	0.95 (0.79–1.26)	0.86 (0.76–1.05)	1.04 (0.82–1.54)
Creatine kinase	126 (66–288)	118 (56–210)	128 (66–306)
Troponin	0.03 (0.01–0.07)	0.02 (0.01–0.03)	0.03 (0.01–0.08)
Troponin > 0.9	90 (19.3)	3 (3.9)	87 (22.3)
Median BNP	57 (24–171)	25 (13–60)	67 (26–196)

Data are reported as *n* (%) or median (IQR).
ALC = absolute lymphocyte count; BMI = body mass index; CVA = cerebrovascular accident; dBP = diastolic blood pressure; ESRD = end-stage renal disease (on dialysis); HIV = human immunodeficiency virus; IQR = interquartile range; sBP = systolic blood pressure; WBC = white blood cell count.
*Not all patients had data available (percentages reflect the number with a given finding divided by the total number of patients with data available).
†Not all patients received these labs (percentages reflect the number with a given finding divided by the total labs performed in this population)

with 95% confidence intervals (CIs). All analyses were performed using SAS version 9.4 (SAS Institute, Cary, NC).

RESULTS

During the study period, our health system tested 41,153 patients for COVID-19, of whom 8,673 (21.1%) tested positive for COVID-19. Of those with a positive test result, 1,483 (17.1%) were admitted to the hospital, while 7,190 (82.9%) did not require admission. Among those who were admitted to the hospital, 955 (64.4%) were admitted to the general medical floor, 528 (35.6%) were admitted to the ICU, 282 (19.0%) required mechanical ventilation, and 148 (1.7%) died. As of July 10, 2020, only 66 of the admitted patients from this data set remain in the hospital.

The demographics, clinical symptoms, and laboratory findings are shown in Table 1. Among all patients, the most common age group affected was 19 to 44 years of age (52.2%), followed by 45 to 54 years of age (19.1%) and 55 to 64 years of age (13.6%). We had more female (53.3%) than male patients and a larger proportion of African American patients (26.5%) compared with the other races. Forty-nine percent of patients were Hispanic/Latino. Most patients did not endorse recent international travel and only 26.7% had a known COVID-19 exposure. The most frequent symptoms were cough (71.9%), subjective

Table 2
Events During Hospitalization, Interventions, and Outcomes

	Hospitalized (*N* = 1,483)
Coinfections*	
Positive influenza	54 (3.6)
Positive RSV	3 (0.2)
Complications*	
Positive blood culture	116 (13.2)
Positive sputum culture	184 (97.4)
Cardiac dysrhythmias	142 (9.6)
Developed bacterial pneumonia	68 (4.6)
Developed ARDS	265 (17.9)
Developed rhabdomyolysis (CK ≥ 1,000)	38 (8.7)
Interventions	
High-flow nasal cannula	1,131 (76.3)
CPAP/BPAP	197 (13.3)
Prone positioning	222 (15.0)
Inhaled pulmonary vasodilators	99 (6.7)
ECMO	13 (0.9)
Vasopressors	71 (4.8)
Steroids	676 (45.6)
Lopinavir/ritonavir	15 (1.0)
Hydroxychloroquine	345 (23.3)
Remdesivir	136 (9.2)
Tocilizumab	152 (10.2)
Outcomes	
Hospital length of stay (days)	5 (2–9)
ICU length of stay (days)	5.1 (1.9–13.5)
Intubated patients	282 (19.0)
Days of mechanical ventilation	10 (5–17)

Data are reported as *n* (%) or median (IQR).
ARDS = acute respiratory distress syndrome; BPAP = bilevel positive airway pressure; CPAP = continuous positive airway pressure; ECMO = extracorporeal membrane oxygenation; ICU = intensive care unit.
*Not all patients received these studies (percentages reflect the number with a given finding divided by the total labs performed in this population).

fever (47.9%), and dyspnea (42.7%). Anosmia was present in 19.4% of patients. The most common laboratory abnormalities were an elevated C-reactive protein level (96.8%), elevated LDH level (82.7%), elevated ferritin level (75.3%), elevated D-dimer level (73.6%), lymphopenia (65.7%), and hypoalbuminemia (42.2%).

Events and interventions during hospitalization are demonstrated in Table 2. Co-infection with influenza (3.6%) or respiratory syncytial virus (≤1%) was uncommon in our population. The most common complications were ARDS (17.9%), cardiac dysrhythmias (9.6%), and rhabdomyolysis (8.7%). Three-quarters of patients received high-flow nasal cannula oxygen therapy and 23.3% received hydroxychloroquine. Steroids were given in 45.6% of cases.

Multivariate logistic regression identified several factors associated with an increased risk of hospitalization (Table 3). Age was associated with an increased risk of hospitalization for each decade of life, ranging from an OR of 1.67 (95% CI = 1.36 to 2.06) for patients aged 45 to 54 years of age to an OR of 7.32 (95% CI = 5.02 to 10.68) for patients over 75 years of age. Male patients (OR = 1.69, 95% CI = 1.44 to 1.98) and those with Hispanic/Latino ethnicity (OR = 1.52, 95% CI = 1.18 to 1.92) were more likely to be admitted, as were patients with hypertension (OR = 1.77, 95% CI = 1.46 to 2.16), diabetes mellitus (OR = 1.84, 95% CI = 1.53 to 2.22), prior CVA (3.20, 95% CI = 1.99 to 5.14), CAD (OR = 1.45, 95% CI = 1.03 to 2.06), CHF (OR = 1.79, 95% CI = 1.23 to 2.61), chronic kidney disease (OR = 2.60, 95% CI 1.77 to 3.83), ESRD (OR = 2.22, 95% CI = 1.12 to 4.41), and cirrhosis (OR = 2.03, 95% CI = 1.42 to 2.91). Symptoms of dyspnea (OR = 4.53, 95% CI = 3.75 to 5.47) and fever (OR = 1.43, 95% CI = 1.19 to 1.71) were also predictive of admission.

Factors associated with an increased risk of critical illness included male sex (OR = 1.45, 95% CI = 1.12 to 1.88), congestive heart failure (OR = 1.45, 95% CI = 1.00 to 2.12), OSA (OR = 1.58, 95% CI = 1.07 to 2.33), blood-borne cancer (OR = 3.53, 95% CI = 1.26 to 9.86), leukocytosis (OR = 1.58, 95% CI = 1.15 to 2.17), ANC/ALC ≥ 6 (OR = 1.61, 95% CI = 1.20 to 2.17), hypoalbuminemia (OR = 1.80, 95% CI = 1.39 to 2.32), elevated AST (OR = 1.66, 95% CI = 1.20 to 2.29), elevated lactate (OR = 1.95, 95% CI = 1.40 to 2.73), elevated D-dimer (OR = 1.44, 95% CI = 1.05 to 1.97), and elevated troponin (OR = 3.65, 95% CI = 2.03 to 6.57).

DISCUSSION

This analysis of 8,673 cases at a major academic health system in Chicago is one of the largest collective series of COVID-19 cases to date and one of very few large data sets performed in the United States. In this report, we summarized the most common features of the disease in our cohort and predictors of both hospitalization and critical illness.

While much of the literature has arisen out of areas that had a rapid escalation of cases at the start of the pandemic (e.g., China, Italy, New York, Seattle), there is limited literature evaluating secondary sites in the

Table 3
Multivariable Regression for Hospitalization

	N (%)	Adjusted OR (95% CI)
Age group (years)		
0–18	432 (5.0)	0.92 (0.60–1.43)
19–44	4,528 (52.2)	Reference
45–54	1,657 (19.1)	1.67 (1.36–2.06)
55–64	1,176 (13.6)	1.99 (1.58–2.51)
65–74	552 (6.4)	4.55 (3.40–6.09)
75 or older	328 (3.8)	7.32 (5.02–10.68)
Sex		
Female	4,625 (53.3)	Reference
Male	4,045 (46.6)	1.69 (1.44–1.98)
Race		
White	1,797 (20.7)	1.04 (0.81–1.32)
African American	2,301 (26.5)	Reference
Asian	119 (1.4)	0.99 (0.51–1.93)
Other	2,661 (30.7)	1.05 (0.78–1.40)
Unknown	1,795 (20.7)	1.17 (0.80–1.71)
Ethnicity		
Hispanic or Latino	4,281 (49.4)	Reference
Not Hispanic or Latino	3,785 (43.6)	0.66 (0.52–0.85)
Unknown	607 (7.0)	0.38 (0.19–0.76)
Tobacco use		
Former	838 (9.7)	0.84 (0.68–1.05)
Current	406 (4.7)	0.75 (0.54–1.05)
Never	7,429 (85.7)	Reference
Comorbidities		
Asthma	736 (8.5)	0.82 (0.65 –1.04)
COPD	117 (1.3)	1.62 (0.93–2.82)
Hypertension	1,917 (22.1)	1.77 (1.46–2.16)
Hyperlipidemia	1,242 (14.3)	0.78 (0.63–0.96)
Diabetes mellitus	1,269 (14.6)	1.84 (1.53–2.22)
Prior CVA	158 (1.8)	3.20 (1.99–5.14)
Coronary artery disease	318 (3.7)	1.45 (1.03–2.06)
Congestive heart failure	280 (3.2)	1.79 (1.23–2.61)
Chronic kidney disease	380 (4.4)	2.60 (1.77–3.83)
Current ESRD	124 (1.4)	2.22 (1.12–4.41)
Cirrhosis	207 (2.4)	2.03 (1.42–2.91)
Obstructive sleep apnea	288 (3.3)	1.05 (0.76–1.45)
Blood-borne cancer	38 (0.4)	1.30 (0.55–3.09)
Solid organ cancer	506 (5.8)	0.65 (0.50–0.84)
HIV	32 (0.4)	0.68 (0.25–1.84)
Solid organ transplant	65 (0.7)	0.90 (0.43–1.85)
BMI		
<30	2,490 (28.7)	Reference
≥30	1,290 (14.9)	1.15 (0.96–1.37)
Unknown	4,893 (56.4)	0.06 (0.05–0.08)
Symptoms		
Anosmia	884 (19.4)	0.51 (0.39–0.67)
Abdominal pain	171 (3.7)	1.51 (0.95–2.42)
Bruising/bleeding	28 (0.6)	1.47 (0.52–4.13)
Cough	3,282 (71.9)	0.88 (0.71–1.08)
Dyspnea	1,946 (42.7)	4.53 (3.75–5.47)
Fever (subjective)	2,186 (47.9)	1.43 (1.19–1.71)
Headache	361 (7.9)	0.67 (0.44–1.02)
Myalgias	1,299 (28.5)	0.73 (0.59–0.91)
Sore throat	963 (21.1)	0.58 (0.45–0.75)
Vomiting	115 (2.5)	1.41 (0.77–2.59)

BMI = body mass index; CVA = cerebrovascular accident; ESRD = end-stage renal disease (on dialysis); HIV = human immunodeficiency virus.

United States that have had more time to prepare for COVID-19. When compared with the largest data set from New York, our cohort had a significantly lower rate of mortality and critical illness.[17] There are many factors that may have contributed to this lower mortality rate, which may include the additional time available to prepare the hospital system, lower overall exposure rates due to social isolation efforts, and differences in resource availability. Of note, our population was also younger and more likely to be female and had fewer comorbidities than this cohort, which may also have been protective.[17] We may also have tested more liberally than other sites due to increased availability of testing later in the pandemic.

Consistent with prior literature, cough was the most common symptom, present in 72% of cases.[6,18] However, contrary to the study by Guan et al.,[18] we found significantly higher rates of dyspnea in our cohort. Interestingly, while 48% of patients reported a history of subjective fevers, only 12% of patients had a fever on presentation. This is much lower than the rate from the existing literature, which have found the rates of fever ranging from 31% to 94%.[6,17] Similar to prior studies, we found that an elevated ferritin level and lymphopenia were common.[6,17,18] However, we identified significantly higher C-reactive protein levels and D-dimer levels than prior literature.[17,18] The rate of concomitant influenza infection in our study was low, although higher than that of the New York data.[17] We also found that 13% of our population developed bacteremia during their hospitalization, which is higher than expected for hospitalized patients but similar to data among ICU patients without COVID-19.[19]

Table 4
Multivariable Regression for Critical Illness

	N (%)	OR (95% CI)
Age group (years)		
19–44	367 (24.7)	Reference
45–54	298 (20.1)	1.07 (0.74–1.55)
55–64	307 (20.7)	0.99 (0.68–1.44)
65–74	263 (17.7)	1.01 (0.67–1.52)
75 or older	367 (24.7)	0.81 (0.51–1.28)
Sex		
Female	691 (46.6)	Reference
Male	792 (53.4)	1.45 (1.12–1.88)
Race		
White	362 (24.4)	0.86 (0.61–1.19)
African American	554 (37.4)	Reference
Other	432 (29.1)	1.21 (0.90–1.63)
Comorbidities		
COPD	84 (5.7)	1.50 (0.87–2.58)
Hypertension	897 (60.5)	1.23 (0.91–1.67)
Hyperlipidemia	592 (39.9)	1.17 (0.87–1.56)
Diabetes mellitus	634 (42.8)	1.21 (0.93–1.58)
Prior CVA	121 (8.2)	1.43 (0.91–2.25)
Congestive heart failure	218 (14.7)	1.45 (1.00–2.12)
Chronic kidney disease	306 (20.6)	0.89 (0.60–1.32)
Current ESRD	106 (7.1)	1.14 (0.67–1.97)
Obstructive sleep apnea	154 (10.4)	1.58 (1.07–2.33)
Blood-borne cancer	18 (1.2)	3.53 (1.26–9.86)
Symptoms		
Anosmia	104 (9.4)	1.06 (0.63–1.78)
Cough	800 (71.9)	0.95 (0.70–1.30)
Headache	43 (3.9)	0.69 (0.29–1.65)
Myalgias	246 (22.1)	0.89 (0.62–1.28)
Labs		
WBC		
≥10	339 (24.1)	1.58 (1.15–2.17)
≤ 4	144 (10.2)	1.00 (0.65–1.54)
ALC ≤ 1.5	1,108 (79.1)	1.00 (0.71–1.40)
ANC/ALC ≥ 6	569 (40.6)	1.61 (1.20–2.17)
Total bilirubin > 1.3	82 (6.2)	1.02 (0.61–1.71)
Albumin < 3.5	780 (58.8)	1.80 (1.39–2.32)
AST > 40	657 (49.5)	1.66 (1.20–2.29)
ALT > 40	466 (35.3)	0.88 (0.63–1.22)
LDH ≥ 245	605 (86.4)	1.14 (0.66–1.97)
Lactate ≥ 2	259 (29.7)	1.95 (1.40–2.73)
D-dimer > 0.49	323 (79.4)	1.44 (1.05–1.97)
C-reactive protein >8	633 (98.3)	1.41 (0.95–2.11)
Ferritin > 300 (men) or 150 (women)	563 (81.1)	1.14 (0.69–1.87)
Troponin > 0.9	87 (22.3)	3.65 (2.03–6.57)

BMI = body mass index; CVA = cerebrovascular accident; ESRD = end-stage renal disease (on dialysis); HIV = human immunodeficiency virus.

We found that the most common factors associated with hospitalization were increased age, male sex, Hispanic/Latino ethnicity, hypertension, diabetes mellitus, prior CVA, CAD, CHF, chronic kidney disease, and ESRD, which is consistent with prior data demonstrating increased risk of worse outcomes in these patients.[6,8,9,15,17,18] Interestingly, we also identified an increase rate of hospitalization among patients with cirrhosis, which has not been previously described. The reason for this is unclear, but it is possible that this may reflect worsened baseline health similar to the aforementioned factors.

Several factors were associated with an increased risk of critical illness. These included male sex, CHF, OSA, blood-borne cancer, leukocytosis, elevated ANC/ALC, hypoalbuminemia, elevated AST, elevated lactate, elevated D-dimer, and elevated troponin. Among these, one the most predictive was an elevated troponin. There has been increasing recognition of the association between COVID-19 and cardiovascular complications.[20] Therefore, it is not surprising that an elevated troponin is associated with an increased risk of critical illness. Leukocytosis was another predictor, which was also demonstrated in the study by Guan et al.[18] Early literature has also proposed that an elevated ANC/ALC may be predictive of critical illness in this population.[21] Hypoalbuminemia was another risk factor in our population. While there has been limited analysis of this in prior studies,[6,22,23] it is possible that this may signify a patient population with less physiologic reserve who may be more likely to deteriorate.

LIMITATIONS

It is important to consider several limitations with regard to the present study. First, this was studied at a single hospital system in Chicago, Illinois, and may not reflect other locations. However, this is the first large study to be performed in this location and we believe it lends unique insights into the disease. Additionally, while a dedicated data registry was used, some data were not reported or available. Where possible, we have accounted for this in the logistic regression, although we acknowledge that it would be preferable to have all data available for each outcome. Due to the retrospective nature of this database, we were unable to control for unmeasured confounders. Moreover, many discharged patients did not receive laboratory testing, so we are unable to comment on the role of laboratory testing on admission decisions. We are also

not able to determine the degree to which COVID-19 influenced admission decisions. Finally, testing was primarily limited to symptomatic patients, so it is likely that we may have missed some asymptomatic patients in this cohort.

CONCLUSION

This study described the clinical and laboratory features associated with COVID-19 among patients in Chicago, Illinois. Advanced age, male sex, Hispanic/Latino ethnicity, hypertension, diabetes mellitus, prior cerebrovascular accident, coronary artery disease, congestive heart failure, chronic kidney disease, end-stage renal disease, cirrhosis, and symptoms of fever or dyspnea were more commonly associated with admission, while male sex, congestive heart failure, obstructive sleep apnea, blood-borne cancer, leukocytosis, an elevated absolute neutrophil count/absolute lymphocyte count, hypoalbuminemia, an elevated aspartate aminotransferase, an elevated lactate, and elevated D-dimer and an elevated troponin were associated with critical illness. We believe these findings will be valuable for understanding the epidemiology of COVID-19 in secondary sites within the United States and for assessing risk factors associated with hospitalization and critical illness. Future studies should validate these findings at other locations in the United States and utilize them in conjunction with other cohorts to develop decision tools to risk stratify patients for admission and critical illness.

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References

1. World Health Organization. Situation Report 172. Available at: https://www.who.int/emergencies/diseases/novel-coronavirus-2019/situation-reports/. Accessed Jul 10, 2020.
2. Holshue ML, DeBolt C, Lindquist S et al. First case of 2019 novel coronavirus in the United States. N Engl J Med 2020;382:929–36.
3. Centers for Disease Control and Prevention. Coronavirus Disease 2019 (COVID-19) Cases in U.S. 2020. Available at: https://www.cdc.gov/coronavirus/2019-ncov/cases-updates/cases-in-us.html. Accessed Jul 10, 2020.
4. Chicago Department of Public Health. Chicago COVID-19 Update, April 30, 2020. Available at: https://www.chicago.gov/city/en/sites/covid-19/home/latest-data.html. Accessed Jul 10, 2020.
5. Ghinai I, McPherson TD, Hunter JC, et al. First known person-to-person transmission of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) in the USA. Lancet 2020;395:1137–44.
6. Zhou F, Yu T, Du R, et al. Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: a retrospective cohort study. Lancet 2020;395:1054–62.
7. Wu C, Chen X, Cai Y, et al. Risk factors associated with acute respiratory distress syndrome and death in patients with coronavirus disease 2019 pneumonia in Wuhan China. JAMA Intern Med 2020;180:1–12.
8. Grasselli G, Zangrillo A, Zanella A, et al Baseline characteristics and outcomes of 1591 patients infected with SARS-CoV-2 admitted to ICUs of the Lombardy region Italy. JAMA 2020;323:1574–81.
9. CDC COVID-19 Response Team. Severe outcomes among patients with coronavirus disease 2019 (COVID-19) - United States, February 12-March 16, 2020. MMWR Morb Mortal Wkly Rep 2020;69:343–6.
10. Wu Z, McGoogan JM, Characteristics of and important lessons from the coronavirus disease 2019 (COVID-19) outbreak in China. JAMA 2020;323:1239.
11. Ji D, Zhang D, Xu J, et al. Prediction for progression risk in patients with COVID-19 pneumonia: the CALL score. Clin Infect Dis 2020;ciaa414. [Epub ahead of print] https://doi.org/10.1093/cid/ciaa414
12. Livingston E, Bucher K. Coronavirus disease 2019 (COVID-19) in Italy. JAMA 2020;323:1335.
13. Chen T, Wu D, Chen H, et al. Clinical characteristics of 113 deceased patients with coronavirus disease 2019: retrospective study. BMJ 2020;368:m1091.
14. Yang J, Zheng Y, Gou X, et al Prevalence of comorbidities in the novel Wuhan coronavirus (COVID-19) infection: a systematic review and meta-analysis. Int J Infect Dis 2020;94:91–95.
15. CDC COVID-19 Response Team. Preliminary estimates of the prevalence of selected underlying health conditions among patients with coronavirus disease 2019 - United States, February 12-March 28, 2020. MMWR Morb Mortal Weekly Report 2020;69:382–6.
16. Jordan RE, Adab P, Cheng KK. Covid-19: risk factors for severe disease and death. BMJ 2020;368:m1198.
17. Richardson S, Hirsch JS, Narasimhan M, et al. Presenting characteristics, comorbidities, and outcomes among 5700 patients hospitalized with COVID-19 in the New York City area. JAMA 2020;323:2052–9.
18. Guan WJ, Ni ZY, Hu Y, et al Clinical characteristics of coronavirus disease 2019 in China. N Engl J Med 2020;382:1708–20.

19. Vincent JL, Sakr Y, Singer M, et al. Prevalence and outcomes of infection among patients in intensive care units in 2017. JAMA 2020;323:1478–87.
20. Long B, Brady WJ, Koyfman A, Gottlieb M. Cardiovascular complications in COVID-19. Am J Emerg Med 2020;38:1504–07.
21. Yang AP, Liu JP, Tao WQ, Li HM. The diagnostic and predictive role of NLR, d-NLR and PLR in COVID-19 patients. Int Immunopharmacol 2020;84:106504.
22. Mo P, Xing Y, Xiao Y, et al. Clinical characteristics of refractory COVID-19 pneumonia in Wuhan China. Clin Infect Dis 2020;ciaa270 [Epub ahead of print] https://doi.org/10.1093/cid/ciaa270
23. Gong J, Ou J, Qiu X, et al. A tool to early predict severe corona virus disease 2019 (COVID-19): a multicenter study using the risk nomogram in Wuhan and Guangdong, China. Clin Infect Dis. 2020;71:833–40.