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ORIGINAL ARTICLE

The Prognostic Value of Electrocardiogram at Presentation to Emergency Department in Patients With COVID-19

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Abstract

Objective: To study whether combining vital signs and electrocardiogram (ECG) analysis can improve early prognostication.

Methods: This study analyzed 1258 adults with coronavirus disease 2019 who were seen at three hospitals in New York in March and April 2020. Electrocardiograms at presentation to the emergency department were systematically read by electrophysiologists. The primary outcome was a composite of mechanical ventilation or death 48 hours from diagnosis. The prognostic value of ECG abnormalities was assessed in a model adjusted for demographics, comorbidities, and vital signs.

Results: At 48 hours, 73 of 1258 patients (5.8%) had died and 174 of 1258 (13.8%) were alive but receiving mechanical ventilation with 277 of 1258 (22.0%) patients dying by 30 days. Early development of respiratory failure was common, with 53% of all intubations occurring within 48 hours of presentation. In a multivariable logistic regression, atrial fibrillation/flutter (odds ratio [OR], 2.5; 95% CI, 1.1 to 6.2), right ventricular strain (OR, 2.7; 95% CI, 1.3 to 6.1), and ST segment abnormalities (OR, 2.4; 95% CI, 1.5 to 3.8) were associated with death or mechanical ventilation at 48 hours. In 108 patients without these ECG abnormalities and with normal respiratory vitals (rate <20 breaths/min and saturation >95%), only 5 (4.6%) died or required mechanical ventilation by 48 hours versus 68 of 216 patients (31.5%) having both ECG and respiratory vital sign abnormalities.

Conclusion: The combination of abnormal respiratory vital signs and ECG findings of atrial fibrillation/flutter, right ventricular strain, or ST segment abnormalities accurately prognosticates early deterioration in patients with coronavirus disease 2019 and may assist with patient triage.

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The global pandemic of coronavirus disease 2019 (COVID-19) is caused by infection with severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2).[1] In the United States, COVID-19 has infected more than 3.4 million people, leading to more than 138,000 deaths.[1,2] Severe cases can result in respiratory failure with acute respiratory distress syndrome, shock, and death.[3] Some patients remain stable with

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mild symptoms, and others develop rapid deterioration after a period of stability lasting up to a week or more.[1,4,5]

Known markers of poor prognosis include age, comorbidities, and high sequential organ failure assessment score.[5] In patients with severe infection, numerous laboratory findings have been associated with adverse outcomes including hematologic disturbances and inflammatory biomarkers.[5] However, there is a limited understanding of how presenting vital signs relate to final outcome from COVID-19, hampering the development of effective approaches for triaging patients early in their clinical course. Additionally, there is increasing evidence of the prognostic capacity of cardiac involvement in COVID-19.[6,7] Electrocardiographic (ECG) abnormalities have been described, but there have been no large studies of ECG abnormalities in COVID-19 patients nor their correlation with clinical outcomes.[8,9]

Early triage of patients who will require higher levels of care is crucial because of the high volume of patients admitted with the disease. In this study, we sought to determine if data available early in a patient's emergency department (ED) presentation (demographics, comorbidities, vital signs, and ECG) could prognosticate the composite outcome of mechanical ventilation or death by 48 hours after COVID-19 diagnosis. We hypothesized that abnormalities found on ECGs performed at presentation would add additional prognostic capacity after adjusting for the above data in a multivariable logistic regression model. Lastly, we explored time from presentation to mechanical ventilation or death to better understand the disease course.

METHODS

Data Collection

All patients 18 years of age or older who tested positive for SARS-CoV-2 using a reverse-transcriptase–polymerase-chain-reaction assay of a nasopharyngeal or oropharyngeal sample at Columbia University Irving Medical Center, Morgan Stanley Children's Hospital of New York, and New York–Presbyterian Allen Pavilion were enrolled in this study. To ensure all patients had 14-day outcomes, patients must have received a positive diagnosis between March 1, 2020, and April 3, 2020. Data were collected using chart reviews and electronic health records abstraction. This study was conducted with approval from the Columbia University Irving Medical Center Institutional Review Board.

Abstracted data included demographics, comorbidities, symptoms, vital signs, laboratory findings, ECGs, and clinical outcomes. Comorbidities were assessed by manual chart review and included hypertension, diabetes, obesity (defined as body mass index $\geq$30 kg/m^2, pulmonary disease (including asthma, chronic obstructive pulmonary disease, interstitial lung disease, or any primary lung disease that required home oxygen therapy or daily treatment), stage 3-5 chronic kidney disease (CKD), heart failure with reduced ejection fraction (HFrEF, defined as ejection fraction $<$50%), heart failure with preserved ejection fraction (HFpEF, defined as clinical diagnosis found in patient records), obstructive coronary artery disease (CAD; defined as left main disease $\geq$50% or other vessels $\geq$70%, treated or untreated), active cancer (defined as metastatic cancer, cancer that required treatment within the last 6 months, or cancer undergoing active observation), or personal history of cancer that did not meet the active cancer definition. Non-metastatic basal cell carcinoma and squamous cell carcinoma of the skin were excluded from the cancer criteria.

Abstracted laboratory data included white blood cell count, absolute lymphocyte count, hemoglobin, creatinine, C-reactive protein (CRP), and erythrocyte sedimentation rate. For each lab assay, the first laboratory test that was performed during the encounter was defined as the "initial" test. In addition, the most abnormal result (peak or nadir depending on clinical relevance) of each lab any point during the 14-day period was recorded.

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TABLE 1. Characteristics of Adult Patients Diagnosed With Coronavirus Disease 2019[a]

		Outcome 48 hours after diagnosis		
	Total	Alive, never received mechanical ventilation	Alive, received mechanical ventilation	Died
N (%)	1258 (100)	1011 (80)	174 (14)	73 (6)
Demographics				
Age, mean (SD), years	61.6 (18.4)	60.55 (6)	61.32 (35)	76.51 (105)
Male	685 (54)	532 (53)	111 (64)	42 (58)
Comorbidities				
No comorbidities	209 (17)	189 (19)	19 (11)	1 (1)
Hypertension	715 (57)	557 (55)	107 (61)	53 (73)
Diabetes	461 (37)	349 (35)	74 (43)	40 (55)
Obesity	428 (34)	336 (33)	78 (45)	17 (23)
Primary lung disease	208 (17)	161 (16)	29 (17)	20 (27)
CKD	197 (16)	147 (15)	29 (17)	22 (30)
HFrEF	84 (7)	57 (6)	14 (8)	13 (18)
HFpEF	54 (4)	43 (4)	6 (3)	5 (7)
CAD	144 (11)	111 (11)	25 (14)	9 (12)
Cancer, active	53 (4)	47 (5)	5 (3)	3 (4)
Cancer, history	71 (6)	57 (6)	11 (6)	3 (4)
Two or more comorbidities	691 (55)	547 (54)	103 (59)	45 (62)
Presenting symptoms				
Fever	489 (39)	408 (40)	66 (38)	18 (25)
Cough	402 (32)	336 (33)	55 (32)	13 (18)
Shortness of breath	368 (29)	263 (26)	81 (47)	26 (36)
Gastrointestinal complaints	124 (10)	117 (12)	6 (3)	1 (1)
Weakness	84 (7)	74 (7)	7 (4)	3 (4)
Chest pain	40 (3)	35 (3)	5 (3)	0 (0)
Presenting vital signs				
Abnormal temperature (<36° or >38° C)	368 (29)	292 (29)	55 (32)	23 (32)
Heart rate >100 beats/min	536 (43)	418 (41)	81 (47)	39 (53)
Oxygen saturation <96%	719 (57)	555 (55)	127 (73)	37 (51)
Respiratory rate ≥20 breaths/min	352 (28)	228 (23)	90 (52)	34 (47)
Systolic blood pressure <100 mm Hg	110 (9)	89 (9)	9 (5)	12 (15)
Presenting electrocardiogram				
Patients with ECGs	850	675	132	43
Normal sinus rhythm	557 (66)	465 (69)	72 (55)	20 (47)
Sinus bradycardia	15 (2)	13 (2)	0	2 (5)
Sinus tachycardia	220 (26)	161 (24)	46 (35)	13 (30)
Atrial fibrillation or flutter	42 (5)	23 (3)	11 (10)	8 (19)
Atrial ectopy	66 (8)	52 (8)	7 (6)	7 (18)
PR >240 ms	14 (2)	12 (2)	2 (2)	0
PR depression present	8 (1)	6 (1)	1 (1)	1 (2)
Ventricular ectopy	44 (5)	34 (5)	5 (4)	5 (12)
Pathologic Q Waves	72 (8)	51 (8)	12 (9)	9 (21)
QRS >120 ms	70 (8)	55 (8)	10 (8)	5 (12)
Left ventricular hypertrophy	96 (11)	71 (11)	15 (12)	10 (24)
Low QRS voltage	29 (3)	22 (3)	3 (2)	4 (10)
Right ventricular overload[b]	34 (4)	23 (3)	10 (8)	1 (2.4)
Poor R wave progression	118 (14)	85 (13)	24 (18)	9 (21)
	117 (14)	78 (12)	25 (19)	14 (33)

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TABLE 1. Continued

	Total	Outcome 48 hours after diagnosis		
		Alive, never received mechanical ventilation	Alive, received mechanical ventilation	Died
Any ST segment Elevation/ depression				
ST elevation or depression ≥1mm	40 (5)	27 (4)	11 (8)	2 (5)
QTc (Fredericia) ≥500 ms	64 (8)	43 (6)	12 (9)	9 (21)

[a]CAD = obstructive coronary artery disease; CKD = stage 3 or greater chronic kidney disease; ECG = electrocardiogram; HFpEF = heart failure with preserved ejection fraction; HFrEF = heart failure with reduced ejection fraction which was defined as a clinical diagnosis of systolic heart failure or a baseline echocardiogram with left ventricular ejection fraction <50%.

[b]Right ventricular overload was defined as the presence of right ventricular hypertrophy or S1Q3T3. Any ST segment elevation/ depression includes sub-millimeter changes from baseline, but ST elevations and depressions must have occurred in two contiguous leads to be considered positive.

Electrocardiograms

Twelve-lead ECGs were abstracted and analyzed using the MUSE Cardiology Information System (GE Healthcare, Chicago, IL). An "initial ECG" was defined as one obtained within 6 hours of presentation or diagnosis of COVID-19. Ventricularly paced ECGs (n=9) were excluded from analysis. Only the earliest eligible electrocardiogram per patient was used. All ECGs were analyzed by a board-certified electrophysiologist (E.W., J.D., J.M., H.Y., F.E., or D.S.) using a standardized reading protocol which included ECG intervals, rate, rhythm, axis, QRS morphology, voltage, and ST or T wave abnormalities (complete criteria are detailed in the Supplemental Material, available online at http://www.mayoclinicproceedings.org).

Clinical Outcomes

Analysis of clinical outcomes was assessed by chart review. Patients were grouped into one of three mutually exclusive groups: 1) alive, never required mechanical ventilation; 2) alive, required mechanical ventilation; or 3) died of any cause. To ensure disease outcome was adequately captured, all patients were required to have 14 days of follow-up after their initial positive SARS-CoV-2 test to be included in this study. The primary outcome for the study was defined as receiving mechanical ventilation (excluding emergent intubation during unsuccessful resuscitation) or death at any point in the 48 hours after COVID-19 diagnosis.

Statistical Analysis and Multivariable Regression Model

Descriptive statistics including mean, standard deviation, median, interquartile range (IQR), and frequencies were determined for demographics, comorbidities, laboratory findings, ECG parameters, and clinical outcomes. The Shapiro-Wilk test was used to assess normality of key variables, and where applicable nonparametric testing was conducted. Categorical variables were assessed using χ^2 analysis. Continuous variable means were compared using Student *t* tests or the Mann-Whitney U test. Where assumptions of normality were met, mean, standard deviation, and 95% CIs are described. Nonparametric results are described with median and IQRs. All statistical tests were performed in Python 3.4 (Wilmington, DE) and SPSS v26 (Chicago, IL).

All variables in Table 1 underwent univariable logistic regression to the primary outcome. Those with a *P* value nearing .05 were candidates for inclusion in a multivariable logistic regression model. The multivariable logistic regression model was used to determine the odds ratios (ORs) in predicting the primary outcome as a binary event. The variables selected were those regularly available within the first hour of a patient's

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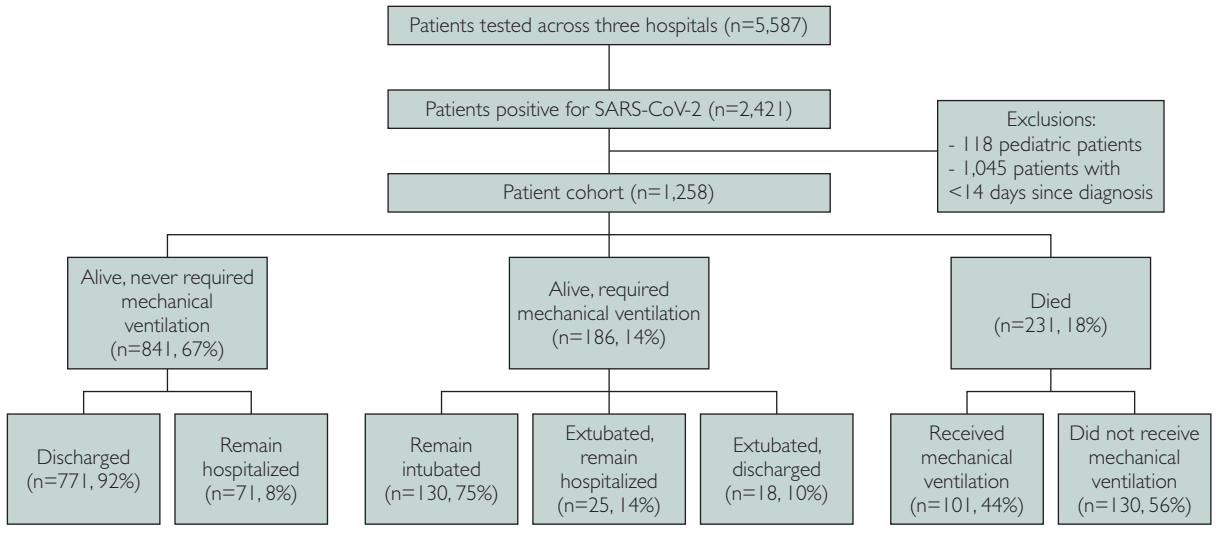

FIGURE 1. Patient outcomes at 14 days after coronavirus disease 2019 diagnosis.

presentation to the ED, including demographics, comorbidities, vital signs, and ECG abnormality. Abnormal respiratory vitals were defined as a respiratory rate >20 breaths/min, oxygen saturation <96%, or oxygen therapy via non-rebreather (NRB) or full-face mask (FFM) at presentation. We then evaluated how a simplified algorithm looking at the presence of the most significant risk factors from the multivariable logistic regression model would do in discriminating 48-hour outcome. We also assessed discriminative capacity for 14-day outcome to ensure deaths and intubations occurring after 2 days did not significantly deviate from the 48-hour model's findings.

RESULTS

Patient Characteristics, Comorbidities, Laboratory Findings, and Outcomes

From March 1 to April 3, 2020, 5587 individuals were tested for COVID-19 with 2421 (43.3%) having positive results. A total of 1258 patients who were admitted to the hospital were included in the study. Demographics, comorbidities, presentation vital signs, and outcomes are displayed in Table 1. The mean age was 61.6 years (SD, 18.4 years) and 563 (44.8%) patients were female. The most common comorbidities were hypertension (n=753; 56.8%), diabetes (n=461; 36.6%), obesity (n=428; 34.0%), primary lung disease (n=208; 16.5%), and CKD (n=197; 15.7%). Prior known cardiovascular disease included CAD (n=144; 11.4%), HFrEF (n=84; 6.6%), and HFpEF (n=54; 4.3%). The most common symptoms reported at the time of triage were fever (n=489; 38.8%), cough (n=402; 32.0%), shortness of breath (n=368; 29.3%), gastrointestinal complaints (n=124; 9.9%), weakness (n=84; 6.7%), and chest pain (n=40; 3.2%).

At 48 hours, 1011 of 1258 patients (80.4%) were alive without receiving mechanical ventilation, 174 (13.8%) received mechanical ventilation but had not died, and 73 (5.8%) had died (Figure 1). During the 14-day period, 287 of 1258 patients (22.8%) were intubated, of which 16 (5.8%) were extubated and discharged, 36 (12.5%) were extubated but remained hospitalized, 121 (42.2%) remained intubated, and 115 (40.1%) died. The rate of early clinical decompensation was high, with a median time from hospital arrival to mechanical ventilation of 1 day (IQR, 0 to 4 days) and a median time of hospital arrival

TABLE 2. Multivariable Logistic Regression Model to Predict Mechanical Ventilation or Death at 48 Hours[a]

	Odds ratio	95% CI	*P*
Age (per 10 years)	1.08	0.91-1.2	.31
Male	1.30	0.86-1.96	.21
Hypertension	1.39	0.85-2.30	.19
Diabetes	1.56	1.01-2.40	.042
Atrial fibrillation or flutter	2.54	1.05-6.2	.39
Right ventricular overload	2.7	1.30-6.12	.007
ST segment abnormality	2.38	1.49-3.84	<.001
Respiratory rate >20 breaths/min	3.26	2.24-4.73	<.001
Oxygen saturation ≤ 95%	2.08	1.32-3.28	<.001
Heart rate >100 beats/min	1.3	0.88-1.93	.194

[a]Variables from Table 1 with *P* values less than .05 in univariable logistic regression were included in multivariable logistic regression and reported.

to death of 6 days (IQR, 3 to 10 days). Mortality increased from 231 of 1258 (18.4%) patients at 14 days to 277 (22.0%) patients at 30 days.

Patients who met the primary outcome tended to be older (mean age, 66.3 years vs 60.4 years), male (62.4% vs 52.1%), have hypertension (67.1% vs 54.8%), diabetes (47.2% vs 33.7%), and CKD (19.6% vs 15.1%). On presentation they were more likely to have a respiratory rate greater than 20 breaths/min (50.2% vs 22.1%) and oxygen saturation less than or equal to 95% (67% vs 55%). There were differences noted in earliest creatinine level (median, 1.3 vs 1.0 mg/dL) and CRP (184.7 vs 89.6 mg/L) but differences in erythrocyte sedimentation rate (73 vs 63 mm/h) and absolute lymphocyte count (0.88 vs 1.06 × 10^3 cells/μL) were less pronounced. Laboratory results are further detailed in the Supplemental Material.

Vital Signs

Vital sign abnormalities on presentation are shown in Table 1. The median temperature was 37.4° C (IQR, 36.8 to 38.2 ° C) and 361 of 1258 patients (29.0%) had a temperature greater than or equal to 38.0 ° C. The median heart rate was 98 beats/min (IQR, 86 to 110 beats/min) and median systolic blood pressure was 124 mm Hg (IQR, 111 to 142 mm Hg). The median respiratory rate was 20 breaths/min (IQR, 18 to 22 breaths/min) and the median oxygen saturation was 94% (IQR, 90% to 97%). Six hundred eighty-two of 1258 (54.2%) patients met criteria for abnormal respiratory vitals (respiratory rate >20 breaths/min, saturation ≤95%, or oxygen therapy via NRB or FFM).

Electrocardiographic Findings

Initial ECGs for 850 patients were available for analysis. The most common rhythm was sinus rhythm (65.6%) followed by sinus tachycardia (25.9%), and atrial fibrillation or flutter (4.9%).

Ninety-six of 850 patients (11.3%) met criteria for left ventricular hypertrophy and 29 (3.4%) patients had low QRS voltage. The QTc (Bazett) was prolonged (>460 ms if QRS <120 ms or >500 ms if QRS >120 ms) in 240 patients (28.2%) and markedly prolonged (>500 ms if QRS <120 ms or >550 if QRS >120 ms) in 43 patients (5.1%). Among 812 ECGs with QRS duration less than 120 ms, there was ST elevation or depression in two contiguous leads in 117 patients (13.8%) with 40 (4.7%) being greater than or equal to 1 mm. A full list of ECG findings is detailed in Table 1.

Triage Approach Based on Respiratory Vital Signs and ECG

All variables in Table 1 underwent univariable logistic regression in predicting 48-hour outcome. All variables with *P* values less than or equal to .05 were included in a

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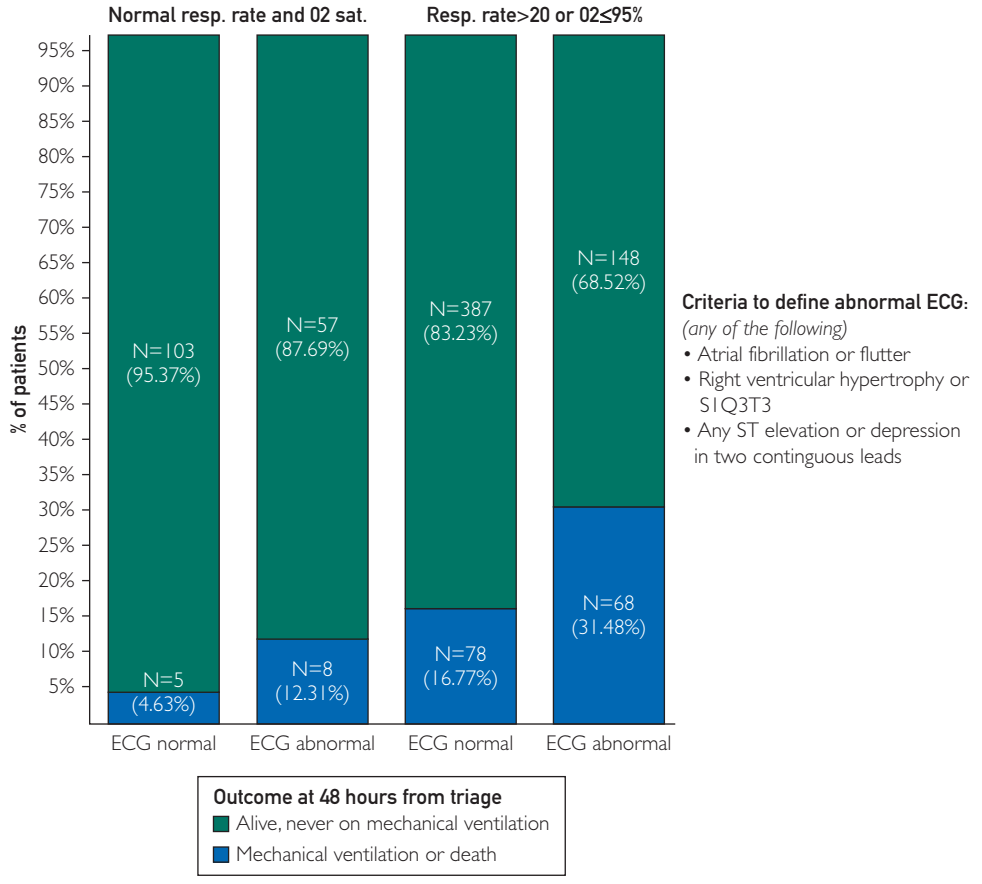

FIGURE 2. Electrocardiogram (ECG) abnormalities at time of presentation are prognostic of mechanical ventilation or death at 48 hours. The ability to prognosticate 48-hour outcome was assessed using the first ECG and vital signs recorded in the emergency department. Electrocardiogram abnormality was defined as the presence of atrial fibrillation or flutter, right ventricular hypertrophy or S1Q3T3, or any ST elevation or depression in two contiguous leads. Respiratory vital sign abnormality was defined as a respiratory rate greater than 20 breaths/min, saturation less than or equal to 95%, or requiring oxygen therapy by non-rebreather or full face mask. The absence of any of these ECG abnormalities and any respiratory abnormality made the likelihood of intubation or death at 48 hours less than 5%.

multivariable logistic regression model as shown in Table 2. In our final multivariable model, significant variables included respiratory rate greater than 20 breaths/min (OR, 3.3; 95% CI, 2.2 to 4.7), oxygen saturation less than or equal to 95% or oxygen therapy via NRB or FFM (OR, 2.1; 95% CI, 1.3 to 3.3), presence of atrial fibrillation/flutter (OR, 2.5; 95% CI, 1.1 to 6.2), right ventricular strain (OR, 2.7; 95% CI, 1.3 to 6.1), ST segment abnormality (OR, 2.4; 95% CI, 1.5 to 3.8), and history of diabetes requiring medical therapy (OR, 1.6; 95% CI, 1.0 to 2.4) as detailed in Table 2. No significant collinearity was found among all variables included in the model (highest variance inflation factor = 1.8). The hypothesis that ECG abnormalities had additive prognostic value after adjusting for the presence of demographics, comorbidities, and vital signs was accepted. We then combined the two vital sign abnormalities and three ECG abnormalities into two binary variables (abnormal respiratory vitals and abnormal ECG findings). At 48 hours after diagnosis, 5 (4.6%) of patients with none of the three ECG

abnormalities and normal respiratory vital signs received mechanical ventilation or died, compared with 68 (31.5%) of patients with any ECG abnormality and any abnormal respiratory vital sign. The presence of any of the three ECG abnormalities increased the rate of mechanical ventilation or death from 4.6% to 12.3% in patients with normal respiratory vital signs, and from 16.8% to 31.5% in patients with abnormal respiratory vital signs (Figure 2). Looking at 14-day and 30-day outcome, these five variables (two respiratory vitals and three ECG abnormalities) continued to all be significant in multivariable regression. The pathway to outcome at 14 days for all patients is detailed in Figure 3.

DISCUSSION

We analyzed 1258 patients with COVID-19 seen at three hospitals in New York City during the peak of the COVID-19 pandemic. The principal findings of this study include: 1) rapid clinical deterioration is common in admitted patients, with 53.4% of intubations occurring within 48 hours; 2) 33% of admitted patients either died or required mechanical ventilation within 14 days of COVID-19 diagnosis; and 3) combining abnormal ECG and abnormal respiratory vital signs quickly identifies a group of patients at high risk for mechanical ventilation or death.

Myocardial injury is an important marker for severe COVID-19.[8] ECG remains the simplest assessment for myocardial involvement. To our knowledge, no study on COVID-19 has had a majority of patients with ECGs performed at presentation and assessed its prognostic capacity. Although triage and management during a patient's admission evolves when additional information such as laboratory values and imaging become available, it is important to be able to quickly screen patients upon arrival to the ED to plan for the level of care they may need. Abnormalities in initial vitals and presentation ECG can be detected rapidly in a range of clinical settings. More studies are needed to determine how initial presentation affects outcome beyond the most acute phase of COVID-19.

The Need for Rapid Triage in COVID-19 Patients

Understanding risk factors for COVID-19 severity remains critical because of a need for rapid triage as well as potentially guiding resource allocation. Studies have reported age, hypertension, diabetes, sequential organ failure assessment score, neutrophilia, elevated lactate dehydrogenase, and D-dimer as prognostic factors for patients with COVID-19.[5,9] A study from New York described male sex, obesity, elevated liver function tests, ferritin, and CRP as predictors of mechanical ventilation.[9] In addition, cardiac injury, as measured by elevated troponin levels carries a particularly poor prognosis.[10-12] The Brescia-COVID respiratory severity scale is the most easily applied decision tool developed to date, basing risk on presenting vital signs and chest radiograph, but it lacks input variables that point to extrapulmonary involvement which we believe are critical for effective triage.[13] Unfortunately, the majority of risk factors identified so far are laboratory values that will not be immediately available upon presentation. Using data immediately available such as vital signs and ECG provides a quick, simple, and effective assessment of the patient's prognosis. Herein, we reported a significant increase in event rate when abnormal ECG was incorporated into multivariable regression, with higher prognostic value than every other variable in the model except for abnormal respiratory vitals. We propose that in the setting of triaging COVID-19 patients in the ED, ECG be treated as a sixth vital sign.

Late Presentation of COVID-19 Patients

During this study period, the New York Department of Health found 962 deaths at home were from confirmed or suspected COVID-19 accounting for 9.3% of total COVID-19 deaths in New York City.[14] Given these sobering statistics, our analysis of hospitalized patients may underestimate illness severity on presentation and raising concern

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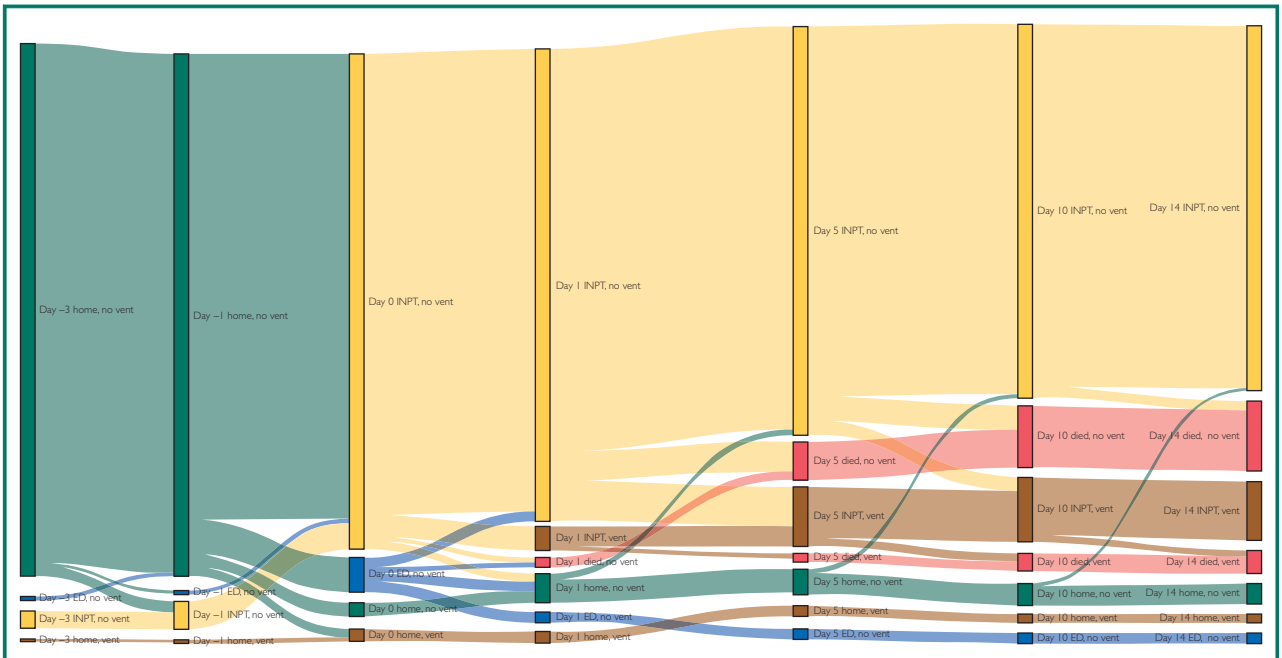

FIGURE 3. Sankey diagram represents patient flow from 3 days before severe acute respiratory coronavirus 2 diagnosis to 14 days after. All unique patient visits to the emergency department (ED) and inpatient (INPT) were included. On any given day, the patient's location (home in green, ED in blue, INPT in yellow), if they were currently on a ventilator (No Vent or Vent), and if they were deceased (Died in red) were assessed. An interactive version of this diagram can be found at https://pelias1525.github.io/COVID_1200.html.

that some patients may be seeking or receiving medical attention too late in their disease course. In the Wuhan experience, the median time of symptom onset to dyspnea was 5 days, symptom onset to hospital admission 7 days, and symptom onset to acute respiratory distress syndrome 8 days.[15] A study including 655 of our patients found a median of 5 days of symptoms before presentation to the ED.[16]

Once respiratory symptoms develop in COVID-19, rapid clinical decline appears to be common. In addition to disease-specific factors, there are patient and medical system features that likely contribute to critical illness of presentation. The news media has highlighted hospital overcrowding and the importance of social distancing, which may make patients more likely to wait before contacting the medical system. When patients call their physicians with possible COVID-19–related symptoms, they are often encouraged to avoid medical attention due to concerns about either disseminating the virus or receiving a nosocomial infection. Considering more intubations occurred within the first 24 hours than any other day, patients who had respiratory symptoms for many days may have benefited from earlier assessment. It remains unclear if earlier presentation would have changed clinical outcome.

The American College of Emergency Physicians among others has noted lack of evidence as the key hurdle to devising criteria for safe triage from the ED.[17] Among those patients planned for admission, it remains a challenge to determine who is likely to decompensate requiring intensive care in the following days. Our study found that among a cohort of COVID-19 patients slated for admission, normal respiratory vitals and no evidence of atrial fibrillation/flutter, right ventricular overload, or ST segment deviation meant there was a less than 5% chance of poor outcome in the next 48 hours. Considering this population only included patients who were sick enough for

admission, we believe these criteria can quickly and effectively determine who is safe for lower-acuity settings.

Study Limitations

As a retrospective analysis during an ongoing pandemic, this study has multiple limitations. First, at the time of data abstraction many patients remained hospitalized with their final outcomes unclear. To ensure equal exposure time, outcome was assessed at 48 hours and again at 14 days. It is likely that additional adverse outcomes will accumulate in these patients as their course progresses. To mitigate for this, we reassessed mortality 2 weeks past censoring at 30 days. Second, data were abstracted from the medical records, and it is probable that comorbidities were incompletely characterized. Third, this analysis begins at the time of presentation to the hospital. The timing of symptom onset was only captured in approximately half of these patients. Lastly, our institution only tested patients who were planned to be admitted, so this cohort does not reflect all patients presenting to the hospital with symptoms concerning for COVID-19.

CONCLUSION

Among 1258 patients with COVID-19, 247 (19.6%) met the primary outcome of mechanical ventilation or death 48 hours after diagnosis. Mortality increased to 231 (18.4%) patients at 48 hours and 277 (22.0%) patients when reassessed at 30 days. The combination of abnormal respiratory vital signs and ECG with presence of atrial fibrillation/flutter, right ventricular overload, or ST segment abnormality at presentation is easily obtained, highly prognostic of 48-hour outcome, and should form the basis of early triage for in-hospital level of care. More patients are intubated in the first 24 hours from presentation than any other day, indicating need for rapid triage and raising concerns that some patients are presenting late in their disease course. Further study is needed to clarify the mechanisms of cardiovascular involvement in COVID-19, identify ideal criteria for when patients should seek medical attention, and determine if earlier presentation would improve patient outcomes.

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SUPPLEMENTAL ONLINE MATERIAL

Supplemental material can be found online at http://www.mayoclinicproceedings.org. Supplemental material attached to journal articles has not been edited, and the authors take responsibility for the accuracy of all data.

Abbrevationsand Acronyms: **COVID-19** = coronavirus disease 2019; **ECG** = electrocardiogram; **IQR** = interquartile range; **SARS-CoV-2** = severe acute respiratory syndrome coronavirus 2

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