Retrospective study of the impact of diabetes on the severity and prognosis of COVID-19

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Abstract. Patients with diabetes coexisting with viral infection tend to have poor outcomes, but the association between diabetes and coronavirus disease 2019 (COVID-19) prognosis is controversial at present. The present study reviewed and analyzed the data of 1,892 patients with COVID-19 admitted to Shaanxi Provincial People's Hospital (Xi'an, China). Demographic, clinical, laboratory and treatment data as well as clinical outcomes were extracted from the electronic medical records and compared between patients with and without diabetes. Multivariate logistic regression analysis was used to determine the risk factors affecting the prognosis of COVID-19. Compared with patients without diabetes, the levels of glucose, C-reactive protein, procalcitonin, creatinine, total bilirubin and plasma D-dimer were significantly increased in patients with diabetes, while the levels of lymphocytes and albumin were significantly decreased ($P<0.05$). Multivariate logistic regression analysis revealed that platelet count, albumin, total bilirubin and lymphocytes were significantly correlated with the severity of COVID-19. Diabetes mellitus was an independent prognostic factor that affected the mortality outcome of patients with COVID-19. Additionally, an age of ≥80 years, male sex, cerebral infarction complications and a critical diagnosis of COVID-19 at admission were risk factors for critical illness during hospitalization. The results of the present study suggest that diabetes may be a risk factor for the rapid progression and poor prognosis of COVID-19. Therefore, further attention should be paid to individuals with diabetes in order to prevent rapid deterioration.

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Introduction

In early 2020, coronavirus disease 2019 (COVID-19) became a global epidemic, affecting the health of individuals in every country (1). Due to economic pressure and widespread vaccination against COVID-19, the 'zero infection' policy of COVID-19 was lifted in various parts of China in December 2022 (2). As a result, there has been a rise in the number of COVID-19 infections (the confirmed cases increased from ~62,715 in November 2022 to ~806,394 in December 2022), which has affected numerous healthy individuals, as well as patients already inflicted with other diseases (3).

Diabetes is one of the most common diseases among the elderly population (the global incidence of diabetes in individuals aged >80 years is >20%) and contributes to morbidity worldwide (4,5). Studies have shown that individuals with diabetes are more susceptible to various pathogens, such as *Mycobacterium tuberculosis*, *Streptococcus pneumoniae* and *Staphylococcus aureus* (6,7). In addition, diabetes often leads to morbidity and mortality as well as healthcare expenditures (8). In numerous studies, both diabetes and obesity demonstrate harmful effects on host immunity and serve as risk factors for COVID-19 (9-12). An international, multicenter retrospective meta-analysis demonstrated that diabetes and excessive weight/obesity are independent, non-additive risk factors for the severity of COVID-19 hospitalization (13). However, a Mendelian randomized study reported that obesity, rather than type 2 diabetes, is the main risk factor for COVID-19 hospitalization (14). Another study demonstrated that patients with coexisting COVID-19 and diabetes tend to have more severe disease and poorer clinical outcomes, but only age was an independent predictor of mortality (15). The reasons for the differences in these results include variations in the study population, inconsistency in the age of inclusion and differences in study methods. Therefore, based on the aforementioned controversy, further investigation of the interaction between diabetes and COVID-19 in the current COVID-19

pandemic is warranted to potentially elucidate prevention strategies and further research opportunities in this specific population. In the present study, the demographics, comorbidities and other characteristics were analyzed, including disease severity and prognosis, to investigate whether they differed between patients with COVID-19 with and without diabetes.

Materials and methods

Study design, participants and data collection. The present study involved a single-center retrospective analysis of patients aged ≥18 years, admitted to Shaanxi Provincial People's Hospital (Xi'an, China) between December 2022 and February 2023. The patients were diagnosed with COVID-19 through reverse transcription polymerase chain reaction testing of throat swab samples. A total of 3,260 patients with COVID-19 were initially screened for the present study. Data from individuals were excluded if the subjects were aged <18 years or had incomplete medical records. For further study, the remaining 537 patients with diabetes and 1,355 patients without diabetes were included in the present study, and all data were obtained from the electronic medical records of the patients, including demographic, clinical, laboratory and treatment data, complications and clinical outcomes. According to the 10th edition of the COVID-19 Diagnosis and Treatment Protocol of China (16), the severity of COVID-19 is divided into mild (upper respiratory tract infection is the main manifestation), medium (COVID-19 pneumonia can be observed on imaging), severe (shortness of breath or progression of lung imaging lesion >50% compared with medium) and critical (respiratory failure that requires mechanical ventilation). The present study was approved by the Ethics Committee of Shaanxi Provincial People's Hospital (approval no. 2023-R125; Xi'an, China). The requirement for patient informed consent was waived.

Statistical analysis. Data that conformed to a normal distribution are presented as the mean ± SD, and were analyzed using an unpaired two-tailed Student's t-test; data with skewed distributions and/or uneven variances are presented as the median (P25, P75), and a Mann-Whitney U test was used for comparisons between two groups. Count data are presented as frequencies or rates. The group comparisons were assessed using the χ^2 test. Multivariate logistic regression was used to analyze the influencing factors of COVID-19 severity, mortality outcome and critical illness during hospitalization, and odds ratios (OR) and 95% confidence intervals (95% CI) were used to estimate the relative risk. In order to avoid overfitting in the model, a number of variables including age, sex, BMI and complications were chosen for multivariable analysis on the basis of previous findings and clinical constraints (17). The variance inflation factor (VIF) was used to assess the multicollinearity between the predictor variables. All analyses were performed using SPSS 26.0 software (IBM Corp.). P<0.05 was considered to indicate a statistically significant difference.

Results

Demographic and clinical characteristics. A total of 3,260 patients with COVID-19 were enrolled in the present retrospective study, and 1,368 patients with incomplete data of various test indicators were excluded. The final sample included 1,892 patients, including 537 patients with and 1,355 patients without diabetes. There were 1,350 (71.4%) patients aged <80 years and 542 (28.6%) patients aged ≥80 years. There were 1,183 male patients (62.5%). The most common symptoms were fever (54.4%) and cough (61.5%), followed by fatigue (28.8%) and myalgia (9.1%). Patients had one or more complications, including hypertension (48.5%), coronary heart disease (25.9%) and cerebral infarction (25.0%). Based on the initial clinical data, the diagnosis of COVID-19 was classified as mild (8.6%), medium (30.6%), severe (46.0%) or critical (14.8%).

As presented in Table I, 34.08% of patients with diabetes were aged ≥80 years, and 68.16% of patients with diabetes were male, both of which were significantly higher compared with the proportion of the patients without diabetes. Patients with diabetes also had a significantly higher body mass index (BMI) compared with patients without diabetes. Furthermore, patients with diabetes had significantly higher rates of combined hypertension (69.60%), coronary heart disease (40.80%) and cerebral infarction (34.80%) compared with patients without diabetes. In addition, more patients with diabetes had severe (51.60%) and critical (16.20%) COVID-19 severity ratings compared with patients without diabetes. However, there were significantly more patients without diabetes with mild (9.40%) and medium (32.50%) COVID-19 severity ratings compared with patients with diabetes.

Laboratory findings and clinical outcomes. Table II presents the laboratory indicators at admission and the clinical outcomes of the patients. As presented in the Table II, compared with patients without diabetes, the levels of blood glucose, C-reactive protein, procalcitonin, creatinine, total bilirubin and plasma D-dimer were significantly increased in patients with diabetes. However, the absolute value of lymphocytes and albumin levels were significantly decreased in patients with diabetes compared with patients without diabetes. These results suggested that patients with COVID-19 and diabetes have more severe inflammatory responses and increased damage to the liver or kidneys compared with patients with COVID-19 without diabetes, which may contribute to the poorer prognosis of patients with COVID-19 and diabetes. In addition, 84.35% of patients with diabetes needed oxygen therapy, and 61.64% of patients required prone position treatment, which were significantly increased compared with that of patients without diabetes.

Regression analysis of COVID-19 severity. Multivariate logistic regression analysis was used to investigate the factors affecting the severity of COVID-19 among patients with COVID-19. The results presented in Table III demonstrate that compared with patients with mild COVID-19, the proportion of patients aged <80 years was significantly increased compared with those aged ≥80 years in the group of patients with medium COVID-19 (OR, 2.649; 95% CI, 1.458-4.812). Additionally, platelet count (OR, 1.004; 95% CI, 1.000-1.007) and total bilirubin (OR, 1.044; 95% CI, 1.001-1.089) were significantly increased in patients with medium COVID-19 compared with those of patients with mild COVID-19. The albumin (OR, 0.936; 95% CI, 0.886-0.989) in patients with

Table I. Baseline patient characteristics.

Characteristic	Patients with diabetes (n=537)	Patients without diabetes (n=1,355)	P-value
Age, n (%)			0.001
<80 years	354 (65.92)	996 (73.51)	
≥80 years	183 (34.08)	359 (26.49)	
Sex, n (%)			0.001
Male	366 (68.16)	817 (60.30)	
Female	171 (31.84)	538 (39.70)	
BMI, mean ± SD	23.05±3.21	22.62±3.63	0.008
BMI class, n (%)			0.017
Level 1	32 (6.10)	140 (10.49)	
Level 2	258 (49.14)	654 (48.99)	
Level 3	180 (34.29)	429 (32.13)	
Level 4	55 (10.48)	112 (8.39)	
dBP, M (P25, P75)	74.0 (67.00, 81.50)	76.00 (70.00, 83.00)	0.637
sBP, M (P25, P75)	134.00 (122.50, 146.50)	130.00 (117.00, 142.00)	<0.001
Hypertension, n (%)	374 (69.60)	543 (40.1)	<0.001
Coronary heart disease, n (%)	219 (40.80)	271 (20.00)	<0.001
Cerebral infarction, n (%)	187 (34.80)	286 (21.10)	<0.001
Fever, n (%)	293 (-54.56)	737 (54.39)	0.653
Cough, n (%)	343 (63.87)	820 (60.52)	0.094
Myalgia, n (%)	44 (8.19)	128 (9.45)	0.267
Fatigue, n (%)	164 (30.54)	381 (28.12)	0.639
COVID-19 severity, n (%)			<0.001
Mild	35 (6.50)	127 (9.40)	
Medium	138 (25.70)	441 (32.50)	
Severe	277 (51.60)	593 (43.80)	
Critical	87 (16.20)	194 (14.30)	

BMI, body mass index; dBP, diastolic blood pressure; sBP, systolic blood pressure; M, median; COVID-19, coronavirus disease 19.

medium COVID-19, albumin (OR, 0.915; 95% CI, 0.869-0.964) in patients with severe COVID-19 and albumin (OR, 0.859; 95% CI, 0.808-0.914) in patients with critical COVID-19 were significantly decreased compared with those of patients with mild COVID-19. Furthermore, the absolute value of lymphocytes (OR, 0.659; 95% CI, 0.463-0.937) in patients with critical COVID-19 were significantly decreased compared with those of patients with mild COVID-19. These results indicated that there was an association between the aforementioned measures and the severity of COVID-19.

Prognostic analysis of the outcome of COVID-19. Additionally, a retrospective analysis of various factors was conducted to determine which parameters were important for predicting the prognosis of patients with COVID-19. As presented in Table IV, multivariate logistic regression analysis was performed after potential factors such as age, sex, BMI rating, hypertension, coronary heart disease, diabetes and cerebral infarction were adjusted for. The data demonstrated that diabetes (OR, 10.294; 95% CI, 7.079-14.970) was an independent prognostic factor that affected the mortality of patients with COVID-19, which suggested that diabetes was a potential risk factor affecting the prognosis of COVID-19. Furthermore, prone position treatment could be used as a protective factor to reduce the mortality outcome of diabetes combined with COVID-19 (OR, 0.442; 95% CI, 0.298-0.656). The results presented in Table V demonstrated that an age of ≥80 years (OR, 1.633; 95% CI, 1.261-2.115), female sex (OR, 0.650; 95% CI, 0.507-0.835), cerebral infarction complications (OR, 1.448; 95% CI, 1.111-1.887) and a critical severity rating of COVID-19 (OR, 2.457; 95% CI, 1.512-3.991) were risk factors for a critical condition during hospitalization.

Discussion

The association between diabetes and infection is an important issue for clinicians. Previous studies have indicated that diabetes is a risk factor for morbidity and mortality from multiple viral infections, including influenza A (2009 H1N1), Middle East respiratory syndrome coronavirus and severe acute respiratory syndrome coronavirus (18-20). However, the association between diabetes and COVID-19 prognosis is currently controversial.

In the present retrospective study, data from 1,892 patients with COVID-19, including 537 patients with diabetes and 1,355 patients without diabetes were analyzed. First, the

Table II. Laboratory data, treatments and clinical outcomes of patients with coronavirus disease 2019.

Variable	Normal range	Patients with diabetes (n=537)	Patients without diabetes (n=1,355)	P-value
Routine blood cell count				
White blood cells, M (P25, P75)	3.50-9.50	6.14 (4.62, 7.81)	6.34 (4.68, 8.12)	0.192
Red blood cells, M (P25, P75)	4.30-5.80	3.97 (3.62, 4.41)	3.96 (3.55, 4.39)	0.872
Platelets, mean ± SD	125.00-350.00	184.60±89.69	192.99±91.26	0.065
Neutrophils, M (P25, P75)	1.80-6.30	4.30 (3.02, 6.12)	4.60 (3.14, 6.47)	0.554
Lymphocytes, M (P25, P75)	1.10-3.20	0.94 (0.63, 1.40)	1.04 (0.67, 1.50)	0.011
Hemoglobin, mean ± SD	130.00-175.00	120.40±20.28	120.92±21.08	0.782
Biochemical tests				
GPT, M (P25, P75)	9.00-50.00	17.00 (11.00, 26.50)	21.00 (13.00, 34.00)	0.475
GOT, M (P25, P75)	15.00-40.00	23.00 (14.00, 28.00)	23.00 (16.50, 38.50)	0.067
Total protein, mean ± SD	65.00-85.00	60.11±7.67	59.28±7.11	0.382
Albumin, mean ± SD	40.00-55.00	32.54±4.68	32.86±4.99	0.005
Total bilirubin, M (P25, P75)	0.00-23.00	10.70 (8.57, 14.75)	9.92 (6.29, 14.45)	0.004
Creatinine, M (P25, P75)	53.00-123.00	71.40 (54.30, 116.20)	66.00 (50.30, 87.10)	<0.001
Creatine kinase, M (P25, P75)	50.00-310.00	60.00 (43.50, 120.50)	58.00 (35.00, 121.00)	0.551
LDH, M (P25, P75)	15.00-65.00	44.20 (38.00, 59.70)	48.30 (41.45, 63.50)	0.371
Blood glucose, M (P25, P75)	3.90-6.10	8.92 (6.66, 13.52)	5.88 (4.92, 7.11)	<0.001
PaO_2, M (P25, P75)	80.00-100.00	82.00 (65.00, 100.50)	78.00 (66.50, 92.50)	0.601
SaO_2, M (P25, P75)	91.90-99.00	96.00 (92.65, 97.80)	95.50 (93.25, 97.40)	0.377
$PaCO_2$, mean ± SD	35.00-45.00	35.56±5.36	37.01±6.11	0.064
Other tests, M (P25, P75)				
C-reactive protein	<10.00	31.32 (10.00, 61.89)	24.43 (10.00, 57.40)	0.001
Ferritin	30.00-400.00	385.00 (219.50, 643.07)	397.71 (245.62, 702.00)	0.745
Procalcitonin	0.00-0.05	0.09 (0.05, 0.33)	0.09 (0.05, 0.21)	0.047
IL-6	<7.00	23.72 (1.56, 63.51)	10.42 (1.50, 47.64)	0.057
D-dimer	0.00-1.00	1.12 (0.77, 2.02)	1.11 (0.85, 2.65)	0.033
Prothrombin time	11.00-13.00	12.00 (11.45, 13.00)	12.20 (11.60, 13.05)	0.351
Need for oxygen, n (%)	-	453 (84.35)	1,080 (79.70)	<0.001
Need for prone position, n (%)	-	331 (61.64)	758 (55.94)	0.003
Clinical outcomes, n (%)				0.513
Mortality	-	25 (4.66)	54 (3.99)	
Alive	-	512 (95.34)	1,300 (96.01)	
Critical condition during hospitalization, n (%)				0.140
Yes	-	164 (30.54)	368 (27.16)	
No	-	373 (69.46)	987 (72.84)	
Days in the hospital, M (P25, P75)	-	14.00 (10.00, 19.50)	12.00 (9.00, 18.50)	0.068

GPT, glutamic pyruvic transaminase; GOT, glutamic oxaloacetic transaminase; LDH, lactate dehydrogenase; PaO_2, partial pressure of oxygen; $PaCO_2$, partial pressure of carbon dioxide; SaO_2, oxygen saturation; M, median.

demographic and clinical characteristics of the two groups of patients were compared. The results demonstrated that the proportion of elderly patients (patients aged ≥80 years) with diabetes was significantly increased compared with the proportion of elderly patients without diabetes. Age is one of the risk factors that affects the prognosis of COVID-19 (21). Therefore, an increased proportion of elderly patients with diabetes may indicate a poorer clinical outcome. The results also demonstrated that the proportion of male patients with diabetes was increased compared with the proportion of male patients without diabetes. The results of the multivariate regression analysis indicated that being male was one of the risk factors for critical illness in patients with COVID-19 during hospitalization. The aforementioned results suggested that the prognosis for a male patient with diabetes may be worse compared with that of a female patient with diabetes. Compared with patients without diabetes, an increase in the incidence of other metabolism-associated risk factors in patients with diabetes, including an increase in BMI, hypertension, coronary heart disease and cerebral infarction, is to

Table III. Univariate and multivariate regression analysis examining factors associated with the severity of COVID-19 among patients with COVID-19.

A, Medium COVID-19 severity

	Univariate analysis		Multivariate analysis	
Variable	OR (95% CI)	P-value	OR (95% CI)	P-value
Age, <80 years (vs. ≥80 years)	2.237 (1.498-3.343)	<0.001	2.649 (1.458-4.812)	0.001
Male sex (vs. female)	1.151 (0.812-1.632)	0.430	0.935 (0.560-1.561)	0.798
BMI level 1 (vs. level 4)	1.037 (0.452-2.377)	0.933	1.611 (0.512-5.064)	0.415
BMI level 2 (vs. level 4)	0.843 (0.455-1.560)	0.586	1.250 (0.540-2.895)	0.603
BMI level 3 (vs. level 4)	0.978 (0.509-1.880)	0.947	1.276 (0.526-3.096)	0.591
Platelets (vs. mild COVID-19)	1.003 (1.001-1.005)	0.011	1.004 (1.000-1.007)	0.023
Lymphocytes (vs. mild COVID-19)	1.034 (0.898-1.191)	0.643	0.946 (0.746-1.201)	0.649
Albumin (vs. mild COVID-19)	0.973 (0.940-1.007)	0.014	0.936 (0.886-0.989)	0.019
Total bilirubin (vs. mild COVID-19)	1.033 (1.006-1.061)	0.018	1.044 (1.001-1.089)	0.046
Creatinine (vs. mild COVID-19)	1.001 (0.999-1.002)	0.289	1.001 (0.999-1.003)	0.206
Prothrombin time (vs. mild COVID-19)	1.031 (0.945-1.126)	0.492	0.983 (0.887-1.089)	0.739
D-dimer (vs. mild COVID-19)	1.038 (0.983-1.096)	0.180	0.964 (0.901-1.032)	0.291
Procalcitonin (vs. mild COVID-19)	1.029 (0.964-1.099)	0.389	1.015 (0.948-1.086)	0.677
Blood glucose (vs. mild COVID-19)	0.991 (0.927-1.058)	0.781	0.974 (0.902-1.053)	0.511
Hypertension (vs. non-hypertension)	0.957 (0.672-1.364)	0.810	1.149 (0.660-2.000)	0.623
Coronary heart disease (vs. non-coronary heart disease)	1.202 (0.783-1.845)	0.400	0.765 (0.411-1.422)	0.397
Cerebral infarction (vs. non-cerebral infarction)	1.291 (0.846-1.969)	0.236	0.910 (0.496-1.671)	0.762

B, Severe COVID-19 severity

	Univariate analysis		Multivariate analysis	
Variable	OR (95% CI)	P-value	OR (95% CI)	P-value
Age, <80 years (vs. ≥80 years)	0.943 (0.655-1.358)	0.753	1.471 (0.862-2.511)	0.157
Male sex (vs. female)	1.850 (1.318-2.597)	<0.001	1.465 (0.909-2.363)	0.117
BMI level 1 (vs. level 4)	1.237 (0.549-2.787)	0.607	1.656 (0.565-4.855)	0.358
BMI level 2 (vs. level 4)	1.039 (0.567-1.902)	0.902	1.541 (0.703-3.375)	0.280
BMI level 3 (vs. level 4)	1.437 (0.759-2.721)	0.266	1.919 (0.840-4.383)	0.122
Platelets (vs. mild COVID-19)	1.003 (1.001-1.005)	0.003	1.005 (1.002-1.007)	0.002
Lymphocytes (vs. mild COVID-19)	0.809 (0.676-0.969)	0.021	0.908 (0.727-1.136)	0.399
Albumin (vs. mild COVID-19)	0.917 (0.887-0.949)	<0.001	0.915 (0.869-0.964)	0.001
Total bilirubin (vs. mild COVID-19)	1.019 (0.993-1.047)	0.158	1.035 (0.993-1.078)	0.108
Creatinine (vs. mild COVID-19)	1.001 (1.000-1.003)	0.074	1.001 (0.999-1.002)	0.476
Prothrombin time (vs. mild COVID-19)	1.026 (0.942-1.117)	0.558	0.947 (0.858-1.045)	0.280
D-dimer (vs. mild COVID-19)	1.028 (0.974-1.085)	0.322	0.973 (0.918-1.031)	0.351
Procalcitonin (vs. mild COVID-19)	1.027 (0.962-1.096)	0.421	0.999 (0.933-1.070)	0.988
Blood glucose (vs. mild COVID-19)	1.049 (0.986-1.115)	0.129	0.996 (0.928-1.069)	0.908
Hypertension (vs. non-hypertension)	0.624 (0.444-0.877)	0.007	0.866 (0.518-1.448)	0.584
Coronary heart disease (vs. non-coronary heart disease)	0.719 (0.481-1.076)	0.109	0.803 (0.453-1.425)	0.454
Cerebral infarction (vs. non-cerebral infarction)	0.764 (0.514-1.134)	0.182	0.841 (0.481-1.472)	0.545

C, Critical COVID-19 severity

	Univariate analysis		Multivariate analysis	
Variable	OR (95% CI)	P-value	OR (95% CI)	P-value
Age, <80 years (vs. ≥80 years)	0.541 (0.359-0.815)	0.003	1.383 (0.754-2.536)	0.295

Table III. Continued.

C, Critical COVID-19 severity

Variable	Univariate analysis		Multivariate analysis	
	OR (95% CI)	P-value	OR (95% CI)	P-value
Male sex (vs. female)	1.891 (1.272-2.813)	0.002	1.241 (0.710-2.170)	0.449
BMI level 1 (vs. level 4)	1.538 (0.618-3.830)	0.355	1.227 (0.3594.191)	0.744
BMI level 2 (vs. level 4)	0.945 (0.469-1.903)	0.874	1.107 (0.443-2.766)	0.827
BMI level 3 (vs. level 4)	1.114 (0.532-2.333)	0.774	1.438 (0.549-3.764)	0.460
Platelets (vs. mild COVID-19)	1.001 (0.999-1.003)	0.341	1.003 (1.000-1.006)	0.061
Lymphocytes (vs. mild COVID-19)	0.420 (0.316-0.558)	<0.001	0.659 (0.463-0.937)	0.002
Albumin (vs. mild COVID-19)	0.843 (0.810-0.877)	<0.001	0.859 (0.808-0.914)	<0.001
Total bilirubin (vs. mild COVID-19)	1.000 (0.968-1.032)	0.983	0.993 (0.945-1.043)	0.782
Creatinine (vs. mild COVID-19)	1.001 (0.999-1.002)	0.338	0.998 (0.996-1.000)	0.121
Prothrombin time (vs. mild COVID-19)	1.069 (0.979-1.167)	0.139	0.988 (0.887-1.101)	0.830
D-dimer (vs. mild COVID-19)	1.061 (1.005-1.120)	0.032	1.045 (0.989-1.105)	0.118
Procalcitonin (vs. mild COVID-19)	1.033 (0.967-1.104)	0.333	1.009 (0.940-1.082)	0.807
Blood glucose (vs. mild COVID-19)	1.106 (1.037-1.180)	0.002	1.059 (0.982-1.143)	0.137
Hypertension (vs. non-hypertension)	0.575 (0.389-0.851)	0.006	0.818 (0.451-1.485)	0.510
Coronary heart disease (vs. non-coronary heart disease)	0.455 (0.292-0.710)	0.001	0.533 (0.281-1.010)	0.054
Cerebral infarction (vs. non-cerebral infarction)	0.094 (0.683-0.437)	0.094	0.847 (0.449-1.601)	0.610

COVID-19, coronavirus disease 2019; BMI, body mass index; OR, odds ratio; CI, confidence interval. The variance inflation factor value of each variable was <5, which indicated that there was no multicollinearity between variables.

Table IV. Univariate and multivariate regression analysis examining factors associated with patient mortality among patients with COVID-19.

Variable	Univariate analysis		Multivariate analysis	
	OR (95% CI)	P-value	OR (95% CI)	P-value
Age, ≥80 years (vs. <80 years)	1.325 (0.997-1.761)	0.052	1.204 (0.826-1.753)	0.334
Female sex (vs. male)	0.784 (0.590-1.041)	0.092	0.805 (0.559-1.160)	0.244
BMI level 2 (vs. level 1)	1.273 (0.753-2.152)	0.368	1.157 (0.578-2.318)	0.680
BMI level 3 (vs. level 1)	1.331 (0.775-2.286)	0.300	1.411 (0.688-2.891)	0.347
BMI level 4 (vs. level 1)	1.578 (0.829-3.001)	0.165	1.441 (0.617-3.363)	0.399
Diabetes (vs. non-diabetes)	9.312 (6.888-12.587)	<0.001	10.294 (7.079-14.970)	<0.001
Hypertension (vs. non-hypertension)	1.932 (1.468-2.542)	<0.001	0.965 (0.666-1.397)	0.849
Coronary heart disease (vs. non-coronary heart disease)	2.135 (1.616-2.820)	<0.001	1.304 (0.908-1.874)	0.150
Cerebral infarction (vs. non-cerebral infarction)	1.692 (1.272-2.253)	<0.001	1.135 (0.780-1.652)	0.509
COVID-19 severity				
Medium (vs. mild)	0.863 (0.515-1.444)	0.574	0.725 (0.371-1.414)	0.345
Severe (vs. mild)	0.999 (0.612-1.629)	0.995	0.946 (0.505-1.771)	0.862
Critical (vs. mild)	1.026 (0.584-1.800)	0.930	1.017 (0.499-2.073)	0.964
Need for oxygen (vs. no need for oxygen)	1.244 (0.818-1.892)	0.308	1.073 (0.634-1.815)	0.793
Need for prone position (vs. no need for prone position)	0.737 (0.546-0.994)	0.045	0.442 (0.298-0.656)	<0.001
Critical condition during hospitalization (vs. non-critical condition during hospitalization)	1.008 (0.749-1.357)	0.956	0.865 (0.593-1.262)	0.452

COVID-19, coronavirus disease 2019; BMI, body mass index; OR, odds ratio; CI, confidence interval. The variance inflation factor value of each variable was <5, which indicated that there was no multicollinearity between variables.

Table V. Univariate and multivariate regression analysis examining factors associated with a critical condition during hospitalization among patients with COVID-19.

	Univariate analysis		Multivariate analysis	
Variable	OR (95% CI)	P-value	OR (95% CI)	P-value
Age, ≥80 years (vs. <80 years)	2.117 (1.711-2.621)	<0.001	1.633 (1.261-2.115)	<0.001
Female sex (vs. male)	0.598 (0.482-0.742)	<0.001	0.650 (0.507-0.835)	0.001
BMI level 2 (vs. level 1)	0.756 (0.534-1.068)	0.113	0.916 (0.609-1.377)	0.674
BMI level 3 (vs. level 1)	0.694 (0.483-0.997)	0.048	0.930 (0.604-1.430)	0.739
BMI level 4 (vs. level 1)	0.564 (0.349-0.911)	0.019	0.834 (0.477-1.457)	0.523
Diabetes (vs. non-diabetes)	1.003 (0.998-1.008)	0.268	1.047 (0.802-1.366)	0.736
Hypertension (vs. non-hypertension)	1.179 (0.947-1.468)	0.140	1.059 (0.822-1.363)	0.658
Coronary heart disease (vs. non-coronary heart disease)	1.288 (1.054-1.574)	0.014	0.895 (0.680-1.177)	0.426
Cerebral infarction (vs. non-cerebral infarction)	1.378 (1.103-1.721)	0.005	1.448 (1.111-1.887)	0.006
COVID-19 severity				
Medium (vs. mild)	0.748 (0.492-1.138)	0.175	0.884 (0.549-1.423)	0.612
Severe (vs. mild)	1.316 (0.889-1.947)	0.170	1.248 (0.804-1.937)	0.323
Critical (vs. mild)	3.061 (1.987-4.715)	<0.001	2.457 (1.512-3.991)	<0.001
Need for oxygen (vs. no need for oxygen)	2.269 (1.597-3.224)	<0.001	1.456 (0.981-2.161)	0.062
Need for prone position (vs. no need for prone position)	1.344 (1.060-1.705)	0.015	0.955 (0.721-1.266)	0.751

COVID-19, coronavirus disease 2019; BMI, body mass index; OR, odds ratio; CI, confidence interval. The variance inflation factor value of each variable was <5, which indicated that there was no multicollinearity between variables.

be expected (22). These complications were all significantly associated with a history of diabetes in the present study, suggesting that these risk factors may contribute to a poor prognosis of COVID-19 infection in patients with diabetes. In addition, the severity of COVID-19 in all patients was assessed, which revealed that there was an increased proportion of severe cases of COVID-19 in patients with diabetes compared with in patients without diabetes. This suggested that patients with diabetes were more likely to progress to severe disease after infection with COVID-19.

Previous studies have demonstrated that serum levels of inflammation-associated biomarkers, including IL-6, C-reactive protein and procalcitonin, are notably increased in patients with COVID-19, and are associated with the prognosis of the disease (23,24). Laboratory results at admission in the present study demonstrated that, compared with patients without diabetes, C-reactive protein and procalcitonin, which are associated with inflammatory responses, were significantly increased in patients with diabetes, while lymphocytes and albumin were significantly reduced in patients with diabetes. This suggested that the aforementioned parameters may reflect severe inflammation in the lungs and lead to the worsening of COVID-19. D-dimer is a degradation product of fibrin, which is one of the main markers of coagulation activity. High serum D-dimer concentration is associated with a variety of thrombotic diseases (25,26). In the present study, serum D-dimer concentrations were revealed to be significantly increased in patients with diabetes compared with patients without diabetes. This suggested that patients with COVID-19 and diabetes were more likely to develop a pre-thrombotic state of hypercoagulability.

Furthermore, a regression analysis between various factors at admission and the severity of COVID-19 was conducted, and the data indicated that platelets, albumin, total bilirubin and lymphocytes were significantly associated with the severity of COVID-19. This suggested that the changes of the aforementioned factors may serve a role in influencing the course of COVID-19. Therefore, monitoring these indicators may be of significance for disease diagnosis, disease grading and prognosis assessment.

Finally, prognostic factors of COVID-19 were investigated through regression analysis, which revealed that diabetes was significantly associated with poor outcomes of COVID-19. This indicated that diabetes was a potential risk factor affecting the prognosis of COVID-19. These findings emphasized the need for increased clinical attention to patients with diabetes and COVID-19. This could involve more vigilant monitoring, early intervention and possibly tailored treatment strategies for individuals with diabetes who become infected with COVID-19. In the present study, prone position treatment was revealed to act as a protective factor, reducing mortality from COVID-19. Additionally, the results of the present study demonstrated that patients aged ≥80 years, male, with cerebral infarction complications and a critical diagnosis of COVID-19 at admission were at high risk for critical illness during hospitalization. This information could aid healthcare providers in identifying individuals at an increased risk and in implementing appropriate interventions.

The present study has a number of limitations: i) This was a single-center retrospective study and further large-scale multicenter studies are needed to validate the findings of the present study; ii) due to the lack of consideration of diabetes

treatment drugs, the association between blood glucose control and COVID-19 outcomes cannot be demonstrated; and iii) the effects of vaccination and antiviral treatment were not considered in the present study (27,28). However, vaccination and antiviral treatment were comparable in patients with and without diabetes; therefore, the final results may not be impacted by this.

In conclusion, the present study benefited from a substantial sample size, which enhanced the reliability and generalizability of the findings. Additionally, the present study considered various demographic, clinical and laboratory parameters to investigate the association between diabetes and COVID-19 prognosis, thereby leading to a thorough analysis. The present study demonstrated that diabetes was significantly associated with the clinical outcome of COVID-19, which suggested that diabetes was an important factor affecting the prognosis of COVID-19. Therefore, managing and controlling blood sugar may have a positive impact on both the short and long-term prognosis of COVID-19. In the future, the association between the degree of diabetes control and the outcome of COVID-19 should be further characterized. Additionally, prospective intervention studies should be conducted in order to demonstrate whether controlling blood glucose levels could improve the prognosis of COVID-19.

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Availability of data and materials

The data generated in the present study may be requested from the corresponding author.

Authors' contributions

LS, XY, BC, XS, JW and CX contributed to the study conception and design. Data collection was performed by LS, XY and XS. Data analysis was performed by XY and BC. JW and CX collaborated in the discussion of the results. LS and XY confirm the authenticity of all the raw data. All authors read and approved the final manuscript.

Ethics approval and consent to participate

The present study was approved by the Ethics Committee of Shaanxi Provincial People's Hospital (approval no. 2023-R125). The requirement for patient consent was waived as the present study was retrospective.

Patient consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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