Risk factors and electrocardiogram characteristics for mortality of critical inpatients with COVID-19

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Research article

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Abstract

Background

The novel severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) has subsequently spread worldwide. The number of death has increased rapidly. However, the possible risk factors that lead to death in critical inpatients with coronavirus disease 2019 (COVID-19) are not yet fully known. This study was to explore the risk factors for mortality of critical inpatients with COVID-19.

Methods

In this single-centered, retrospective study, we enrolled 113 critical patients with COVID-19 in Renmin Hospital of Wuhan University between Feb 1, 2020 and Mar 15, 2020. Data were collected using a standard method including clinical records and laboratory findings. Outcomes of survivors and death were compared.

Results

A total of 113 critical patients (from 29 to 95 years) with COVID-19 were recruited, 50 (44.25%) died and 63 recovered (55.75%). The proportion of patients with ventricular arrhythmia was higher in the death group than the recovery group (24.0% vs 4.4%; $p = 0.021$), and was higher among myocardial damage cases than non-myocardial damage cases (26.1% vs 4.3%; $p = 0.013$). Multivariate analysis confirmed four independent predictors related to mortality of COVID-19: age > 70 yrs (HR 1.84, 95% CI 1.03–3.28), initial neutrophil count more than $6.5 \times 10^9/L$ (HR 3.43, 95% CI 1.84–6.40), C-reactive protein greater more than 100 mg/L (HR 1.93, 95% CI 1.04–3.59), and lactate dehydrogenase more than 300 U/L (HR 2.90, 95% CI 1.26–6.67). Immunoglobulin treatment (HR 0.39, 95% CI 0.21–0.73) can reduce the risk of death. There was no significant difference in the QT interval between patients with and without hydroxychloroquine treatment.

Conclusions

Old age (> 70 years), neutrophilia, C-reactive protein greater more than 100 mg/L and lactate dehydrogenase more than 300 U/L are high-risk factors for mortality of critical patients with COVID-19. The incidence of ventricular arrhythmia was higher in deceased patients than survivors.

Introduction

At present, the novel severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) has outbreak and spread throughout the world. The patients' common clinical manifestations included fever, nonproductive cough, dyspnea, myalgia, fatigue, normal or decreased leukocyte counts, and radiographic evidence of

pneumonia [1]. Although most patients are thought to have a favorable prognosis, older patients and those with chronic underlying conditions may have worse outcomes. Patients with severe illness may develop dyspnea and hypoxemia within 1 week after onset of the disease, which may quickly progress to acute respiratory distress syndrome (ARDS) or multiple organ failure (MOF) [2]. Previous study has reported that the mortality was 62% among critically ill patients with coronavirus disease 2019 (COVID-19) in Wuhan [3]. However, the possible risk factors leading to poor clinical outcome have not been well delineated.

Regarding fever, hypoxemia and myocardial injury caused by COVID-19, it is relevant to highlight that this condition can easy to cause arrhythmia [4, 5]. In a cohort of patients with COVID-19, Wang observed that arrhythmias were present in 16.7% of patients [6]. However, due to the lack of strict epidemiological investigation, the occurrence and outcome of arrhythmia in patients with COVID-19 are still unclear. In the present study, we aim to investigate the risk factors and electrocardiogram (ECG) characteristics for mortality of critical inpatients with COVID-19.

Methods

Patients selection

This single-centre, retrospective, observational study was done at Renmin Hospital of Wuhan University (Wuhan, China). 113 critical inpatients with COVID-19 from Feb 1 to Mar 15, 2020 were enrolled. All patients were confirmed with COVID-19 tested positive by using RT-PCR on samples from respiratory tract. Diagnosis of COVID-19 was based on the WHO's interim guidelines [7]. All cases matched clinical classification of critical type. Critical was defined based on New coronavirus pneumonia prevention and control program in China (6th edition) [8]. This study was approved by the Institutional Ethics Committee of Renmin Hospital of Wuhan University.

Data Collection

Epidemiological, clinical, laboratory, ECG characteristics, treatment and outcomes data were obtained with data collection forms from electronic medical records. Two experienced clinicians entered data and reviewed the data. Information recorded included demographic data, medical history, symptoms, signs, chronic diseases, laboratory findings, ECG and treatment measures. The date of disease onset was defined as the day when the symptom was noticed. The criteria for the confirmed-diagnosis of SARS-CoV-2 was that at least one gene site was amplified to be positive for nucleocapsid protein (NP) gene and open reading frame (ORF) 1ab gene [9].

Outcomes

The outcome was death or discharged. Discharge standard were defined according to the guidance of New coronavirus pneumonia prevention and control program in China (6th edition) [8].

Statistical analysis

Categorical variables were expressed as number (%) and compared by Pearson Chi-square test or Fisher's Exact test. Univariate analysis was used to evaluate the demographics, and clinical factors associated with mortality of COVID-19. We used Kaplan-Meier survival analysis to estimate the patient survival fraction and the stratified log-rank test to compare the difference of survival distributions between different groups. Time to events (death) was defined as the time from illness onset to events. Two groups were created: 'death' and 'recovery' to study the relationship between high-risk factors and mortality of COVID-19 using hazard ratios (HRs) generated by the Cox proportional hazards regression model. A forward selection procedure was then used to construct an initial model. Based on the clinical experience, a final model was selected. Proportional hazards assumptions were verified systematically for proposed models. Hypothesis testing was conducted using a two-sided test, with an alpha value of 0.05 to indicate statistical significance. Forest plot was created based on multivariate Cox regression results. All analyses were done using SPSS (version 20.0) and GraphPad Prism 8.0. .

Results

Baseline characteristics

A total of 113 patients with critical COVID-19 were included in this study, 68 were male and 45 were female. The mean age was 67.3 ± 14.1 years, range from 29 to 95 years. 50 (44.3%) died and 63 recovered (55.7%) before Mar 15, 2020. Baseline characteristics of the 113 confirmed cases were shown in Tables 1. There was a significant difference among age groups (> 70 years and < 70 years) and clinical outcome (death and recovery) ($P = 0.008$). Hypertension ($p = 0.042$) and temperature greater than 39°C ($p = 0.039$) were more common in patients who died. There were no significant differences in the gender, chronic diseases (such as diabetes, cerebrovascular disease, COPD, chronic kidney disease and chronic liver disease) and first symptoms (such as fever, cough, fatigue, anorexia, myalgia, dyspnea, pharyngalgia, diarrhea, vomiting and dizziness) between death group and recovery group.

Laboratory Findings

In table 2, the following factors were associated with a high risk of death from COVID-19: white blood cell count more than $9.5 \times 10^9/\text{L}$ ($p = 0.001$), initial neutrophil count more than $6.5 \times 10^9/\text{L}$ ($p < 0.001$), initial lymphocyte count less than $0.6 \times 10^9/\text{L}$ ($P = 0.011$), C-reactive protein more than 100 mg/L ($p < 0.001$), D-dimer more than 20 mg/L ($p = 0.003$), hypersensitive troponin I more than 0.04 pg/mL ($p = 0.004$), blood urea nitrogen more than 8 mmol/L ($p = 0.011$), lactate dehydrogenase more than 300 U/L ($p < 0.001$), and lactic acid more than 3 mmol/L ($p = 0.014$). However, there were no differences in hemoglobin less than

120 g/L, platelet count less than $100 \times 10^9/L$, procalcitonin more than 0.5 ng/mL, creatine kinase-MB more than 5 ng/mL, alanine aminotransferase more than 50 U/L, aspartate aminotransferase more than 40 U/L, albumin less than 30 g/L, creatinine more than 100 $\mu\text{mol/L}$, creatine kinase more than 200 $\mu\text{mol/L}$ and B-type natriuretic peptide (BNP) more than 900 pg/mL between the death group and recovery group.

ECG Outcome And Treatment

The ECG was available for 70 patients, of whom 35.7% died, and 64.3% survived. Table 3 shows the characteristics of ECG. Ventricular arrhythmias were recorded in 8 patients. In the death group, there were 5 cases of premature ventricular contraction and 1 case of ventricular tachycardia. In the recovery group, 2 cases had premature ventricular contraction. The proportion of patients with ventricular arrhythmia was higher in the death group than the recovery group (24.0% vs 4.4%; $p = 0.021$), and was higher among myocardial damage cases than non-myocardial damage cases (26.1% vs 4.3%; $p = 0.013$). There was a significant difference of abnormal ECG between death group and recovery group ($p = 0.041$). However, there was no significant difference in ST-T abnormality between patients with and without myocardial damage. Furthermore, the other arrhythmic events, such as sinus tachycardia, atrioventricular block, and atrial arrhythmia showed no difference between death group and recovery group. There was no significant difference in the QT interval between patients with and without hydroxychloroquine treatment. Figure 1 shows an example of the initial ECG of a dead patient. The ECG shows sustained ventricular tachycardia.

Table 4 shows the proportion of patients with abidol (82.5% vs 58.0%; $p = 0.004$) and hydroxychloroquine treatment (23.8% vs 4.0%; $p = 0.003$) was higher in the recovery group than the death group. The other antiviral drugs such as lopinavir/ritonavir, ribavirin, interferon α -2b injection, ganciclovir and oseltamivir showed no difference between death group and recovery group. In addition, glucocorticoid therapy, immunoglobulin, albumin therapy, oxygen therapy, noninvasive ventilation (NIV) and invasive mechanical ventilation (IMV) were no significant difference in critical cases (between death group and recovery group).

Risk Factors Associated With Death

Kaplan-Meier survival analysis was used to analyze the patient survival function. Supplemental Figure S1 shows survival curves of patients in different ages (< 70 years and > 70 years). Elderly patients were more common in death group than in recovered group ($p = 0.009$). The survival curve of those who had initial neutrophil count $> 6.5 \times 10^9/L$ was lower than that in patients with initial neutrophil count $< 6.5 \times 10^9/L$ ($p < 0.001$) (Supplemental Figure S2). The survival curve of cases with C-reactive protein > 100 mg/L was lower than that in patients with C-reactive protein < 100 mg/L ($p < 0.001$) (Supplemental Figure S3). The survival curve of cases with lactate dehydrogenase > 300 U/L was lower than that in patients with lactate dehydrogenase < 300 U/L ($p < 0.001$) (Supplemental Figure S4). Immunoglobulin therapy were more common in recovered group than in death group ($p = 0.227$) (Supplemental Figure S5).

Cox proportional hazards regression model confirmed the independent predictors of mortality with COVID-19 as shown in Table 5. The independent mortality predictors of COVID-19 were age > 70 yrs (HR 1.84, 95% CI 1.03–3.28), initial neutrophil count more than $6.5 \times 10^9/L$ (HR 3.43, 95% CI 1.84–6.40), C-reactive protein greater more than 100 mg/L (HR 1.93, 95% CI 1.04–3.59), and lactate dehydrogenase more than 300 U/L (HR 2.90, 95% CI 1.26–6.67), which were all distributed to the right of the invalid line, as shown in Fig. 2. Immunoglobulin treatment (HR 0.39, 95% CI 0.21–0.73) can reduce the risk of death and was distributed to the left of the invalid line in the Forest plot.

Discussion

This present retrospective study identified several risk factors for the mortality with COVID-19. In particular, Old age (> 70 years), neutrophilia, C-reactive protein greater more than 100 mg/L and lactate dehydrogenase more than 300 U/L were associated with higher odds of critical in-hospital death. Our study also showed that the incidence of ventricular arrhythmia was higher in deceased patients than survivors. However, there was no difference in abnormal ST-T and QT interval between deceased patients and survivors.

In a little over three months, SARS-CoV-2 has spread worldwide and caused far greater morbidity and mortality than either SARS or MERS [10]. Previous studies have shown that older age, D-dimer greater than 1 µg/mL and greater cardiac troponin are the potential risk factors of inpatients with COVID-19 [11, 12]. The number of cases increased rapidly throughout the world, and even higher in severe type. However, the risk factors for death are not fully understood in critical cases. In the present study, we analyzed the possible risk factors of death with COVID-19. All patients' characteristics and laboratory findings were included to interpret the relationship between risk factors and death of critical COVID-19 at early stage. The risk factors related to death included older age, neutrophilia, C-reactive protein greater more than 100 mg/L and increased lactate dehydrogenase. Chen suggested that 2019nCoV is more likely to infect older adult males with chronic comorbidities as a result of the weaker immune functions of these patients [2]. We also found that the proportion of elderly patients and hypertension was higher in patients who died. Therefore, as one of independent risk factors, age related chronic diseases still plays an important role in outcome of critical cases. In addition, the results of the present study showed that patients with COVID-19 who died had significantly higher neutrophil counts than survivor cases. Considering that older age is associated with declined immune competence [13], therefore, older age related to death may be due to less robust immune responses.

Cytokine storm and viral evasion of cellular immune responses are thought to play important roles in disease severity [14]. The present findings showed that CRP greater more than 100 mg/L was significantly associated with case fatality. A significant increase in CRP levels, as documented for bacterial infections, can also occur with viral infections [15]. It is well known that CRP is a classic acute phase protein. It can be concluded that a higher CRP value may result from a more severe COVID-19. Lactate dehydrogenase more than 300 U/L is another independent high-risk factor for mortality.

Increased lactate dehydrogenase was related to heart failure or MOF which may lead to fatality of COVID-19 [16].

SARS-CoV-2 infection is associated with inflammatory mediators that may play important roles in the cardiac and arrhythmic complications [17–19]. Previous study reported that 16.7% of patients with COVID-19 had arrhythmia and 7.2% had acute heart injury [6]. However, other studies have reported that the incidence of arrhythmia in patients with COVID-19 was only 0.3%, which was relatively low [20, 21]. In our study, to the best of our knowledge, we first reported that ECG characteristics in the critical patients. We found that the incidence of arrhythmia was about 45.7% in the critical patients and the incidence of ventricular arrhythmia was high in patients with myocardial damage and in patients who died. However, we found that ventricular arrhythmia or abnormal ECG is not the independent risk factor for mortality in critical inpatients with COVID-19. Furthermore, there was no difference in QT interval between dead and survivors, and there was no significant difference in ST-T abnormality between patients with and without myocardial damage. Taken together, these results showed that critical inpatients with COVID-19 are prone to ventricular arrhythmia or abnormal ECG, which is caused by myocardial damage.

Hydroxychloroquine is known to have anti-inflammatory and antiviral effects and is used for rheumatoid arthritis and SARS [22, 23]. The side effect of hydroxychloroquine may include gastrointestinal symptoms and QT prolongation syndrome, especially in patients with renal or hepatic dysfunction [24]. However, our results showed that hydroxychloroquine treatment was not associated with higher odds of critical in-hospital survivor. Furthermore, hydroxychloroquine treatment during hospitalization was not associated with QT prolongation.

There are several limitations to this study. First, most of the patients didn't have a 24-hour Holter. Short bursts of arrhythmias may be missed. Second, few patients were given antiarrhythmic drugs, such as amiodarone and propafenone. Whether the antiarrhythmic drugs affect the occurrence of arrhythmia needs further study. Third, due to the retrospective study design and the limited patients, data from larger populations and multiple centers is warranted to further confirm the risk of mortality during hospitalization. The end, this is a retrospective and observational study and most of the patients were seriously ill at the time of admission. Very few patients had echocardiographic data and the patient's height and weight data were also missing, so we could not get the results of echocardiography and BMI.

Conclusions

Old age (> 70 years), neutrophilia, C-reactive protein greater more than 100 mg/L, and lactate dehydrogenas more than 300 U/L are high-risk factors which were related to fatality of critical patients with COVID-19. Immunoglobulin treatment can reduce the risk of death. The proportion of patients with ventricular arrhythmia was higher in the deceased patients than the survivors.

Abbreviations

SARS-CoV-2
novel severe acute respiratory syndrome coronavirus 2
COVID-19
coronavirus disease 2019
ARDS
acute respiratory distress syndrome
MOF
multiple organ failure
ECG
electrocardiogram
NP
nucleocapsid protein
ORF
gene and open reading frame
COPD
chronic obstructive pulmonary disease
BNP
B-type natriuretic peptide
NIV
noninvasive ventilation
IMV
invasive mechanical ventilation

Declarations

Availability of data and materials

The data supporting the conclusions of this article is included within the article (and its additional files). These patients have not been reported in any other submission by anyone else.

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable.

Conflict of interests

The authors declare that they have no competing interests.

Note

one case combined with first degree A-V block, complete RBBB, left anterior fascicular block and prolonged QT.

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Author contributions

LL, ZS and HB conducted the systematic literature search, analysed data and wrote the manuscript. CX and WS revised the manuscript for intellectual content. ZQ is the guarantor of this work and, as such, had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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Not Applicable

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Tables

Tables 1 Characteristics of clinical symptoms of the study population

Characteristics	No.(%)			P-value
	All cases (n=113)	Death cases (n=50)	Recovery cases (n=63)	
Sex				
male	68(60.18)	33(66.00)	35(55.56)	0.260
female	45(39.82)	17(34.00)	28(44.44)	
Age(yrs)				
>70	52(46.02)	30(60.00)	22(34.92)	0.008
Chronic diseases				
hypertension	49(43.36)	27(34.00)	22(34.92)	0.042
cardiovascular disease	23(20.35)	14(28.00)	9(14.29)	0.072
diabetes	21(18.58)	9(18.00)	12(19.05)	0.887
cerebrovascular disease	8(7.08)	5(10.00)	3(4.76)	0.463 ^a
COPD	12(10.62)	7(14.00)	5(7.94)	0.299
chronic kidney disease	6(5.31)	3(6.00)	3(4.76)	1.000 ^a
chronic liver disease	4(3.54)	2(4.00)	2(3.17)	1.000 ^a
malignancy	5(4.42)	2(4.00)	3(4.76)	1.000 ^a
First symptom				
fever	104(92.04)	47(94.00)	57(90.48)	0.729 ^a
temperature>39°C	60(53.10)	32(64.00)	28(44.44)	
cough	69(61.06)	30(60.00)	39(61.90)	0.039
fatigue	50(44.25)	25(50.00)	25(39.68)	0.837
anorexia	48(42.48)	24(48.00)	24(38.10)	0.273
myalgia	11(9.73)	5(10.00)	6(9.52)	0.290
dyspnea pharyngalgia	69(61.06)	31(62.00)	38(60.32)	1.000 ^a
diarrhea	11(9.73)	7(14.00)	4(6.35)	0.855
vomiting	18(15.93)	7(14.00)	11(17.46)	0.211 ^a
dizziness	5(4.42)	2(4.00)	3(4.76)	0.618
	8(7.08)	3(6.00)	5(7.94)	1.000 ^a
				1.000 ^a

^a Fisher's exact test.

Tables 2 Characteristics of laboratory results in patients with COVID-19

Characteristics	No.(%)			P-value
	All cases (n=113)	Death cases (n=50)	Recovery cases (n=63)	
White blood cell count>9.5×10 ⁹ /L	22(19.47)	17(34.00)	5(7.94)	0.001
Initial neutrophil count>6.5×10 ⁹ /L	38(33.63)	28(56.00)	10(15.87)	<0.001
Initial lymphocyte count<0.6 ×10 ⁹ /L	44(38.94)	26(52.00)	18(28.57)	0.011
Hemoglobin<120g/L	49(43.36)	20(40.00)	29(46.03)	0.520
Platelet count<100×10 ⁹ /L	18(15.93)	11(22.00)	7(11.11)	0.116
C-reactive protein>100mg/L	44(38.94)	31(62.00)	13(20.63)	<0.001
Procalcitonin>0.5ng/mL	21(18.58)	12(24.00)	9(14.29)	0.187
D-dimer>20mg/L Creatine kinase-MB>5ng/mL	15(13.27)	12(24.00)	3(4.76)	0.003
Hypersensitive troponin I>0.04pg/mL	15(13.27)	8(16.00)	7(11.11)	0.447
Alanine aminotransferase>50U/L	38(33.63)	24(48.00)	14(22.22)	0.004
Aspartate aminotransferase>40U/L	39(34.51)	17(34.00)	22(34.92)	0.919
Albumin<30g/L	57(50.44)	29(58.00)	28(44.44)	0.152
Blood urea nitrogen>8mmol/L	21(18.58)	12(24.00)	9(14.29)	0.187
Creatinine>100umol/L	44(38.94)	26(52.00)	18(28.57)	0.011
Creatine kinase>200U/L	20(17.70)	11(22.00)	9(14.29)	0.286
Lactate dehydrogenase>300U/L	24(21.24)	14(28.00)	10(15.87)	0.117
BNP>900pg/mL	73(64.60)	42(84.00)	31(49.21)	<0.001
Lactic acid>3mmol/L	39(34.51)	21(42.00)	18(28.57)	0.136
	34(30.09)	21(42.00)	13(20.63)	0.014

BNP ,brain natriuretic peptide

Tables 3 Characteristics of ECG outcome with the study population

Characteristics	No.(%)		P-value	No.(%)		P-value
	Myocardial damage cases (n=23)	Non-myocardial damage cases (n=47)		Death cases (n=25)	Recovery cases (n=45)	
Abnormal ECG	18(78.26)	27(57.45)	0.088	20(80.00)	25(55.56)	0.041
Abnormal ST-T	11(47.83)	16(34.04)	0.266	12(48.00)	15(33.33)	0.227
anterior ST-T changes	5(21.74)	2(4.26)		4(16.00)	3(6.67)	
inferior ST-T changes	3(13.04)	1(2.13)		2(8.00)	2(4.44)	
all lead ST-T changes	4(17.39)	6(12.77)	0.719 ^a	6(24.00)	10(22.22)	0.477 ^a
Prolonged QT	5(21.74)	4(8.51)	0.143 ^a	5(20.00)	5(11.11)	0.060 ^a
Sinus tachycardia	0(0)	3(6.38)	0.546 ^a	6(24.00)	3(6.67)	0.548 ^a
Sinus bradycardia	3(13.04)	2(4.26)	0.322 ^a	0(0)	3(6.67)	0.341 ^a
Atrioventricular block	1(4.35)	2(4.26)		2(8.00)	2(4.44)	
RBBB	2(8.70)	0(0)		2(8.00)	1(2.22)	
LBBB	2(8.70)	0(0)		1(4.00)	1(2.22)	
first degree A-V block	3(13.04)	2(4.26)	0.322 ^a	3(12.00)	2(4.44)	0.341 ^a
Pathological Q wave	5(21.74)	2(4.26)	0.035 ^a	3(12.00)	4(8.89)	0.694 ^a
Atrial arrhythmia	2(8.70)	1(2.13)		1(4.00)	2(4.44)	
atrial premature beat	1(4.35)	0(0)	0.013 ^a	1(4.00)	0(0)	0.021 ^a
atrial tachycardia						
atrial fibrillation						
Ventricular arrhythmia						
PVC						
ventricular tachycardia						

ECG: electrocardiogram; RBBB: right bundle branch block; LBBB: left bundle branch block PVC: premature ventricular contraction

^a Fisher's exact test.

Note: one case combined with first degree A-V block, complete RBBB, left anterior fascicular block and prolonged QT.

Tables 4 Characteristics of treatment of patients with COVID-19 in two groups

Characteristics	No.(%)			P-value
	All cases (n=113)	Death cases (n=50)	Recovery cases (n=63)	
Antiviral drug				
lopinavir/ritonavir	4(3.54)	2(4.00)	2(3.17)	1.000 ^a
ribavirin	56(49.56)	23(46.00)	33(52.38)	0.500
abidol hydroxychloroquine interferon α-2b injection	81(71.68)	29(58.00)	52(82.54)	0.004
ganciclovir	17(15.04)	2(4.00)	15(23.81)	0.003
oseltamivir	21(18.58)	9(18.00)	12(19.05)	0.887
Glucocorticoid therapy	20(17.70)	11(22.00)	9(14.29)	0.286
Immunoglobulin	34(30.09)	18(36.00)	16(25.40)	0.222
Albumin therapy	70(61.95)	30(60.00)	40(63.49)	0.704
Oxygen therapy	73(64.60)	29(58.00)	44(69.84)	0.191
NIV	27(23.89)	10(20.00)	17(26.89)	0.387
IMV	53(46.90)	22(44.00)	31(49.21)	0.582
	56(49.56)	26(52.00)	30(47.62)	0.644
	4(3.54)	2(4.00)	2(3.17)	1.000 ^a

NIV, noninvasive ventilation; IMV, invasive mechanical ventilation;

^a Fisher's exact test.

Tables 5 Cox proportional hazards regression model of risk factors for COVID-19

Characteristics	coefficient	Standard error (coefficient)	wald	P-value	HR(95%CI)
Age>70yrs	0.608	0.295	4.246	0.039	1.84(1.03-3.28)
Initial neutrophil count>6.5×10 ⁹ /L	1.232	0.319	14.930	<0.001	3.43(1.84-6.40)
	0.656	0.318	4.272	0.039	1.93(1.04-3.59)
reactive protein>100mg/L	1.063	0.425	6.249	0.012	2.90(1.26-6.67)
Lactate dehydrogenase>300U/L	-0.935	0.320	8.568	0.003	0.39(0.21-0.73)
Immunoglobulin treatment					

HR, hazard ratio; CI, confidence interval

Figures

Figure 1

An example of the initial electrocardiographic (ECG) of a dead patient. Results show sustained ventricular tachycardia.

Figure 2

Forest plot of factors associated with mortality of critical COVID-19 by Cox regression analysis.

Supplementary Files

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- [Supplementarydata.docx](#)