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ORIGINAL RESEARCH

Combination of Chest Computed Tomography Value and Clinical Laboratory Data for the Prognostic Risk Evaluation of Patients with COVID-19

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Objective: This study aims to investigate the independent prognostic factors of patients with coronavirus disease 2019 (COVID-19) and thereafter construct a related prognostic model.

Methods: The subjects were screened following the COVID-19 diagnostic criteria. The independent prognostic factors were selected based on the indicators, including medical history, clinical manifestation, laboratory tests, imaging examination and clinical prognosis. Subsequently, we constructed a nomogram model to predict short-term prognosis.

Results: Clinical information was obtained from 393 COVID-19 patients admitted to Zhongshan Hospital at Xiamen University between December 2022 and January 2023. The independent risk factors determined by Cox multivariate regression analysis included gender (OR: 0.355, 95% CI: 0.16~0.745), age (OR: 3.938, 95% CI: 1.221~15.9), pectoral muscle index (PMI, OR: 4.985, 95% CI: 2.336~11.443), pneumonia severity score (PSS, OR: 6.486, 95% CI: 2.082~21.416) and lactate dehydrogenase (LDH, OR: 3.857, 95% CI: 1.571~10.266). A short-term prognostic nomogram was developed based on the five independent risk factors above. The area under the receiver operating characteristic (ROC) curve (AUC) of the nomogram model was 0.857. The calibration curve confirmed the outcomes of the prognostic model, which exhibited excellent consistency with the actual results.

Conclusion: In summary, gender, age, pectoral muscle index, pneumonia severity score, and lactate dehydrogenase are all independent risk factors for COVID-19 mortality. Thus, the nomogram based on the above indicators can predict the risk of mortality in COVID-19 patients. This may have the potential of being clinical application in prognostic evaluation of COVID-19.

Keywords: COVID-19, risk factors, nomogram, prognoses, evaluation study

Research Background

Coronavirus disease 2019 (COVID-19) is a novel infectious disease that has rapidly spread in more than 200 countries and regions since its outbreak in December 2019. The spread of the virus poses a significant global hazard to human health.[1] Most patients infected with COVID-19 have good clinical outcomes, with only mild clinical signs including fever and dry cough. However, a few patients had multiple organs dysfunction (including lungs and heart) and even death.[2,3]

Gender, age, hypertension, diabetes mellitus, and obesity are the risk factors for poor prognosis in severe COVID-19 patients.[4] Additionally, dystrophy and cachexia are linked to poor prognosis in COVID-19 patients.[5–7] Schiaffino et al used axial Computed Tomography(CT) imaging at the T5 and T12 vertebrae levels to assess the cross-sectional area and attenuation of the paravertebral muscle of patients with COVID-19. As a consequence, low muscle mass was

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independently associated with Intensive care unit(ICU) admission and in-hospital mortality rates.[8] Kim et al used the chest CT scan at the 12th thoracic vertebra to determine the baseline cross-sectional area of the pectoral muscle of COVID-19 patients. The lowest quartile of the pectoral muscle index (PMI, the cross-sectional area of the pectoral muscle was divided by the square of the height) was used to identify the patients with sarcopenia. The results revealed that patients with sarcopenia had a more prolonged hospital stay and a higher death rate. Also, sarcopenia was an independent predictor of hospital stay but was not linked to mortality.[9] Additionally, scholars have estimated the pectoral muscle index using the cross-sectional area manifested in the CT image at the 12th thoracic vertebra. They discovered that the index was not associated with poor outcomes including mortality, ICU admission rate, or invasive mechanical ventilation.[10,11] Summarily, the effect of the pectoralis muscle CT value on the prognostic risk evaluation of COVID-19 individuals varied among studies, warranting additional investigation.

One study revealed that multiple hematological indices, including hemoglobin (Hgb), hematocrit (HCT), white blood Cell (WBC) and platelet (PLT), and biochemical parameters including alanine aminotransferase (ALT), aspartate aminotransferase (AST) and lactate dehydrogenase (LDH) were altered in COVID-19 patients. Lymphocyte(Lym) and PLT counts significantly decreased in severe cases and death. In contrast, WBC counts increased dramatically, and biomarkers for inflammation, heart and muscle injury, hepatorenal function, and coagulation function also significantly increased.[12] Laboratory indicators including C-reactive protein (CRP), D-dimer (DD), coagulation test, LDH, and procalcitonin(PCT) were associated with the severity and poor prognosis of COVID-19 patients. The above indices can predict severity, ICU admission rate, and mortality.[13]

Currently, there are few studies combining CT characteristics with clinical laboratory data. Lin et al found that chest CT features are positively associated with CRP, ESR, and LDH and can indicate disease severity.[14] The findings suggest that combining chest CT features and clinical laboratory data provide clinical value in assessing the prognostic risk of COVID-19 individuals. This study compared the demographic characteristics, pectoralis muscle CT value, and clinical laboratory data between the survival and death groups to identify potential risk factors of death and establish the nomogram predicting the risk of death among COVID-19 patients. The above results provide a reference for the clinical diagnosis and treatment of COVID-19 patients.

Data and Methods

Study Subjects

A retrospective study on the clinical information of COVID-19 patients (male, 257 cases; female, 136 cases; ≤60 years old, 77 cases; and >60 years old, 316 cases) admitted to Zhongshan Hospital at Xiamen University was conducted between December 2022 and January 2023. Inclusion criteria: (1) age ≥18 years; (2) the patients confirmed with a positive viral nucleic acid of COVID-19; (3) the patients undergoing chest CT imaging and showing signs of viral pneumonia on CT imaging (patients confirmed with the diagnosis criteria of common, severe and critical COVID-19 were included). Exclusion criteria: (1) age <18 years; (2) the chest CT picture revealed a motional artifact; (3) incomplete clinical data. Complied with the Declaration of Helsinki, the study was approved by Zhongshan Hospital Xiamen University ethics committee (Ethical approval number: (XMZSYYKY 2023–086) and all patients signed the informed consent form.

Methods

Collection of Clinical Data

This study collected patient demographic information, including age, gender, height, body weight, underlying condition (diabetes, cardiovascular disorder, malignant tumor), symptoms, laboratory examination, and imaging. Laboratory examination included creatine kinase (CK), MB isoenzyme of creatine kinase (CK-MB), high-sensitivity cardiac troponin T (hs-TnT), N-terminal pro-brain natriuretic peptide (NT-proBNP), PCT, DD, WBC, Lym, neutrophil count (Neu), monocyte count (Mono), Hgb, PLT, β-hydroxybutyric acid (β-HB), CRP, albumin (ALB), ALT, AST, glutamyltranspeptidase (GGT), alkaline phosphatase (ALP), cholinesterase (CHE), glucose (GLU), LDH, blood urea nitrogen (BUN) and

creatinine (Cre). The above information represents the initial examination results obtained within 24 hours after admission.

Clinical Classification

Clinical classification followed the "Diagnosis and Treatment Protocol for COVID-19 (Trial Version 10)" published by the National Health Commission of the People's Republic of China:[15] (a) Mild cases: The clinical symptoms were mild, and imaging showed no pneumonia signs. (B) Common cases: showing fever and respiratory symptoms with radiological findings of pneumonia. (c) severe cases: meeting any of the following criteria: (1) respiratory distress, RR≧30 breaths/min; (2) finger oxygen saturation≤93% at rest; (3) arterial partial pressure of oxygen PaO_2/ FiO_2≤300mmHg; (4) Those with progressive deterioration of clinical symptoms and chest imaging showing apparent lesion progression within 24–48 hours >50% of the time will be categorized as severe; (d) critical cases: respiratory failure requiring mechanical ventilation; shock; and other organ failure needing ICU care.

Measurement and Evaluation of Pectoral Muscle Mass

Chest CT results within 24 hours after admission were considered baseline results. The uniaxial chest CT image analysis at the 4th thoracic vertebra above the aorta arch was performed by two well-disciplined radiologists and independently through slicematic software. The pectoral muscle area (PMA) was calculated using the Hounsfield (HU) value as a unit (range: −29 to +150), and the square of the height corrected the PMA to calculate PMI. The image is shown in Figure 1.

Pneumonia Severity Score (PSS)

Two thoracic surgeons with at least five-year work experience evaluated the pneumonia severity respectively and independently. Evaluation standard: no pneumonia: 0 points; mild pneumonia (20–40%): 1 point; moderate pneumonia (40–60%): 2 points; severe pneumonia (>60%): 3 points.[16]

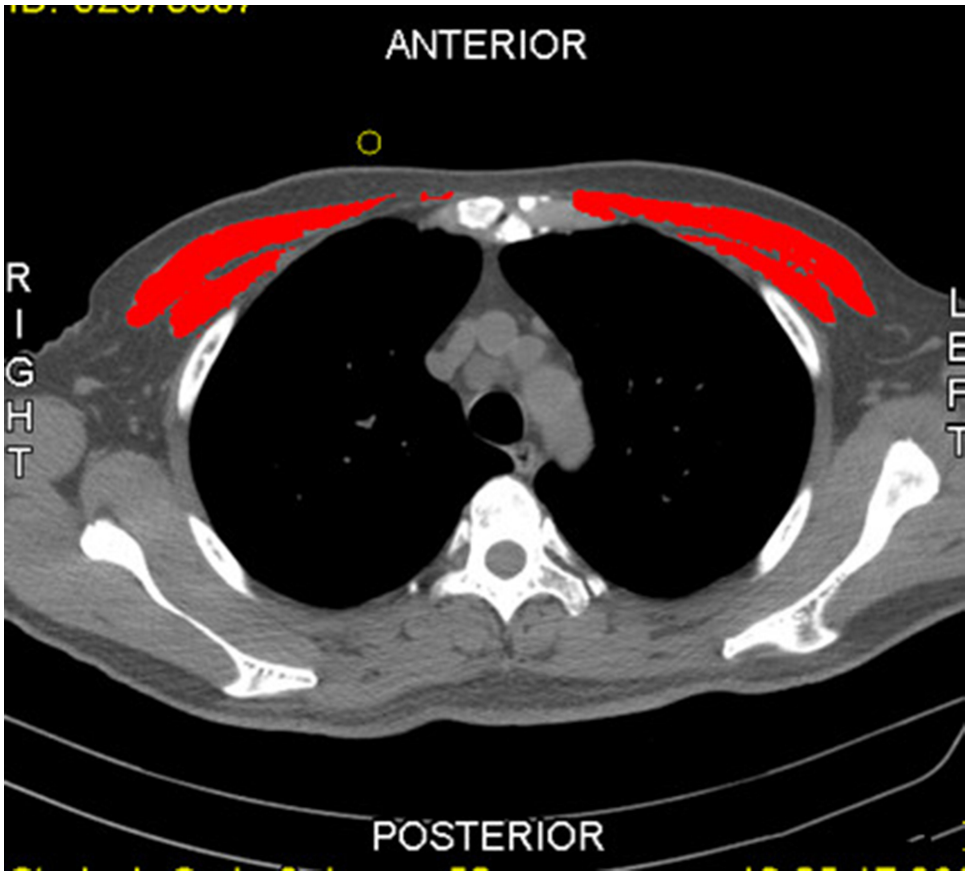

Figure 1 The cross-section of the chest CT image at the 4th thoracic vertebra and the red marking area was the PMA.

Statistical Analysis

SPSS 24.0 software was used in all data analyses. The exact probability of the Chi-square or Fisher tests was used to compare the groups. Data in Table 1-3 were analyzed using univariate Cox regression analysis. The variables with statistical significance were then analyzed using multivariate Cox regression analysis. The independent risk factors were used to establish the prognostic nomogram. $P < 0.05$ was considered to be statistically significant.

Results

Comparison of General Data Between COVID-19 Patients in the Survival and Death Groups

The differences in body temperature, heart rate, malignant tumor, coronary heart disease, diabetes mellitus, and body mass index(BMI) on admission between the two groups were not statistically significant (P>0.05). In the death group, the

Table 1 Comparison of General Data Between COVID-19 Patients in the Survival and Death Groups

Indicator	Survival Group	Death Group	X^2	P-value
Gender				
Male	187 (60.9%)	70 (81.4%)		
Female	120 (39.1%)	16 (18.6%)	12.455	<0.001
Age				
≤60 years old	73 (23.8%)	4 (4.7%)		
>60 years old	234 (76.2%)	82 (95.3%)	15.601	<0.001
Body temperature				
Normal	247 (80.5%)	70 (81.4%)		
Rise	60 (19.5%)	16 (18.6%)	0.038	0.845
Heart rate				
Normal	220 (71.7%)	56 (65.1%)		
Increase	87 (28.3%)	30 (34.9%)		0.242*
Inoculation of vaccine				
No	100 (32.6%)	41 (47.7%)		
One dose	36 (11.7%)	15 (17.4%)		
Two doses	59 (19.2%)	15 (17.4%)		
Three doses	112 (36.5%)	15 (17.4%)	13.61	0.003
Malignant tumor				
No	270 (87.9%)	73 (84.9%)		
Yes	37 (12.1%)	13 (15.1%)	0.568	0.451
Hypertension				
No	171 (55.7%)	27 (31.4%)		
Yes	136 (44.3%)	59 (68.6%)	15.875	<0.001
Coronary heart disease				
No	304 (99.0%)	85 (98.8%)		
Yes	3 (1.0%)	1 (1.2%)		1.000*
Diabetes mellitus				
No	209 (68.1%)	51 (59.3%)		
Yes	98 (31.9%)	35 (40.7%)	2.311	0.128
Chronic renal insufficiency				
No	250 (81.4%)	55 (64.0%)		
Yes	57 (18.6%)	31 (36.0%)	11.812	0.001
BMI				
≥18.5	282 (91.9%)	84 (97.7%)		
<18.5	25 (8.1%)	2 (2.3%)	3.554	0.059

Note: *Fisher's exact probabilities.

Table 2 Comparison of Pectoralis Muscle CT Value Between COVID-19 Patients in the Survival and Death Groups

Indicator	Survival Group	Death Group	X^2	P-value
PMI				
High	155 (50.5%)	12 (14.0%)		
Low	152 (49.5%)	74 (86.0%)	36.697	<0.001
PSS				
0	159 (51.8%)	18 (20.9%)		
1	98 (31.9%)	25 (29.1%)		
2	39 (12.7%)	21 (24.4%)		
3	11 (3.6%)	22 (25.6%)	59.137	<0.001

Table 3 Comparison of Laboratory Parameters Between COVID-19 Patients in the Survival and Death Groups

Indicator	Survival Group	Death Group	X^2	P-value
Hs-TnT				
Normal	93 (30.3%)	6 (7.0%)		
Increase	214 (69.7%)	80 (93.0%)	19.381	<0.001
NT-proBNP				
Normal	106 (34.5%)	9 (10.5%)		
Increase	201 (65.5%)	77 (89.5%)	18.792	<0.001
PCT				
Normal	177 (57.7%)	33 (38.4%)		
Increase	130 (42.3%)	53 (61.6%)	10.039	0.002
CRP				
Normal	32 (10.4%)	0 (0.0%)		
Increase	275 (89.6%)	86 (100.0%)	9.759	0.002
DD				
Normal	86 (28.0%)	4 (4.7%)		
Increase	221 (72.0%)	82 (95.3%)	20.766	<0.001
CK				
Normal	227 (73.9%)	54 (62.8%)		
Increase	80 (26.1%)	32 (37.2%)	4.099	0.043
CKMB				
Normal	242 (78.8%)	49 (57.0%)		
Increase	65 (21.2%)	37 (43.0%)	16.690	<0.001
LDH				
Normal	158 (51.5%)	9 (10.5%)		
Increase	149 (48.5%)	77 (89.5%)	46.215	<0.001
BUN				
Normal	228 (74.3%)	35 (40.7%)		
Increase	79 (25.7%)	51 (59.3%)	34.199	<0.001
Cre				
Normal	216 (70.4%)	38 (44.2%)		
Increase	91 (29.6%)	48 (55.8%)	20.131	<0.001
GLU				
Normal	103 (33.6%)	14 (16.3%)		
Increase	204 (66.4%)	72 (83.7%)	9.585	0.002
β-HB				
Normal	162 (52.8%)	39 (45.3%)		
Increase	145 (47.2%)	47 (54.7%)	1.480	0.224

(*Continued*)

Table 3 (Continued).

Indicator	Survival Group	Death Group	X^2	P-value
ALB				
Normal	59 (19.2%)	6 (7.0%)		
Decrease	248 (80.8%)	80 (93.0%)	7.293	0.007
ALT				
Normal	271 (88.3%)	68 (79.1%)		
Increase	36 (11.7%)	18 (20.9%)	4.801	0.028
AST				
Normal	191 (62.2%)	33 (38.4%)		
Increase	116 (37.8%)	53 (61.6%)	15.582	<0.001
GGT				
Normal	242 (78.8%)	60 (69.8%)		
Increase	65 (21.2%)	26 (30.2%)	3.099	0.078
ALP				
Normal	289 (94.1%)	74 (86.0%)		
Increase	18 (5.9%)	12 (14.0%)	6.236	0.013
WBC				
Normal	246 (80.1%)	56 (65.1%)		
Increase	61 (19.9%)	30 (34.9%)	8.511	0.004*
Neu				
Normal	246 (80.1%)	52 (60.5%)		
Increase	61 (19.9%)	34 (39.5%)	14.174	<0.001
Lym				
Normal	303 (98.7%)	85 (98.8%)		
Increase	4 (1.3%)	1 (1.2%)		1.000*
Mono				
Normal	246 (80.1%)	76 (88.4%)		
Increase	61 (19.9%)	10 (11.6%)	3.083	0.079
Hgb				
Normal	201 (65.5%)	49 (57.0%)		
Decrease	106 (34.5%)	37 (43.0%)	2.095	0.148
PLT				
Normal	278 (90.6%)	73 (84.9%)		
Decrease	29 (9.4%)	13 (15.1%)	2.263	0.133
Saturation of blood oxygen				
Normal	224 (73.0%)	39 (45.3%)		
Decrease	83 (27.0%)	47 (54.7%)	23.144	<0.001

Note: *Fisher's exact probabilities.

proportion of male patients (gender), patients > 60 years old (age), patients without immunizations, and patients with hypertension and chronic renal insufficiency was more significant than that in the survival group, the difference was statistically significant (P<0.05, Table 1).

Comparison of Pectoralis Muscle CT Value Between COVID-19 Patients in the Survival and Death Groups

The difference in PMI and PPS on admission between the two groups was statistically significant (P<0.05). The proportion of patients in the death group with low PMI and moderate or severe PSS was significantly higher than that in the survival group (Table 2).

Comparison of Laboratory Parameters Between COVID-19 Patients in the Survival and Death Groups

The difference between β-HB, GGT, Lym, Mono, Hgb, and PLT on admission between the two groups revealed no statistical significance ($P>0.05$). The proportion of patients with increased hs-TnT, NT-proBNP, PCT, CRP, DD, CK, CKMB, BUN, Cre, GLU, ALT, AST, ALP, WBC, and Neu, and with decreased ALB and saturation of blood oxygen in the death group were significantly higher than that in the survival group. The difference was statistically significant ($P<0.05$, Table 3).

Analysis of the Risk Factors for Death of COVID-19 Patients

Gender, age, blood oxygen saturation, vaccination, hypertension, chronic renal insufficiency, PMI, PSS, hs-TnT, NT-proBNP, PCT, CRP, DD, CK, CKMB, LDH, BUN, Cre, GLU, ALB, ALT, AST, GGT, ALP, WBC and Neu on admission were the death risk factors in COVID-19 patients, according to the results of a Cox regression analysis. Among these characteristics, being female (gender) and having three vaccination doses (vaccine immunization) were protective (Table 4).

Table 4 Analysis of the Risk Factors for the Death of COVID-19 Patients

Related Indicators	N	Univariate Analysis		Multivariate Analysis	
		OR (95% CI)	P-value	OR (95% CI)	P-value
Gender					
Male	257				
Female	136	0.356 (0.198, 0.642)	<0.001	0.355 (0.16, 0.745)	0.008
Age					
≤60 years old	77				
>60 years old	316	6.395 (2,266.18.047)	<0.001	3.938 (1,221.15.9)	0.033
Body temperature					
Normal	317				
Increase	76	0.941 (0,510.1.735)	0.845	-	
Heart rate					
Normal	276				
Increase	117	1.355 (0,815.2.252)	0.242	-	
Saturation of blood oxygen					
Normal	263				
Decrease	130	3.252 (1,985.5.328)	<0.001	1.338 (0,676.2.627)	0.398
Inoculation of vaccine					
No	141				
One dose	51	1.016 (0,503.2.054)	0.964	0.601 (0,227.1.526)	0.292
Two doses	74	0.62 (0,316.1.216)	0.164	0.584 (0,229.1.43)	0.248
Three doses	127	0.327 (0,171.0.626)	<0.001	0.622 (0,261.1.43)	0.271
Tumor					
No	343				
Yes	50	1.3 (0,657.2.572)	0.452	-	
Hypertension					
No	198				
Yes	195	2.748 (1,653.4.566)	<0.001	1.642 (0,809.3.333)	0.169
Coronary heart disease					
No	389				
Yes	4	1.192 (0,122.11.608)	0.88	-	
Diabetes mellitus					
No	260				
Yes	133	1.464 (0,894.2.395)	0.13	-	

(*Continued*)

Table 4 (Continued).

Related Indicators	N	Univariate Analysis		Multivariate Analysis	
		OR (95% CI)	P-value	OR (95% CI)	P-value
Chronic renal insufficiency					
No	305				
Yes	88	2.472 (1,461.4.183)	<0.001	1.189 (0,504.2.801)	0.693
BMI					
≥18.5	366				
<18.5	27	0.269 (0,062.1.157)	0.078	-	
PMI					
High	167				
Low	226	6.288 (3,284.12.042)	<0.001	4.985 (2,336.11.443)	<0.001
PSS					
0	177				
1	123	2.253 (1,169.4.343)	0.015	1.258 (0,525.3.052)	0.608
2	60	4.756 (2,314.9.776)	<0.001	2.351 (0,903.6.25)	0.082
3	33	17.667 (7,382.42.278)	<0.001	6.486 (2,082.21.416)	0.002
Hs-TnT					
Normal	99				
Increase	294	5.794 (2,441.13.756)	<0.001	1.002 (0.32, 3.421)	0.998
NT-proBNP					
Normal	115				
Increase	278	4.512 (2,176.9.357)	<0.001	1.746 (0,672.4.842)	0.265
CT					
Normal	210				
Increase	183	2.187 (1,340.3.570)	0.002	1.503 (0.73, 3.123)	0.27
CRP					
Normal	32				
Increase	361	15.125 (2,045.112.324)	0.008	1.23 (0,142.25.361)	0.834
DD					
Normal	90				
Increase	303	7.977 (2,836.22.436)	<0.001	2.27 (0,712.9.154)	0.2
CK					
Normal	281				
Increase	112	1.681 (1,014.2.789)	0.044	0.734 (0,348.1.517)	0.408
CKMB					
Normal	291				
Increase	102	2.811 (1,693.4.668)	<0.001	2.007 (0.98, 4.14)	0.057
LDH					
Normal	167				
Increase	226	9.072 (4,390.18.747)	<0.001	3.857 (1,571.10.266)	0.004
BUN					
Normal	263				
Increase	130	4.205 (2,549.6.937)	<0.001	1.532 (0,659.3.627)	0.325
Cre					
Normal	254				
Increase	139	2.998 (1,835.4.899)	<0.001	1.53 (0,608.3.824)	0.363
GLU					
Normal	117				
Increase	276	2.597 (1,397.4.825)	0.003	1.399 (0,633.3.208)	0.414
β-HB					
Normal	201				
Increase	192	1.346 (0,833.2.176)	0.225	-	

(*Continued*)

Table 4 (Continued).

Related Indicators	N	Univariate Analysis		Multivariate Analysis	
		OR (95% CI)	P-value	OR (95% CI)	P-value
ALB					
Normal	65				
Decrease	328	3.172 (1,320.7.623)	0.01	0.679 (0,213.2.35)	0.523
ALT					
Normal	339				
Increase	54	1.993 (1,066.3.723)	0.031	1.41 (0,548.3.623)	0.474
AST					
Normal	224				
Increase	169	2.644 (1,617.4.325)	<0.001	0.698 (0.31, 1.537)	0.377
GGT					
Normal	302				
Increase	91	1.613 (0,944.2.756)	0.08	0.874 (0,371.2.062)	0.759
ALP					
Normal	363				
Increase	30	2.604 (1,201.5.644)	0.015	1.082 (0,359.3.212)	0.888
WBC					
Normal	302				
Increase	91	2.16 (1,278.3.651)	0.004	1.621 (0,392.6.804)	0.505
Neu					
Normal	298				
Increase	95	2.637 (1,575.4.414)	<0.001	0.852 (0,217.3.237)	0.815
Lym					
Normal	388				
Increase	5	0.891 (0,098.8.079)	0.918	-	
Mono					
Normal	322				
Increase	71	0.531 (0,259.1.086)	0.083	-	
Hgb					
Normal	250				
Decrease	143	1.432 (0,879.2.331)	0.149	-	

With the significant single factors of death occurrence as independent variables and death as dependent variable, multi-factor binary Logistics regression analysis revealed that gender, age, PMI, PSS, and LDH remained independent risk factors for the mortality of COVID-19 patients.

Construction of a Nomogram Based on Independent Risk Factors for Mortality of COVID-19 Patients

The independent risk factors including gender, age, PMI, PSS, and LDH—obtained by multivariate Cox regression analysis were used as predictors. R language was employed to develop a prognostic mortality model for COVID-19 patients (Figure 2). Each risk factor was assigned various points based on the extent of impact on the clinical outcome, before adding up the scores. The total scores were translated into the risk of death of a particular patient to predict the risk.

The calibration curve was used to verify the consistency between the predicted death rate of COVID-19 patients and the actual observed value. The results showed that the broken lines connected by five points were uniformly distributed near the diagonal, indicating that the predicted mortality rate of the graph was consistent with the actual clinical mortality rate (Figure 3).

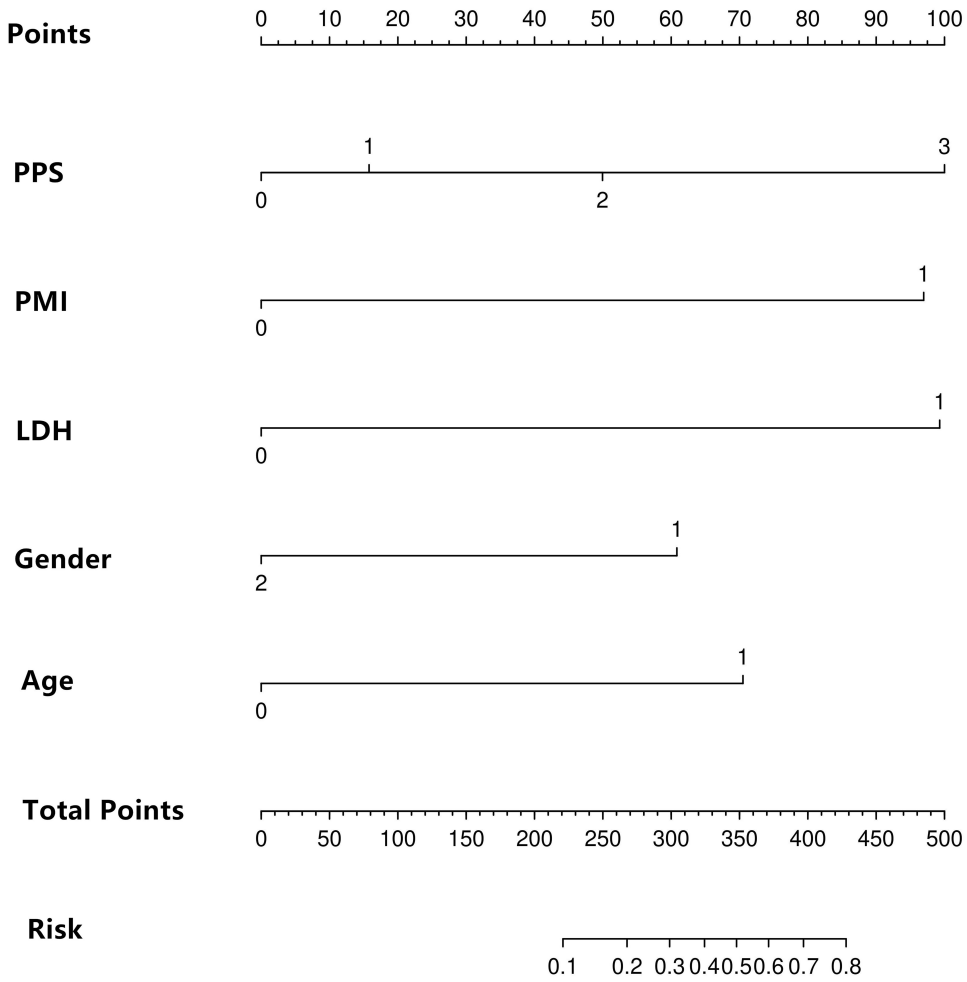

Figure 2 Prognostic nomogram model of risk for death in patients with COVID-19.
Notes: PPS, PMI, LDH, gender and age of a single patient were corresponding to the top scoring scale bar. Subsequently, the five scores were added up. According to the total score, the corresponding value in the Total Points scale strip was determined. The value in the Risk scale strip matched the above Total Point value, and the patient's risk of death can be predicted.

The mortality of COVID-19 patients was analyzed by the ROC curve to validate the accuracy of the nomogram (Figure 4). The prognostic model had higher clinical significance, as indicated by the ROC area under the curve (AUC) of 0.857.

Discussion

This work collected demographic information, clinical data, CT imaging, and laboratory examination from 393 COVID-19 patients (ie, including common, severe, and critical cases) within 24 hours of admission. Cox multivariate regression analysis was used to determine the independent risk factors associated with death and a probability model was constructed to predict the risk of death. Gender, age, PMI, PSS, and LDH were found to be independent risk factors for COVID-19 mortality. And based on the above indicators, the nomogram can predict the risk of mortality in COVID-19 patients.

The death rate of COVID-19 patients was 21.89% (86/393), higher than that reported by Surov et al (13.53%).[17] This is because the cases in our study included common, severe, and critical patients, whereas mild ones were excluded. The death group was mostly male (81.4%), and most of the patients were above 60 years (95.3%), agreeing with previous reports.[17,18] Du et al reported that age (≥65 years) is an independent and robust death predictor.[18] Additionally, Petrilli et al found that old age (≥75 years) and males are independent predictors of the death of patients infected with COVID-19.[19]

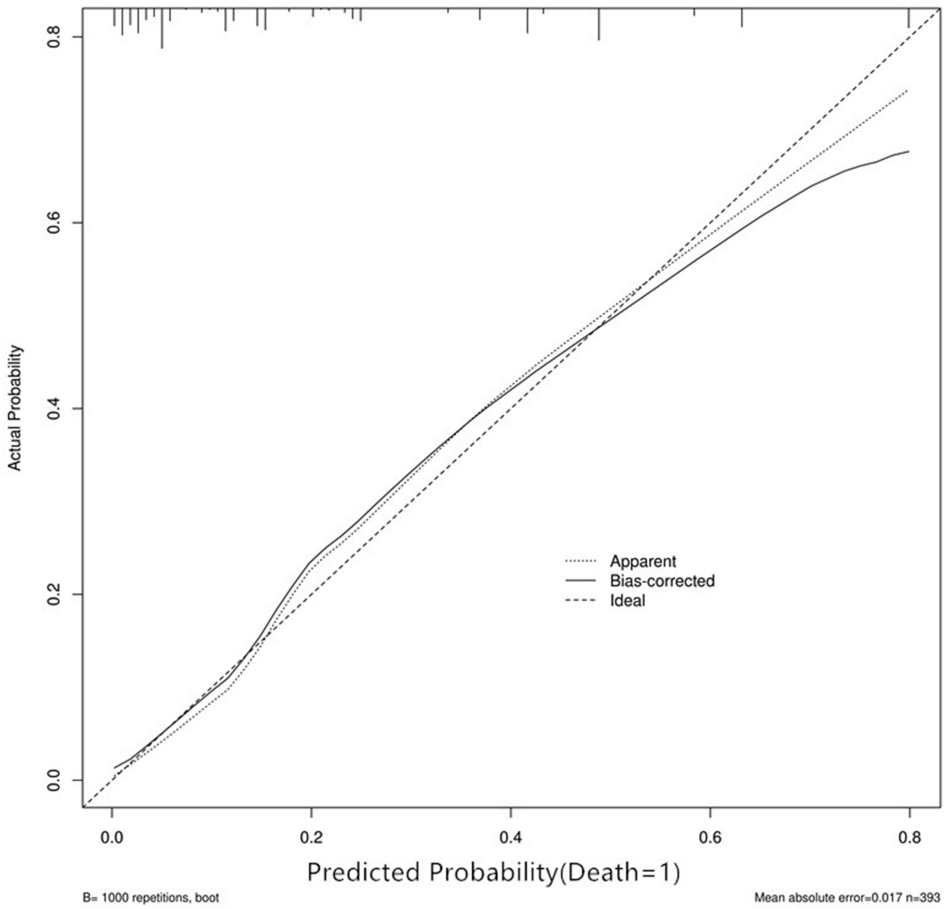

Figure 3 Consistency between the predicted mortality and actual observed results in COVID-19 patients was validated by the calibration curve.

In the present study, patients with COVID-19 who also had hypertension or renal insufficiency died at a higher rate. In contrast, patients with diabetes mellitus, malignant tumors, or coronary heart disease, on the other hand, did not affect their fatality rates. A meta-analysis of 42 studies revealed that acute kidney injury, COPD, diabetes mellitus, hypertension, cardiovascular disorder, cancer, increased D-dimer, male, older age, smoking, and obesity were all risk factors for poor clinical outcomes in COVID-19 patients.[20] Aboueshia et al reported that patients with COVID-19 and cancer had more prolonged hospital stays, however no correlation existed between these factors and death.[21] These findings are consistent with our research findings. Furthermore, we discovered that the proportion of death cases in COVID-19 patients who received three doses of vaccination significantly decreased, matching the findings of Jamie et al.[22] The study reported that vaccination reduced clinical symptoms and disease severity in elderly patients with COVID-19.[22]

Computerized tomography (CT) scanning is a relatively precise means of evaluating pectoral muscle mass. Moreover, the inpatients routinely infected with COVID-19 receive CT imaging. Therefore, CT evaluated pectoral muscle mass to prevent extra examination in this work. Chest CT results within 24 hours after admission were considered the baseline results. Image analysis of the uniaxial chest CT images at the 4th thoracic vertebra above the arch of the aorta was performed using the slicematic software to calculate PMI and PSS. Consequently, the differences in PMI and PSS between patients with COVID-19 in the survival and death groups were statistically significant (P<0.05). Schiaffino et al used axial CT imaging at the T5 and T12 vertebrae to assess the cross-sectional area and attenuation of the paravertebral muscle of COVID-19 patients. The results revealed that low muscle mass was independently associated with ICU admission and in-hospital mortality rates.[8] The proportion of patients in the death group with low PMI and moderate or severe PSS was significantly higher than that in the survival group. These findings revealed that low pectoral muscle mass and pneumonia severity is linked to the death outcome, similar to the reports by Schiaffino et al.[8] Moreover, Ufuk

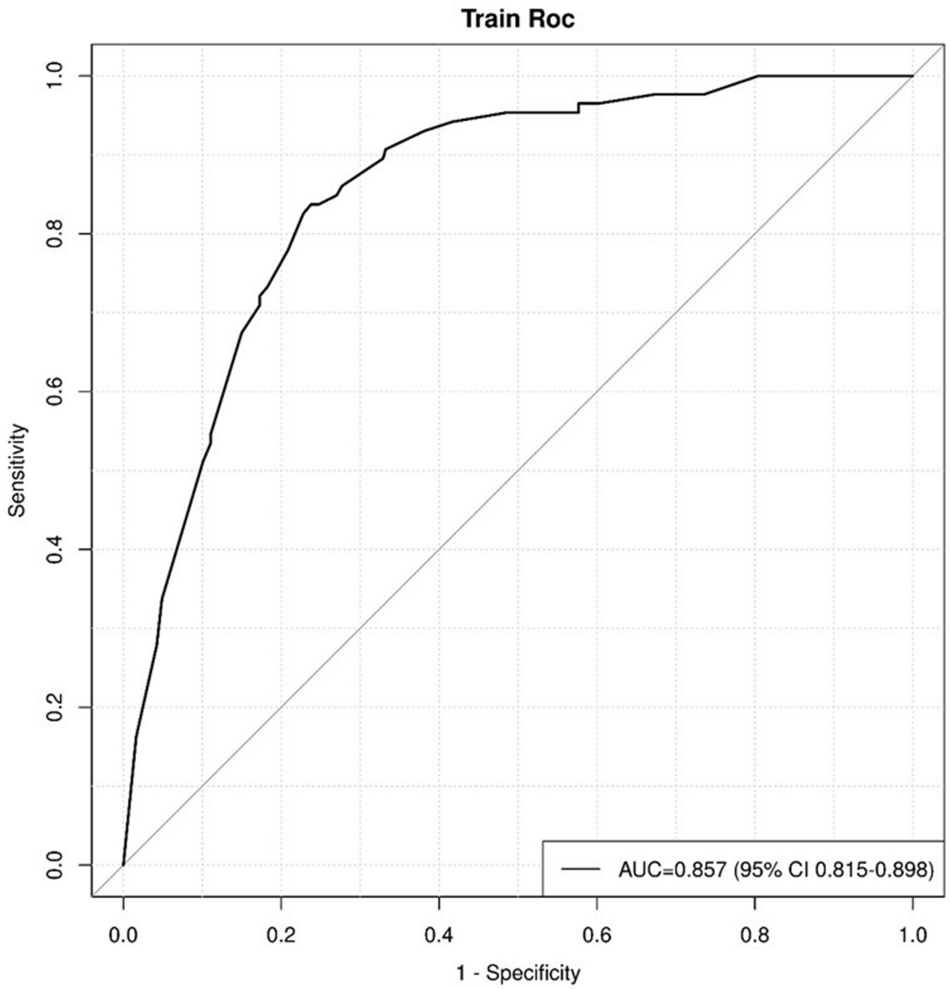

Figure 4 ROC curve of the prognostic nomogram model of risk for death in patients with COVID-19.

et al evaluated PMA, PMI, and PSS of patients infected with COVID-19 on admission and discovered that PMA, PMI, and PSS correlated with the incidence of tracheal intubation, extended hospital stay, and mortality.[23]

Multiple hematological indices including Hgb, HCT, WBC and PLT and biochemical parameters, ie, ALT, AST and LDH were changed in COVID-19 patients. As a result, these indices and parameters have clinical value for diagnostic and prognostic evaluation of COVID-19. Lym and PLT significantly decreased in COVID-19 individuals with severe diseases or mortality. At the same time, there was an increase in WBC levels, biomarkers for inflammation, heart and muscle injury, hepatorenal function, as well as coagulation function increased.[12] We observed an increased number of patients in the death group compared to that in the survival group who had increased hs-TnT, NT-proBNP, PCT, CRP, DD, CK, CKMB, LDH, BUN, Cre, GLU, ALT, AST, ALP, WBC, and Neu or reduced ALB and blood oxygen saturation ($P<0.05$).

The univariate analysis factors that significantly affected the death outcome were designated as independent variables, with death as the dependent variable. The findings of multivariate binary Logistics regression analysis findings revealed that gender, age, PMI, PSS, and LDH remained independent risk factors for the death of COVID-19 patients. Considering the effect of the aforementioned risk factors, the risk of death significantly increased in male patients or patients with advanced age (60 years old), low PMI, moderate or severe PSS, or high LDH. Notably, the univariate Cox proportional hazard model for clinical laboratory data revealed that increased hs-TnT, NT-proBNP, PCT, CRP, DD, CK, CKMB, LDH, BUN, Cre, GLU, ALT, AST, ALP, WBC, or Neu and decreased ALB or blood oxygen saturation were risk factors for the death of COVID-19 patients. In multivariate Cox regression analysis, LDH remained the independent risk factor for

COVID-19 infection-related deaths. Li et al reported increased LDH levels on admission as an independent risk factor for the severity and death of COVID-19 patients.[24] The serum LDH level can significantly increase when acute hypoxia or inflammation occurs. Since COVID-19 infection primarily targets the lungs and causes hypoxia, thrombosis, inflammation, and organ injury, increased LDH in serum is an important laboratory parameter of COVID-19 severity.[25]

Several studies have shown that male patients or patients with advanced age, reduced pectoral muscle mass, abnormal hematological indices or biochemical parameters are more likely to progress to severe and critical cases, and even death, when infected with COVID-19.[12,18,19,23] The above studies emphasized the role of demographic characteristics, clinical features, and laboratory parameters in predicting COVID-19 prognosis. However, less emphasis was focused on the combination of risk factors, including CT features and laboratory parameters within 24 hours after admission, to predict the survival probability of COVID-19 patients for the subsequent weeks. In the present study, the nomogram in our study was based on five independent risk factors, including gender, age, PMI, PSS, and LDH. The calibration curve validated the consistency between the predicted mortality of COVID-19 patients and the observed results. Mortality prediction of the nomogram was consistent with the actual clinical mortality, as revealed by the results of a polygon connected by five points uniformly distributed near the diagonal. Moreover, the ROC curve was used to verify the accuracy of the nomogram by analyzing the mortality of COVID-19 patients. The prognostic model exhibited greater clinical significance, as demonstrated by the results that the AUC of ROC being 0.857.

limitations

This work has compelling limitations. First, the retrospective study concerning clinical cases was conducted in a single hospital with a small sample size. Secondly, all the patients included in the study had common, severe, and critical cases; the mild cases were however excluded. Thirdly, COVID-19 patients without chest CT imaging were also excluded. Only patients with severe to moderate conditions received CT imaging data, explaining the higher mortality in this work. And this might be the potential for sampling bias. Future investigations should be conducted to expand the sample volume among multi-center studies and include all the patients infected with COVID-19 for reducing sampling bias.

Conclusion

In summary, gender, age, PMI, PSS, and LDH are all independent risk factors for COVID-19 mortality. Thus, the nomogram based on the above indicators can predict the risk of mortality in COVID-19 patients. This may have the potential of being clinical application in prognostic evaluation of COVID-19.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors report no conflicts of interest in this work.

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