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# Electrocardiographic Findings in Coronavirus Disease-19: Insights on Mortality and Underlying Myocardial Processes

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## ABSTRACT

**Background:** Coronavirus disease 2019 (COVID-19) is a respiratory syndrome with high rates of mortality, and there is a need for easily obtainable markers to provide prognostic information. We sought to determine whether the electrocardiogram (ECG) on hospital presentation provides prognostic information, specifically related to death.

**Methods and Results:** We performed a retrospective cohort study in patients with COVID-19 who had an ECG at or near hospital admission. Clinical characteristics and ECG variables were manually abstracted from the electronic health record and first ECG. Our primary outcome was death.

**There were:** 756 patients who presented to a large New York City teaching hospital with COVID-19 who underwent an ECG. The mean age was  $63.3 \pm 16$  years, 37% were women, 61% of patients were nonwhite, and 57% had hypertension; 90 (11.9%) died. In a multivariable logistic regression that included age, ECG, and clinical characteristics, the presence of one or more atrial premature contractions (odds ratio [OR] 2.57, 95% confidence interval [CI] 1.23–5.36,  $P = .01$ ), a right bundle branch block or intraventricular block (OR 2.61, 95% CI 1.32–5.18,  $P = .002$ ), ischemic T-wave inversion (OR 3.49, 95% CI 1.56–7.80,  $P = .002$ ), and nonspecific repolarization (OR 2.31, 95% CI 1.27–4.21,  $P = .006$ ) increased the odds of death. ST elevation was rare ( $n = 5$  [0.7%]).

**Conclusions:** We found that patients with ECG findings of both left-sided heart disease (atrial premature contractions, intraventricular block, repolarization abnormalities) and right-sided disease (right bundle branch block) have higher odds of death. ST elevation at presentation was rare. (*J Cardiac Fail* 2020;26:626–632)

**Keywords:** COVID-19, electrocardiography, myocardial injury, mortality.

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is a highly infectious virus that causes coronavirus disease (COVID-19), a respiratory syndrome associated with high rates of critical illness and mortality.<sup>1,2</sup> As a consequence, there is a need to identify prognostic markers that can aid clinicians in the rapid triage of patients, guide clinical decision making, and inform patients and their families about the anticipated disease trajectory. Electrocardiography (ECG) is a broadly available diagnostic test that can be quickly performed

without exposing a large number of personnel to SARS-CoV2. ECG has demonstrated incremental prognostic value in population-based studies and in patients with a variety of underlying cardiovascular conditions, including hypertension,<sup>3–7</sup> and thus offers a particularly appealing modality during the current pandemic. We thus sought to determine whether findings on the first presenting ECG provide prognostic information, specifically related to death, and subsequently provide insights on myocardial processes underlying a poor prognosis.

## Methods

### Study Population and Setting

Our retrospective observational cohort study included patients with confirmed COVID-19 who presented to Weill Cornell Medicine/New York-Presbyterian Hospital, a quaternary referral center and 862-bed teaching hospital, from March 3, 2020, through April 9, 2020. All cases of COVID-19 were confirmed by real-time reverse-transcriptase polymerase chain reaction on nasopharyngeal swabs. We included consecutive patients who presented directly to our hospital and underwent an ECG at or near their

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initial presentation to the hospital. We excluded patients who had complete ventricular pacing, because these ECGs were otherwise nondiagnostic. Using a standardized protocol and REDCap tool,<sup>8</sup> patient data were manually abstracted from the electronic health record using methods that have been previously described.<sup>1</sup> These data were used to develop a COVID-19 registry database.

### Primary Independent Variable: ECG

ECGs were personally reviewed and interpreted by 2 electrocardiographers (S.A.M. and P.O., together responsible for the interpretation of >100,000 ECGs per year) who were blinded to the clinical status of the patients. Any disagreement in interpretation between readers was resolved by consensus. No formal testing of between- or within-reader variability of interpretation was performed for this study. Data extracted from each ECG included heart rate, rhythm categorized as normal sinus rhythm or atrial fibrillation/flutter, the presence of atrial premature contractions (APCs), ventricular premature contractions, atrioventricular block, axis deviation, right bundle branch block (RBBB), left bundle branch block, a nonspecific intraventricular conduction block (IVB) (QRS duration of >110 ms), presence of left or right ventricular hypertrophy, an age indeterminate myocardial infarction, the presence of ST segment or T-wave changes (localized ST elevation, localized T-wave inversion, or other nonspecific repolarization abnormalities), and the Bazett-corrected QT interval (in milliseconds).

### Outcomes

The primary outcome was death occurring through April 23, 2020, ensuring at least 2 weeks of outcome data for all included patients. We ascertained death based on review of discharge summaries and death notes in the electronic health record.

### Covariates

Demographics (age, sex, and race) and preexisting comorbid conditions (smoking status, history of immunosuppression,

diabetes mellitus, hypertension, chronic obstructive pulmonary disease, end-stage renal disease, coronary artery disease [CAD], chronic heart failure, stroke, and active cancer) were abstracted from the electronic health record. Additionally, the clinical decision to start supplemental oxygen therapy owing to hypoxemia within 3 hours of presentation was abstracted from the respiratory flowsheets.

### Statistical Analysis

Statistical analysis was performed using SPSS version 25 software (IBM, Inc., Armonk, NY). Data are presented as mean  $\pm$  standard deviation for continuous variables and proportions for categorical variables. The relationship between clinical and ECG characteristics and death was examined using univariate and multivariable logistic regression analyses. Statistically significant univariate predictors of death were entered into forward selection multivariable models with a *P* value of .05 or less required for entry: an age and ECG variables model; age and clinical variables model; and finally, a model incorporating age, clinical, and ECG variables.

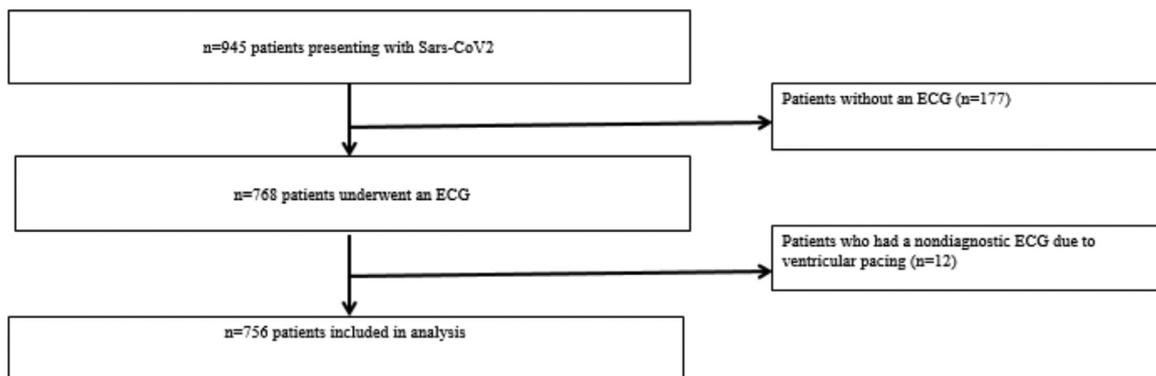
### Oversight

This study was approved by the Weill Cornell Medicine Institutional Review Board, which waived informed consent.

## Results

### Patient Characteristics

From March 3, 2020, through April 9, 2020, 945 patients presented to our hospital and were confirmed by PCR to have SARS-CoV-2. Of these patients, 768 underwent an ECG at or near the time of their admission; 12 patients were excluded from analysis for complete ventricular pacing (Fig. 1). Among the remaining 756 patients, the median time between presentation to the ED and initial ECG was less than 1 day and 94.3% had their ECG within 1 day of presentation. Clinical characteristics of the population are shown in Table 1. The mean age was  $63.3 \pm 16$  years, 37% were women, 61% of patients were nonwhite, 37% had



**Figure 1.** Patients presenting with coronavirus disease-19 from March 3, 2020, to April 9, 2020.

**Table 1.** Baseline Clinical Characteristics of 756 Patients Hospitalized With Coronavirus Disease-19 With 12-Lead Electrocardiograms, Overall and by Survival Status

Variable	All (N = 756)	Survived (n = 666)	Died (n = 90)	P Value
Age (years)				<.001
Mean ± SD	63.3 ± 16.0	61.1 ± 15.3	79.3 ± 11.8	
Median	64.0	62.0	79.6	
Interquartile range	51.9–74.6	50.6–72.2	72.2–88.4	
Female sex	278 (36.8%)	248 (37.2%)	30 (33.3%)	.546
Race				<.001
White	296 (39.2%)	243 (36.5%)	53 (58.9%)	
Black	89 (11.8%)	83 (12.5%)	6 (6.7%)	
Asian	56 (7.4%)	47 (7.1%)	9 (10.0%)	
Other	162 (21.4%)	154 (23.1%)	8 (8.9%)	
Not specified	153 (20.2%)	139 (20.9%)	14 (15.6%)	
Smoker				.001
Never smoker	554 (73.3%)	499 (74.9%)	55 (61.1%)	
Active smoker	29 (3.8%)	28 (4.2%)	1 (1.1%)	
Former smoker	173 (22.9%)	139 (20.9%)	34 (37.7%)	
Obesity (n = 716)	267 (37.3%)	241 (38.3%)	26 (30.2%)	.185
Coronary artery disease	109 (14.4%)	80 (12.0%)	29 (32.2%)	<.001
Heart failure	55 (7.3%)	39 (5.9%)	16 (17.8%)	<.001
Stroke	55 (7.3%)	38 (5.7%)	17 (18.9%)	<.001
Diabetes	222 (29.4%)	194 (29.1%)	28 (31.1%)	.792
Hypertension	427 (56.5%)	360 (54.1%)	67 (74.4%)	<.001
Pulmonary disease	142 (18.8%)	116 (17.4%)	26 (28.9%)	.013
Home oxygen use	155 (20.5%)	135 (20.3%)	20 (22.2%)	.771
Renal disease	72 (9.5%)	58 (8.7%)	14 (15.6%)	.059
Rheumatic disease	46 (6.1%)	41 (6.2%)	5 (5.6%)	1.000
Active cancer	42 (5.6%)	29 (4.4%)	13 (14.4%)	<.001
Immunosuppressed	25 (3.3%)	15 (2.3%)	10 (11.1%)	<.001
Hypoxemia within 3 hours	414 (54.8%)	343 (51.5%)	71 (78.9%)	<.001
Home medication number > median (4)	323 (42.7%)	264 (39.6%)	59 (66.3%)	<.001

SD, standard deviation.

Hypoxemia within 3 hours defined by need for supplemental oxygen. Obesity if body mass index >30 kg/m<sup>2</sup> or ≥27.5 kg/m<sup>2</sup> in Asians.

obesity, and 29% had diabetes mellitus. Cardiovascular conditions were common: 57% had hypertension, 14% had CAD, 7% had heart failure, and 7% had a prior stroke. More than one-half (55%) required supplemental oxygen within the first 3 hours of presentation.

### Electrocardiographic Findings

Baseline electrocardiographic characteristics (Table 2) included a mean heart rate of 90 ± 19 bpm and mean Bazett-corrected QT interval of 449 ± 144 ms. The overwhelming majority were in normal sinus rhythm (94.4%); 5.6% of patients had atrial fibrillation/flutter. Atrioventricular block was rare (2.6%): 19 patients (2.5%) had a first-degree block and 1 patient (0.1%) was in sinus rhythm with complete heart block and a junctional escape rhythm. APCs occurred in 7.7% and ventricular premature contractions in 3.4%. A significant proportion (19.3%) had an abnormal axis—13.8% had left axis deviation and 5.5% had a right or right superior axis deviation. Abnormal intraventricular conduction was found in 11.8%, with RBBB in 7.8%, left bundle branch block in 1.5%, and nonspecific IVB in 2.5%. Left ventricular hypertrophy (15.5%) was more common than right ventricular hypertrophy (4.0%) and evidence of a previous Q-wave myocardial infarction was present in 13.9%.

Repolarization abnormalities were common (40.2%): 0.7% had localized ST elevation, 10.5% localized T-wave inversion, and 29.0% had nonspecific repolarization abnormalities (Table 2).

### Relationship of Clinical and Electrocardiographic Characteristics to Mortality

A total of 90 patients (11.9%) died during the follow-up period. The relationship of clinical and ECG variables to all-cause mortality is shown in Tables 3 and 4. In univariate logistic regression analyses, clinical predictors of death included age, race, prior smoking, existing renal or pulmonary disease, active cancer, being immunosuppressed, and greater number of home medications, but did not include sex, obesity, diabetes, home oxygen, use or a history of rheumatic disease. Additionally, cardiovascular comorbidities (CAD, chronic heart failure, hypertension, or prior stroke) were all strong univariate predictors of death. Hypoxemia requiring supplemental oxygen within 3 hours of presentation was also strongly associated with death (OR 3.52, 95% CI 2.07–5.97, *P* < .001). Notable univariate ECG predictors of death were APCs (OR 3.92, 95% CI 2.13–7.18, *P* < .001), an abnormal axis (OR 3.37, 95% CI 2.11–5.38, *P* < .001), a RBBB or IVB (OR 5.17, 95% CI 3.03–8.81, *P* < .001),

**Table 2.** Baseline Electrocardiographic Characteristics of 756 Patients Hospitalized With Coronavirus Disease-19 With 12-Lead Electrocardiograms, Overall and by Survival Status

Variable	All (n = 756)	Survived (n = 666)	Died (n = 90)	P Value
Heart rate (bpm)	90 ± 19	90 ± 18	89 ± 24	.553
Bazett-corrected QT interval (ms)	449 ± 144	448 ± 153	459 ± 42	.506
Atrial fibrillation or flutter	42 (5.6%)	32 (4.8%)	10 (11.1%)	.027
Atrial premature contractions	58 (7.7%)	40 (6.0%)	18 (20.0%)	<.001
Ventricular premature contractions	26 (3.4%)	20 (3.0%)	6 (6.7%)	.138
Atrioventricular block				.025
None	736 (97.4%)	652 (97.9%)	84 (93.3%)	
First degree	19 (2.5%)	14 (2.1%)	5 (5.6%)	
Third degree	1 (0.1%)	0 (0%)	1 (1.1%)	
Abnormal axis	146 (19.3%)	110 (16.5%)	36 (40.0%)	<.001
Intraventricular conduction block				<.001
None	667 (88.2%)	605 (90.8%)	62 (68.9%)	
Right bundle branch block	59 (7.8%)	40 (6.0%)	19 (21.1%)	
Left bundle branch block	11 (1.5%)	10 (1.5%)	1 (1.1%)	
Nonspecific intraventricular block	19 (2.5%)	11 (1.7%)	8 (8.9%)	
Left ventricular hypertrophy	117 (15.5%)	95 (14.3%)	22 (24.4%)	.019
Right ventricular hypertrophy	30 (4.0%)	22 (3.3%)	8 (8.9%)	.024
Myocardial infarction age undetermined	105 (13.9%)	82 (12.3%)	23 (25.6%)	.001
Localized ST elevation (injury)	5 (0.7%)	4 (0.6%)	1 (1.1%)	1.000
Localized T-wave inversion (ischemia)	80 (10.5%)	61 (9.2%)	19 (21.1%)	.001
Nonspecific repolarization abnormality	219 (29.0%)	182 (27.3%)	37 (41.1%)	.010

Hypoxemia within 3 hours defined by need for supplemental oxygen. Obesity if body mass index  $\geq 30$  kg/m<sup>2</sup> or  $\geq 27.5$  kg/m<sup>2</sup> in Asians.

localized T-wave inversion (OR 2.65, 95% CI 1.50–4.70,  $P < .001$ ), and nonspecific repolarization abnormality (OR 1.86, 95% CI 1.18–2.92,  $P = .007$ ). Additional ECG findings associated with mortality were left and right ventricular hypertrophy and previous Q-wave myocardial infarction, but not heart rate or Bazett-corrected QT interval. Notably, localized ST elevation on presentation was a rare event ( $n = 5$ ) limiting any precise estimate of its association with death in our cohort.

In a forward-selection multivariable logistic regression analysis that included age and statistically significant univariate clinical predictors of mortality from Table 3, we found that CAD, stroke, pulmonary disease, immunosuppressed status, and hypoxemia within 3 hours of arrival increased the odds of death. In a model including age and electrocardiographic variables, APCs, RBBB or IVB, localized T-wave inversion, and nonspecific repolarization abnormality increased the odds of death. Finally, in a multivariable model incorporating age, clinical characteristics, and ECG variables, CAD, an immunosuppressed state, and hypoxemia were the clinical characteristics that remained associated with death. ECG variables that increased the odds of death remained APCs (OR 2.57, 95% CI 1.23–5.36,  $P = .01$ ), a RBBB or IVB (OR 2.61, 95% CI 1.32–5.18,  $P = .002$ ), localized T-wave inversion (OR 3.49, 95% CI 1.56–7.80,  $P = .002$ ), and nonspecific repolarization abnormality (OR 2.31, 95% CI 1.27–4.21,  $P = .006$ , Table 4).

## Discussion

This analysis of more than 750 patients with ECGs is the largest study of noninvasive diagnostic testing in

patients with confirmed COVID-19 to date. Our findings revealed that APCs, RBBB/IVB, localized T-wave inversion, and nonspecific repolarization abnormalities were associated with an increased odds of death after accounting for age and other important clinical characteristics. ST segment elevation, previously described as an important complication of this disease,<sup>9</sup> was rare on presentation. Our findings underscore the potential for ECGs to serve as a valuable tool to inform prognosis, even before many patients develop respiratory failure requiring invasive mechanical ventilation; and provide insights on myocardial processes at play.

APCs occurred in 7.7% of patients, and were associated with a 2.57-fold increased odds of death. Historically, the presence of APCs have correlated with increased left ventricular filling pressures, especially after acute myocardial infarction. Whether the presence of APCs in this clinical scenario is indicative of elevated filling pressures and/or increased myocardial stiffness is not known.<sup>10–12</sup> However, cytokine hypersecretion, a common finding in COVID-19, has also been linked to transient cardiac systolic and diastolic dysfunction.<sup>13</sup> Additionally, our observation of T-wave inversions on ECG and the presence of CAD as risk factors for death, coupled with recent data showing that troponin elevations are common,<sup>14,15</sup> suggest a potential role for subendocardial ischemia as well. Future studies examining the complex interplay between SARS-CoV-2 infection and cardiovascular perturbations like elevated filling pressures, left ventricular stiffness, and myocardial ischemia represent an important and fruitful area for future investigation.

**Table 3.** Univariate Logistic Regression Prediction of Mortality in 756 Patients Hospitalized With COVID-19 With 12-Lead Electrocardiograms

Variable	$\chi^2$	P value	Odds Ratio	95% CI
<b>Clinical characteristics</b>				
Age (per 10 years)	81.7	<.001	2.83	2.24–3.47
Male sex	0.5	.471	1.19	0.75–1.89
Race (relative to white)	20.1	<.001		
Black	6.0	.014	0.33	0.14–0.80
Asian	0.1	.741	0.88	0.41–1.90
Other	13.3	<.001	0.24	0.11–0.52
Not specified	5.9	.015	0.46	0.25–0.86
Smoker	13.5	.001		
Active	1.2	.281	0.33	0.04–2.47
Former	11.6	.001	2.26	1.42–3.61
Obesity ( <i>n</i> = 716)	2.1	.151	0.70	0.43–1.14
Coronary artery disease	23.9	<.001	3.48	2.11–5.74
Heart failure	15.0	<.001	3.48	1.85–6.53
Stroke	18.1	<.001	3.85	2.07–7.16
Diabetes	0.2	.698	1.10	0.68–1.77
Hypertension	12.8	<.001	2.48	1.51–4.07
Pulmonary disease	6.7	.010	1.93	1.17–3.17
Home oxygen use	0.2	.667	1.12	0.66–1.91
Renal disease	4.2	.041	1.93	1.03–3.63
Rheumatic disease	0.1	.823	0.90	0.35–2.23
Active cancer	13.6	<.001	3.71	1.85–7.44
Immunosuppressed	15.8	<.001	5.43	2.36–12.48
Hypoxia within 3 hours	21.8	<.001	3.52	2.07–5.97
Home medication number > median (4)	21.3	<.001	3.00	1.88–4.77
<b>Electrocardiographic characteristics</b>				
Heart rate (bpm)	0.5	.464	1.00	0.98–1.01
Bazett-corrected QT interval (ms)	0.4	.533	1.00	0.99–1.01
Atrial fibrillation or flutter	5.7	.017	2.48	1.17–5.23
Atrial premature contractions	19.4	<.001	3.92	2.13–7.18
Ventricular premature contractions	3.0	.081	2.31	0.90–5.91
Atrioventricular block (any)	2.6	.161	2.77	0.97–7.90
Abnormal axis	25.8	<.001	3.37	2.11–5.38
RBBB or IVB	36.4	<.001	5.17	3.03–8.81
Left ventricular hypertrophy	6.1	.013	1.95	1.15–3.30
Right ventricular hypertrophy	6.0	.014	2.86	1.23–6.62
Myocardial infarction age undetermined	11.1	.001	2.45	1.44–4.14
Localized ST elevation (injury)	0.3	.581	1.86	0.21–16.82
Localized T-wave inversion (ischemia)	11.2	.001	2.65	1.50–4.70
Nonspecific repolarization abnormality	7.2	.007	1.86	1.18–2.92

CI, confidence interval; IVB, intraventricular conduction block; RBBB, right bundle branch block.

Hypoxemia within 3 hours defined by need for supplemental oxygen. Obesity if body mass index  $\geq 30$  kg/m<sup>2</sup> or  $\geq 27.5$  kg/m<sup>2</sup> in Asians

Nonspecific repolarization abnormalities were also associated with death, an observation that has been made in the general population.<sup>5</sup> However, the striking aspect of our observation is that it predicted death in a very short time

**Table 4.** Multivariable Logistic Regression Prediction of Mortality in 756 Patients Hospitalized With Coronavirus Disease-19 With 12-Lead Electrocardiograms

Variable	$\chi^2$	P value	Odds Ratio	95% CI
<b>Age + Clinical variables (model <math>\chi^2 = 170.7</math>, <i>P</i> &lt; .001)</b>				
Age (per 10 years)	66.8	<.001	2.89	2.24–3.72
Coronary artery disease	7.4	.007	2.27	1.26–4.10
Stroke	3.8	.051	2.04	1.00–4.19
Pulmonary disease	4.8	.029	1.96	1.07–3.58
Immunosuppressed	8.5	.004	4.77	1.67–13.64
Hypoxia within 3 hours	18.1	<.001	3.71	2.03–6.78
<b>Age + Electrocardiographic variables (model <math>\chi^2 = 158.9</math>, <i>P</i> &lt; .001)</b>				
Age (per 10 years)	65.8	<.001	2.72	2.15–3.44
Atrial premature contractions	6.9	.009	2.58	1.27–5.21
RBBB or IVB	8.9	.003	2.66	1.40–5.04
Localized T-wave inversion (ischemia)	13.4	<.001	4.12	1.93–8.79
Nonspecific repolarization abnormality	12.2	<.001	2.76	1.56–4.89
<b>Age + clinical + electrocardiographic variables (model <math>\chi^2 = 189.1</math>, <i>P</i> &lt; .001)</b>				
Age (per 10 years)	55.2	<.001	2.72	2.11–3.51
Coronary artery disease	6.5	.011	2.26	1.21–4.23
Immunosuppressed	10.5	.001	5.79	2.00–16.80
Hypoxia within 3 hours	16.3	<.001	3.69	1.95–6.96
Atrial premature contractions	6.4	.012	2.57	1.23–5.36
RBBB or IVB	7.6	.006	2.61	1.32–5.18
Localized T-wave inversion (ischemia)	9.3	.002	3.49	1.56–7.80
Nonspecific repolarization abnormality	7.4	.006	2.31	1.27–4.21

CI, confidence interval; IVB, intraventricular conduction block; RBBB, right bundle branch block

Hypoxemia within 3 hours defined by need for supplemental oxygen. Obesity if body mass index  $\geq 30$  kg/m<sup>2</sup> or  $\geq 27.5$  kg/m<sup>2</sup> in Asians.

period—during hospitalization. Meanwhile, myocardial injury as defined by localized ST segment elevation was rare, occurring in just 5 patients, only 1 of whom died. ST elevation has been described in the setting of COVID-19<sup>9,16</sup>; however, our data suggest that this is not a common finding on hospital presentation and suggest that other findings, which may otherwise be overlooked, merit greater attention up front by clinicians caring for patients with COVID-19.

RBBB/IVB was additionally associated with death, and may reflect a higher incidence of early right ventricular (RV) dysfunction in this population. Given the high rate of respiratory failure in a significant proportion of infected individuals, cardiac dysfunction secondary to increased afterload on the right ventricle (referred to as acute cor pulmonale) is not unexpected. Although ECG findings are insensitive for the detection of acute cor pulmonale,<sup>17</sup> RBBB has been attributed to acute RV overload and distention in multiple studies of acute pulmonary embolism, with a higher frequency noted in cases with larger clot burdens.<sup>18</sup> In a recent study, RV dysfunction was associated with a higher risk of

mortality in patients with COVID-19, independent of all other echocardiographic parameters.<sup>19</sup> To our knowledge, the present study is the first to show that RBBB at the time of presentation, often before the development of acute respiratory failure, is associated with worse survival. Importantly, the mechanisms of pulmonary vascular disease in COVID-19 are incompletely understood and may include early vascular endothelial injury, microcirculatory thrombi, and pulmonary venous thromboembolism.<sup>20</sup> Therefore, the ECG may provide early evidence for an “RV at risk,” even before the onset of severe hypoxemia, pulmonary vasoconstriction, and overt clinical deterioration.

Our study has several strengths. First, clinical data and outcomes were manually abstracted from the electronic health record using a process that has previously shown high reliability.<sup>1</sup> Comorbid conditions manually abstracted from different sections of a medical chart (and often include data from free-text sections of the chart) may be more comprehensive than automated data abstractions from the electronic health record which rely on structured fields and/or billing codes. Second, all ECGs were interpreted by experienced electrocardiographers, which has several advantages, including improved accuracy over automated interpretation.<sup>21</sup> Our study also has several limitations. First, because the course of this disease is ongoing in our institution, data on death for all patients are inherently incomplete, which may bias the results. Of note, all patients had at least 2 weeks of outcome data. Additionally, we had incomplete laboratory data for the majority of patients included in our study. Markers of myocardial injury (namely, troponin and B-type natriuretic peptide) were obtained clinically at the discretion of the clinician caring for the patient, and often well after the initial presentation to the hospital, which is when these ECGs were obtained. Owing to concerns about confounding by indication, we did not include laboratory data in this analysis. Additionally, given that we did not have prior ECGs in all patients, we did not compare the presentation ECG with prior ECGs for the presence of new findings, and this factor should be studied further. We did not formally assess the reliability of the 2 ECG readers. However, these readers review more than 100,000 ECGs per year at this institution and have historically been concordant in their interpretation. Finally, given the large number of variables analyzed, it is possible that some of the associations reported occurred by chance. However, our findings are consistent with emerging data that myocardial processes are an important prognostic indicator in COVID-19.<sup>14,15,19</sup>

In conclusion, our data show that the ECG may be a useful prognostic tool in COVID-19, even among patients who are yet to require invasive mechanical ventilation. Our findings highlight that patients with ECG findings of both left sided heart disease (APCs, IVB, repolarization abnormalities) and right-sided disease (RBBB) have a higher odds of death. Localized ST segment elevation at presentation was rare.

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### Supplementary materials

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