

The Prevalence, Risk Factors and Outcome of Cardiac Dysfunction in Hospitalized Patients with COVID-19

Brief title: Cardiac dysfunction in Patients with COVID-19

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Authors' contribution

LZ and MX contributed to the conception and design of the study. ML and HL contributed to the acquisition of data. YL and ML contributed to the analysis and interpretation of the data. The first draft was written by YL and HL, and all authors revised the manuscript substantially. All authors read and approved the final manuscript. YL, HL and ML contributed equally and shared first authorship.

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Compliance with ethical standards**Conflicts of interest**

The authors declared no conflict of interest.

Ethical approval

The study was approved by Union hospital Tongji Medical College, Huazhong University of Science and Technology Ethics Committee (KY-2020-02.06).

Dear Editor,

Coronavirus disease 2019 (COVID-19) is an emerging outbreak caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). Although sharing considerable similarities with SARS, cardiac injury was more frequently reported in SARS-CoV-2.[1] However, the incidence and clinical significance of cardiac insufficiency in COVID-19 have not yet been well described. The purpose of our study was to pursue the prevalence, risk factors and outcome of cardiac dysfunction in hospitalized patients with COVID-19.

We included 157 consecutive adult patients who were diagnosed with COVID-19. Clinical data were obtained from electronic medical records. Left ventricular (LV) and right ventricular (RV) structure and function were evaluated using bedside transthoracic echocardiography. Heart failure (HF) was classified into heart failure with preserved ejection fraction (HFpEF) and heart failure with reduced ejection fraction (HFrEF). The definitions of HF and RV dysfunction were based on the American Heart Association Guidelines.[2-3]

RV dysfunction was found in 40 (25.5%) unselected patients, 26(28.9%) patients requiring high flow oxygen and 15(41.7%) patients requiring mechanical ventilation. HF was presented in 28 (17.8%) unselected patients consisting of 24 (15.3%) with HFpEF and 4 (2.5%) HFrEF, 22 (24.4%) patients requiring high flow oxygen and 11(30.6%) patients requiring mechanical ventilation. 9 (5.7%) patients had biventricular dysfunction. Clinical and echocardiographic characteristics of patients with COVID-19 are shown in supplementary tables 1 and 2.

Compared with patients without cardiac insufficiency, those with cardiac insufficiency had more comorbidities and complications as well as poorer prognosis. A multivariate logistic regression analysis revealed that acute respiratory distress syndrome (ARDS) was independently predictive of cardiac dysfunction(Supplementary Table

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3), which contributed to higher mortality (Fig. 1A). Moreover, LV and RV dysfunction were more frequent in patients with elevated high-sensitivity troponin I (hs-TNI) than those without (Fig. 1B). During hospitalization, 23 patients died. The incidence of LV and RV dysfunction were higher in non-survivors than survivors (Fig. 1C). The mortality was 3.0% for patients without cardiac dysfunction and normal hs-TNI levels, 6.7% for those with cardiac dysfunction and normal hs-TNI levels, 13.3% for those without cardiac dysfunction but elevated hs-TNI levels, and 64.0% for those with cardiac dysfunction and elevated hs-TNI (Fig. 1D-E). In multivariate Cox analysis, hs-TNI elevation, mechanical ventilation and RV dysfunction were independent predictors of higher mortality (Supplementary Table 4).

Our study demonstrated that the prevalence of RV dysfunction was higher than that of LV dysfunction in patients with COVID-19. Direct viral damage, aggravation of a systemic inflammatory response, and hypoxemia may all contribute to cardiac injury. Furthermore, RV function can be worsened by increased afterload, which are likely involve ARDS, hypoxic pulmonary vasoconstriction, microthrombi within the pulmonary vasculature and microvascular injury.[4-5] Additionally, our findings revealed that mortality was highest in patients with increased troponin associated with RV dysfunction. Elevations of cardiac troponin and RV dysfunction were independently predictive of higher mortality, highlighting the significance of closely monitoring the changes of cardiac troponin and RV function. In summary, elevated cardiac troponin together with RV dysfunction may be crucial for risk stratification of COVID-19 patients and should be taken into consideration when applying prevention and therapy.

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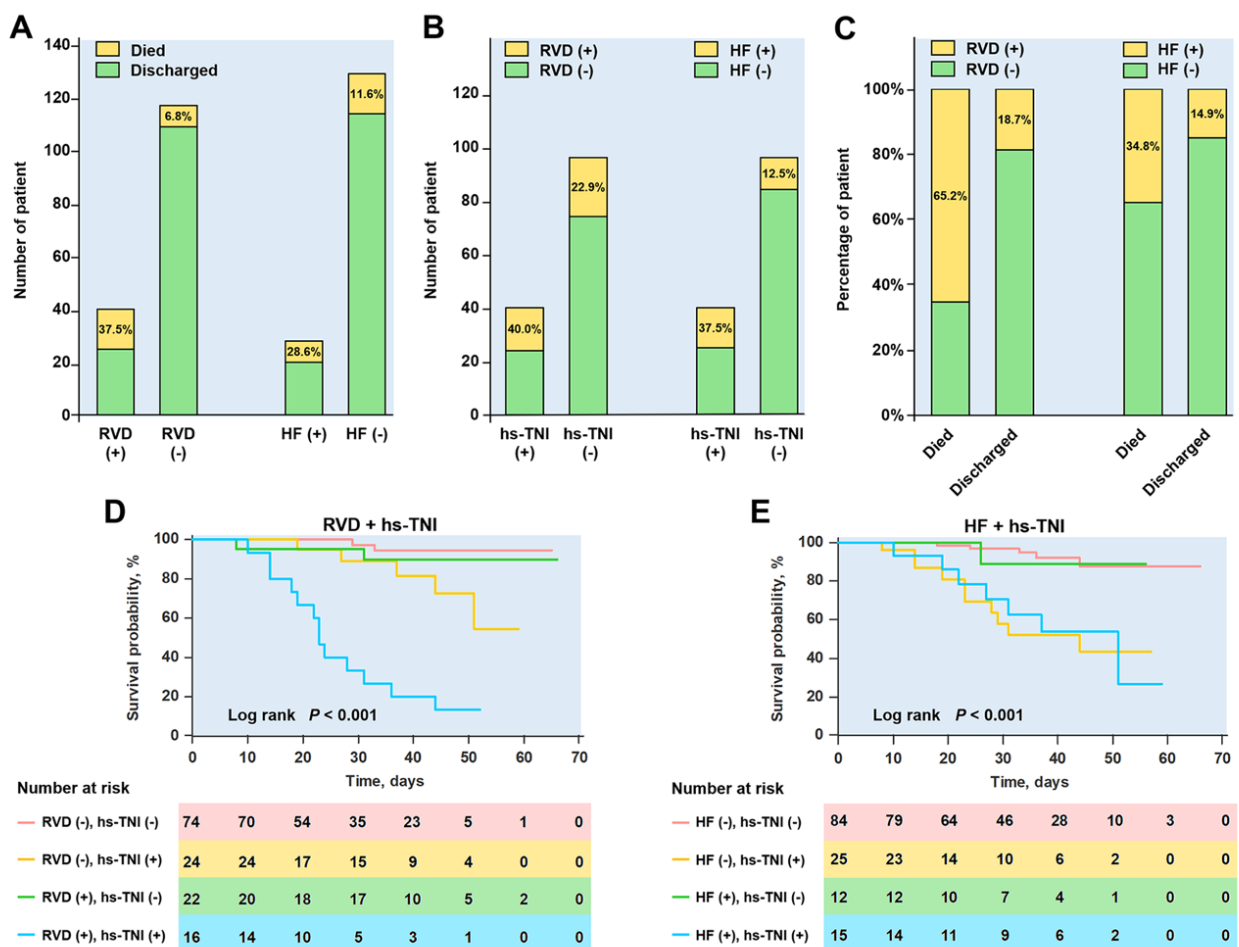
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Figure Legends

Fig. 1. A, Bar graphs illustrate the mortality of patients with/without right ventricular dysfunction(RVD) and patients with/without heart failure (HF). B, Bar graphs show the prevalence of RVD and HF in patients with/without elevated high-sensitivity troponin I (hs-TNI). C, Bar graphs demonstrate the incidence of RVD and HF in non-survivors and survivors. D, Kaplan-Meier curves in COVID-19 patients with/without RVD and with/without elevated hs-TNI Levels; E, Kaplan-Meier curves in COVID-19 patients with/without HF and with/without elevated hs-TNI Levels.



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Supplementary materials

Table 1. Clinical characteristics of patients with COVID-19 according to right ventricular dysfunction and heart failure

Variables	All Patients (n =157)	Without RVD (n=117)	With RVD (n=40)	<i>P</i> Value	Without HF (n=129)	With HF (n=28)	<i>P</i> Value
Clinical characteristics							
Age, years	62.3±13.1	62.5±12.4	61.5±15.0	0.671	63(55,71)	66(58,74)	0.186
Male, n (%)	79(50.3%)	56(47.9%)	23(57.5%)	0.293	65(50.4%)	14(50.0%)	0.970
Body mass index, kg/m ²	24.1±3.1	24.3±3.1	23.6±3.1	0.177	24.0±2.7	24.7±2.7	0.286
Heart rate, beats/min	90±17	91±16	89±18	0.687	86(80,100)	91(81,96)	0.552
Respiratory rate, times/min	23(20,30)	24(20,30)	21(19,30)	0.108	23(20,30)	25(20,32)	0.281
Systolic arterial pressure, mm Hg	133±81	132±18	133±18	0.921	133±18	132±16	0.741
Diastolic arterial pressure, mm Hg	81±12	81±11	81±14	0.977	81±12	80±13	0.719
Smoker, n (%)	17(10.8%)	10(8.5%)	7(17.5%)	0.116	14(10.9%)	1(10.7%)	1.000
Comorbidities							
Hypertension, n (%)	70(44.6%)	46(39.3%)	24(60.0%)	0.023	50(38.8%)	20(71.4%)	0.002
Diabetes, n (%)	23(14.6%)	20(17.1%)	3(7.5%)	0.222	18(14.0%)	5(17.9%)	0.596
Obesity, n (%)	24(15.3%)	21(17.9%)	3(7.5%)	0.183	21(16.3%)	3(10.7%)	0.651
COPD, n (%)	9(5.7%)	5(4.3%)	4(10.0%)	0.342	6(4.7%)	3(10.7%)	0.422
Coronary artery disease, n (%)	26(16.6%)	19(16.2%)	7(17.5%)	0.853	19(14.7%)	7(25.0%)	0.185
Chronic kidney disease, n (%)	3(1.9%)	3(2.6%)	0(0)	0.571	2(1.6%)	1(3.6%)	0.448
Chronic liver disease, n (%)	6(3.8%)	5(4.3%)	1(2.5%)	0.978	4(3.1%)	2(7.1%)	0.291
Arrhythmia, n (%)	6(3.8%)	3(2.6%)	3(7.5%)	0.173	5(3.9%)	1(3.6%)	1.000
Malignancy, n (%)	11(7.0%)	6(5.1%)	5(12.5%)	0.115	10(7.8%)	1(3.6%)	0.706

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Laboratory findings

Lymphocyte count, × 10 ⁹ /L	1.0(0.6,1.4)	1.0(0.7,1.4)	0.9(0.4,1.5)	0.721	1.0(0.6,1.4)	1.0(0.5,1.4)	0.703
D-dimer, mg/L	1.1(0.4,2.7)	1.0(0.5,2.9)	1.1(0.3,2.7)	0.886	1.1(0.4,2.8)	1.2(0.5,2.6)	0.739
PT, s	13.5(12.5,15.0)	13.3(12.5,14.4)	13.9(12.8,15.8)	0.080	13.4(12.5,14.6)	14.2(12.8,16.0)	0.085
APTT, s	37.4(33.3,44.6)	37.0(33.7,42.4)	39.3(32.5,45.7)	0.417	37.2(33.0,44.0)	38.0(34.4,45.5)	0.616
CK-MB, U/L	11(8,18)	10(8,14)	15(8,30)	0.019	11(8,17)	11(6,20)	0.722
hs-TNI, ng/L	4.8(2.2,31.2)	3.9(2.2,26.9)	10.6(3.3,141.4)	0.047	3.9(1.9,26.7)	29.8(4.6,112.9)	0.001
BNP, pg/ml	79.1(35.7,163.9)	67.8(33.1,141.9)	97.3(49.2,271.0)	0.045	53.4(30.2,139.8)	144.2(105.6,353.6)	<0.001
CRP, mg/L	26.5(3.7,67.6)	24.2(3.6,65.1)	39.5(7.5,94.7)	0.260	26.1(3.6,65.1)	47.0(7.8,109.1)	0.301
PCT, ng/ml	0.08(0.05,0.20)	0.08(0.05,0.19)	0.09(0.05,0.35)	0.418	0.08(0.05,0.19)	0.07(0.05,0.25)	0.401
IL-6, pg/ml	5.2(2.4,20.7)	5.2(2.3,15.1)	5.6(3.1,75.8)	0.284	4.3(2.3,15.5)	9.5(3.9,27.1)	0.135
PaO ₂ :FIO ₂ , mmHg	232.0(151.0,268.97)	233.3(156,269.0)	196.5(110.9,421.8)	0.379	234.2(152.8,269.0)	200.7(147.5,236.5)	0.228

Treatments

Antiviral therapy, n (%)	150(95.5%)	113(96.6%)	37(92.5%)	0.372	122(94.6%)	28(100.0%)	0.450
Antibiotic therapy, n (%)	119(75.8%)	87(74.4%)	32(80.0%)	0.472	97(75.2%)	22(78.6%)	0.705
Glucocorticoid therapy, n (%)	65(41.4%)	43(36.8%)	22(55.0%)	0.043	51(39.5%)	14(50.0%)	0.308
Intravenous immune globulin, n (%)	56(35.9%)	38(32.5%)	18(46.2%)	0.123	44(34.4%)	12(42.9%)	0.397
Anticoagulant therapy, n (%)	81(51.6%)	59(50.4%)	22(55.0%)	0.617	67(51.9%)	14(50.0%)	0.852
Diuretics, n (%)	39(24.8%)	24(20.5%)	15(37.5%)	0.032	29(22.5%)	10(35.7%)	0.142
Beta-blockers, n (%)	33(21.0%)	21(17.9%)	12(30.0%)	0.106	24(18.6%)	9(27.3%)	0.111
Alpha-blockers, n (%)	3(1.9%)	2(1.7%)	1(2.5%)	1.000	3(2.3%)	0(0)	1.000
Calcium channel blockers, n (%)	48(30.6%)	33(28.2%)	15(37.5%)	0.271	36(27.9%)	12(42.9%)	0.120
ACE-I/ARB, n (%)	17(10.8%)	11(9.4%)	6(15.0%)	0.325	15(11.6%)	2(7.1%)	0.721
Oxygen therapy, n (%)	139(88.5%)	104(88.9%)	35(87.5%)	0.812	113(81.3%)	26(92.9%)	0.642
High-flow oxygen, n (%)	90(57.3%)	64(54.7%)	26(65.0%)	0.256	68(52.7%)	22(78.6%)	0.012

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Mechanical ventilation, n (%)	37(23.6%)	22(18.8%)	15(37.5%)	0.016	26(20.2%)	11(39.3%)	0.031
IMV, n (%)	26(16.6%)	14(12.0%)	12(30.0%)	0.008	16(12.4%)	10(35.7%)	0.003
NIMV, n (%)	11(7.0%)	8(6.8%)	3(7.5%)	1.000	10(7.8%)	1(3.6%)	0.760
ICU admission, n (%)	27(17.2%)	14(12.0%)	13(32.5%)	0.003	20(15.5%)	7(25.0%)	0.227
Complications							
Acute kidney injury, n (%)	20(12.8%)	13(11.2%)	7(17.5%)	0.305	15(11.7%)	5(17.9%)	0.379
ARDS, n (%)	64(40.8%)	36(30.8%)	28(70.0%)	<0.001	45(34.9%)	19(67.9%)	0.001
Acute heart injury, n (%)	40(29.4%)	24(24.5%)	16(42.1%)	0.043	25(22.9%)	15(55.6%)	0.001
Coagulation dysfunction, n (%)	29(18.5%)	21(17.9%)	8(20.0%)	0.773	21(16.3%)	8(28.6%)	0.129
DVT, n (%)	63(40.1%)	47(40.2%)	16(40.0%)	0.985	48(37.2%)	15(53.6%)	0.109
Shock, n (%)	1(0.6%)	0(0)	1(2.5%)	0.255	0(0)	1(3.6%)	0.178
Prognosis							
Discharge, n (%)	134(85.4%)	109(93.2%)	25(62.5%)	<0.001	114(88.4%)	20(71.4%)	0.022
Death, n (%)	23(14.6%)	8(6.8%)	15(37.5%)	<0.001	15(11.6%)	8(28.6%)	0.022

Data are mean \pm SD, n (%), median (IQR). SD, standard deviation; IQR, interquartile range. COVID-19, coronavirus disease 2019; RVD, right ventricular dysfunction; HF, heart failure; COPD, chronic obstructive pulmonary disease; PT, prothrombin time; APTT, activated partial thromboplastin time; CK-MB, creatine kinase muscle-brain; hs-TNI, high-sensitivity troponin I; BNP, B-type natriuretic peptide; CRP, C-reactive protein; PCT, procalcitonin; IL-6, interleukin-6; PaO₂, partial pressure of oxygen; FIO₂, fraction of inspiration oxygen; ACE-I, angiotensin-converting enzyme inhibitors; ARB, angiotensin II receptor blockers; IMV, invasive mechanical ventilation; NIMV, non-invasive mechanical ventilation; ICU, intensive care unit; ARDS, acute respiratory distress syndrome; DVT, deep vein thrombosis.

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Table 2. Echocardiographic characteristics of patients with COVID-19 according to right ventricular dysfunction and heart failure

Variables	All Patients (n=157)	Without RVD (n=117)	With RVD (n=40)	<i>P</i> Value	Without HF (n=129)	With HF (n=28)	<i>P</i> Value
Left heart							
LA, mm	35.5(32.2,38.1)	35.4(32.3,38.3)	35.8(32.0,37.9)	0.651	34.9(32.1,37.3)	37.2(35.5,41.4)	0.001
LV, mm	45.7±5.1	46.0±4.9	44.8±5.5	0.219	45.7±5.1	45.6±5.0	0.923
IVS, mm	9.6±1.2	9.7±1.2	9.3±1.2	0.082	9.6±1.2	9.9±1.1	0.280
PW, mm	9.2(8.3,9.9)	9.2(8.4,10.2)	8.8(8.1,9.6)	0.015	9.0(8.3,9.9)	9.5(8.9,10.3)	0.202
LVMI, g/m ²	86.9±21.0	89.5±21.3	79.4±18.1	0.017	87.2±20.8	85.6±22.2	0.729
Mitral DT, ms	203±55	205±54	198±58	0.493	205±57	197±46	0.485
Mitral E/A	0.80(0.67,0.94)	0.80(0.68,1.00)	0.77(0.65,0.91)	0.473	0.8(0.7,1.0)	0.8(0.7,0.9)	0.714
e' (septal), cm/s	7.0(6.0,9.0)	7.3(6.2,9.0)	6.0(5.3,8.0)	0.004	7.0(6.0,9.0)	6.0(5.0,8.1)	0.017
e' (lateral), cm/s	10.0(8.0,11.7)	10.0(8.0,11.8)	8.6(7.0,11.1)	0.044	10.0(8.0,11.7)	7.3(6.0,9.9)	0.001
Mitral E/e'	8.9(7.1,11.4)	9.0(7.5,11.3)	8.1(6.7,12.0)	0.406	8.6(6.9,11.2)	10.4(9.1,13.3)	0.001
LVEDVI, mL/m ²	50.1(40.1,60.9)	51.1(42.1,63.0)	48.3(34.9,59.1)	0.204	52.6(42.6,62.9)	44.6(34.7,53.6)	0.063
LVESVI, mL/m ²	18.5(15.3,23.6)	19.0(15.8,23.8)	15.6(13.4,18.9)	0.032	18.8(15.4,23.7)	17.1(13.0,22.0)	0.333
LVEF, %	63.4±7.0	62.9±6.7	65.0±8.0	0.126	64.6(59.5,68.5)	61.5(58.0,66.4)	0.104
LV MPI	0.41(0.36,0.51)	0.40(0.35,0.48)	0.50(0.40,0.60)	0.001	0.42(0.36,0.50)	0.39(0.34,0.55)	0.876
Moderate-severe MR, n (%)	6(3.9%)	5(4.3%)	1(2.6%)	0.985	4(3.1%)	2(7.4%)	0.283
Heart failure, n (%)	28(17.8%)	19(16.2%)	9(22.5%)	0.372	0(0)	28(100.0%)	/
HFrEF, n (%)	4(2.5%)	3(2.6%)	1(2.5%)	1.000	0(0)	4(100.0%)	/
HFpEF, n (%)	24(15.3%)	16(13.7%)	8(20.0%)	0.337	0(0)	24(100.0%)	/
Right heart							
RA, mm	38.3(35.6,41.2)	36.5(34.8,39.0)	45.0(41.4,46.7)	<0.001	38.4(35.7,41.4)	38.2(35.2,41.0)	0.623

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RV, mm	37.8(34.6,45.6)	35.8(34.0,38.9)	48.0(46.0,49.8)	<0.001	38.1(34.7,45.6)	36.6(34.1,45.6)	0.555
Tricuspid E/A	1.0±0.3	1.0±0.3	0.9±0.3	0.021	0.9(0.7,1.2)	0.9(0.8,1.2)	0.594
Tricuspid E/e'	5.5±1.8	5.5±1.9	5.6±1.7	0.861	5.0(4.0,7.0)	6.5(6.0,7.6)	0.280
TAPSE, mm	22.2(20.0,25.4)	23.2(20.6,25.9)	20.8(16.5,22.6)	<0.001	22.3±3.9	22.9±3.4	0.469
RV FAC, %	47.5±6.8	48.8±6.6	44.1±6.2	0.001	47.8±7.2	45.9±3.7	0.077
s', cm/s	13.5±3.2	13.6±3.0	13.1±4.0	0.553	13.4±3.3	13.8±3.2	0.583
RV MPI	0.46±0.14	0.40±0.08	0.60±0.16	<0.001	0.45±0.14	0.47±0.12	0.731
Moderate-severe TR, n (%)	6(3.9%)	5(4.3%)	1(2.6%)	1.000	4(3.1%)	2(7.4%)	0.283
PAH, n (%)	29(35.8%)	18(22.2%)	11(57.9%)	0.022	21(34.4%)	8(40.0%)	0.652
PASP, mmHg	32(24,47)	30(24,42)	46(26,55)	0.013	31(24,46)	34(24,47)	0.404
RVD	40(25.5%)	0(0)	40(100.0%)	/	31(24.0%)	9(32.1%)	0.372

Data are mean ± SD, n (%), median (IQR). SD, standard deviation; IQR, interquartile range. COVID-19, coronavirus disease 2019; RVD, right ventricular dysfunction; HF, heart failure; LA, left atrium; LV, left ventricular; IVS, interventricular septum; PW, posterior wall of left ventricle; LVM, left ventricular mass; EDT, peak E deceleration time of mitral inflow; LVEDVI, left ventricular end diastolic volume index; LVESVI, left ventricular end systolic volume index; LVEF, left ventricular ejection fraction; LV MPI, LV myocardial performance index; MR, mitral regurgitation; HF_rEF, heart failure with reduced ejection fraction; HF_pEF, heart failure with preserved ejection fraction; RA, right atrium; RV, right ventricular; TAPSE, tricuspid annular plane systolic excursion; RV FAC, RV fractional area change; RV MPI, RV myocardial performance index; TR, tricuspid regurgitation; PAH, pulmonary artery hypertension; PASP, pulmonary artery systolic pressure; RVD, right ventricular dysfunction.

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Table 3. Predictors of right ventricular dysfunction and heart failure in patients with COVID-19 by logistic regression

	Right ventricular dysfunction				Heart failure			
	Univariate OR (95% CI)	<i>P</i> Value	Multivariate OR (95% CI)	<i>P</i> Value	Univariate OR (95% CI)	<i>P</i> Value	Multivariate OR (95% CI)	<i>P</i> Value
Age, years	0.99(0.97,1.02)	0.669			1.03(0.99,1.06)	0.145		
Male, n (%)	1.47(0.71,3.04)	0.294			0.99(0.44,2.23)	0.970		
Hypertension (yes vs no)	2.32(1.11,4.82)	0.025		0.159	3.95(1.62,9.65)	0.003		0.051
Diabetes mellitus (yes vs no)	0.39(0.11,1.40)	0.150			1.34(0.45,3.98)	0.597		
Obesity, n (%)	0.37(0.10,1.32)	0.125			0.62(0.17,2.23)	0.462		
Coronary artery disease (yes vs no)	1.09(0.42,2.84)	0.853			1.95(0.76,4.98)	0.165		
Malignancy (yes vs no)	2.64(0.76,9.19)	0.126			0.44(0.05,3.59)	0.444		
Arrhythmia, n (%)	3.08(0.60,15.93)	0.179			0.92(0.10,8.18)	0.939		
ARDS, n(%)	5.25(2.40,11.48)	<0.001	5.52(2.39,12.71)	<0.001	3.94(1.65,9.42)	0.002	3.99(1.41,11.32)	0.009
MV, n (%)	2.59(1.12,5.71)	0.018		0.772	2.56(1.07,6.13)	0.034		0.675
ACE-I/ARB (yes vs no)	1.70(0.59,4.94)	0.329			0.59(0.13,2.72)	0.493		
Lymphocyte count, × 10 ⁹ /L	1.07(0.92,1.24)	0.413			0.86(0.42,1.79)	0.691		
D-dimer, mg/L	0.99(0.83,1.18)	0.900			0.97(0.79,1.18)	0.736		
PT, s	1.06(0.97,1.16)	0.181			1.07(0.98,1.18)	0.145		
APTT, s	1.01(0.98,1.04)	0.602			1.01(0.97,1.05)	0.719		
CK-MB (≥25 vs <25), U/L	3.17(1.38,7.25)	0.006		0.054	0.86(0.30,2.48)	0.782		
hs-TNI (≥26.2 vs <26.2), ng/L	2.24(1.02,4.95)	0.046		0.326	4.20(1.74,10.13)	0.001		0.888
BNP (≥100 vs <100), pg/mL	1.57(0.73,3.40)	0.251			11.17(4.08,30.63)	<0.001	11.39(3.91,33.1)	<0.001
CRP, mg/L	1.00(0.99,1.01)	0.211			1.01(1.00,1.01)	0.170		
PCT, ng/mL	2.88(0.88,9.45)	0.081			1.12(0.38,3.36)	0.838		

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IL-6, pg/mL	1.00(0.99,1.01)	0.405	1.00(0.99,1.00)	0.732
PaO ₂ :FIO ₂ , mmHg	1.00(0.99,1.01)	0.887	1.00(0.99,1.00)	0.187
Moderate–severe MR (yes vs no)	0.62(0.07,5.11)	0.623	2.46(0.43,14.17)	0.314
Moderate–severe TR (yes vs no)	0.60(0.07,5.30)	0.646	2.46(0.43,14.17)	0.314

COVID-19, coronavirus disease 2019; ARDS, acute respiratory distress syndrome; MV, mechanical ventilation; ACE-I, angiotensin-converting enzyme inhibitors; ARB, angiotensin II receptor blockers; PT, prothrombin time; APTT, activated partial thromboplastin time; CK-MB, creatine kinase muscle-brain; hs-TNI, high-sensitivity troponin I; BNP, B-type natriuretic peptide; CRP, C-reactive protein; PCT, procalcitonin; IL-6, interleukin-6; PaO₂, partial pressure of oxygen; FIO₂, fraction of inspiration oxygen; MR, mitral regurgitation; TR, tricuspid regurgitation; OR, odds ratio; CI, confidence interval.

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Table 4. Predictors of mortality in patients with COVID-19 by Cox proportional hazard model

	Univariate Cox regression		Model 1		Model 2		Model 3	
	HR (95% CI)	<i>P</i> Value	ARDS+hs-TNI+MV		ARDS+hs-TNI+MV+HF		ARDS+hs-TNI+MV+RVD	
			HR (95% CI)	<i>P</i> Value	HR (95% CI)	<i>P</i> Value	HR (95% CI)	<i>P</i> Value
Age, years	1.03(0.99,1.06)	0.144						
Hypertension (yes vs no)	2.26(0.96,5.34)	0.063						
Diabetes mellitus (yes vs no)	0.47(0.12,1.99)	0.304						
Obesity, n (%)	1.37(0.40,4.65)	0.616						
Coronary artery disease (yes vs no)	1.99(0.82,4.85)	0.129						
Malignancy (yes vs no)	1.08(0.25,4.60)	0.921						
Arrhythmia (yes vs no)	0.76(0.10,5.63)	0.784						
ARDS (yes vs no)	14.52(3.40,61.98)	<0.001	10.95(1.39,86.42)	0.023	10.95(1.39,86.42)	0.023		0.051
hs-TNI (≥ 26.2 vs <26.2), ng/L	11.27(3.81,33.33)	<0.001	4.57(1.42,14.71)	0.011	4.57(1.42,14.71)	0.011	3.98(1.14,13.88)	0.030
PaO ₂ :FIO ₂ , mmHg	0.99(0.98,1.01)	0.163						
MV (yes vs no)	19.88(6.75,58.59)	<0.001	5,36(1.40,20.51)	0.014	5,36(1.40,20.51)	0.014	8.99(2.23,36.27)	0.002
ACE-I/ARB (yes vs no)	0.77(0.18,3.30)	0.728						
HF (yes vs no)	2.54(1.07,6.00)	0.034				0.877		
RVD (yes vs no)	5.21(2.21,12.29)	<0.001					4.59(1.82,11.58)	0.001
AIC	/	/	145		147		144	
C-index	/	/	0.89*		0.88*		0.91*	

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* $P < 0.05$, model was considered statistically significant. AIC, akaike information criterion; HR, hazard ratio; CI, confidence interval; COVID-19, coronavirus disease 2019; ARDS, acute respiratory distress syndrome; hs-TNI, high-sensitivity troponin I; PaO₂, partial pressure of oxygen; FIO₂, fraction of inspiration oxygen; MV, Mechanical ventilation; ACE-I, angiotensin-converting enzyme inhibitors; ARB, angiotensin II receptor blockers; HF, heart failure; RVD, right ventricular dysfunction.