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ORIGINAL ARTICLE

The effect of diabetes mellitus on disease prognosis in COVID-19 patients

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Abstract

Background In this study, we aimed to evaluate and compare the clinical characteristics, laboratory findings, and outcomes of hospitalized patients with and without diabetes along with poorly vs. well-controlled diabetes.

Methods A total of 341 hospitalized patients with COVID-19 confirmed by RT-PCR and/or chest imaging suggestive of COVID-19 infection were retrospectively included in this study. The patients were divided into 2 groups as diabetic ($n=120$) and non-diabetic ($n=221$). Demographic data, symptoms, comorbidities, and laboratory values were recorded. The patients were classified according to the clinical stages defined by guidance of the WHO for COVID-19. The percentage of patients with severe disease was higher in diabetic group ($n=57$) 47.5% compared to non-diabetic group ($n=61$) 27.8% ($p=0.001$). The percentage of patients requiring oxygen therapy was significantly higher in 61 (51.2%) diabetic group than non-diabetic group 65 (29.4%) ($p=0.001$). The median duration of hospitalization in the diabetic group was 8 days [IQR 6–11.5] that was significantly higher than the non-diabetic group as 7 days [IQR 5–10] ($p=0.009$). The median duration of hospitalization in poorly controlled diabetic group was 9 days [IQR 6.00–16.00] that was significantly higher than well-controlled diabetic group 8 days [IQR 6.00–11.00] ($p=0.006$).

Results Patients with diabetes were more susceptible to COVID-19 infection and the infection was more severe in patients with diabetes compared to patients without diabetes. However, the mortality rate was similar between diabetic and non-diabetic group. Diabetic COVID-19 patients without other comorbidities were not prone to severe infection.

Conclusion Patients with diabetes and comorbidities, apart from the glycemic control, should receive intensive monitoring and disease management.

Keywords COVID-19 · Death · Diabetes · HbA1c · Mechanical ventilation

Introduction

The coronavirus disease 2019 (COVID-19), caused by severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2), has lead to more than 130 million cases and 2,900,000 deaths worldwide by April 2021. In previous studies, patients with diabetes were found to be more susceptible to COVID-19. The prevalence of diabetes was 8%, hypertension 17%, and cardiovascular disease 5% in patients infected with COVID-19 as reported in a metanalysis [1, 2]. The infection was more severe and mortality was higher in patients with diabetes [3, 4]. Wang et al. and Wu et al. found that diabetic patients with COVID-19 were prone to severe and critical disease [5–7]. However, in another meta-analysis, there was no correlation between the severity of disease and diabetes [5, 8]. In fact, diabetes itself is a chronic inflammatory condition. Hyperglycemia and insulin resistance promote increased synthesis of glycosylation end products (AGEs) and proinflammatory cytokines, oxidative stress, and adhesion molecules leading to tissue inflammation [9]. In addition to marked inflammatory response, increased levels of clotting factors and inhibition of fibrinolysis promote the development of a hypercoagulable prothrombotic state in type 2 diabetes [9].

Although some studies suggested that, diabetes, especially, poorly controlled diabetes was associated with worse

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outcome and higher mortality [1, 3, 10], other studies showed that patients with well-controlled or poorly controlled diabetes did not differ significantly in terms of clinical outcomes [11]. Therefore, the data regarding the role of glycemic control in the prognosis of COVID-19 infection is conflicting and risk factors affecting the clinical progression and outcome are still a matter of debate. Also, it is difficult to decide whether diabetes itself increases susceptibility and impacts outcomes from infections or the cardiovascular and renal comorbidities that are frequently associated with diabetes are the main factors involved [9]. In this study, we aimed to evaluate and compare the clinical characteristics, laboratory findings, and outcomes of hospitalized patients with and without diabetes along with poorly vs. well-controlled diabetes from a single center in Turkey.

Materials and methods

This retrospective study included 341 consecutive patients with COVID-19 infection that were hospitalized in the pandemic wards of Tepecik Research and Training Hospital, admitted between March 1, 2020 and May 31, 2020. All COVID-19 patients were diagnosed in acoordance with the WHO interim guidance. The clinical outcomes of all these patients were monitored. The patients were classified according to the clinical stages defined by interim guidance of the WHO for COVID-19 [12]. The clinical stages were mild, moderate, severe, and critical [12, 13]. During hospitalization period, the most advanced clinical stages of the patients were accepted for classification. Mild and moderate cases were defined as non-severe group without signs of hypoxia and pneumonia, inspite of having cough, dyspnea, and fever having blood oxygen saturation (SpO_2) > 90%. Severe and critical stages were defined as severe group. For the diagnosis of severe cases, at least one of the criteria should be included: dyspnea with a respiratory rate > 30 breaths/min, blood oxygen saturation $SpO_2 \leq 90\%$, and with progression in lesion of more than 50% within 24–48 h in chest imaging. Critical cases were respiratory failure with mechanical ventilation need, shock, and dysfunction of other organs requiring ICU care [12]. Diabetic patients were identified based on patient's self-report or medical records confirmed by endocrinologist. Diagnosed diabetes was defined according to the WHO diagnostic criteria of fasting plasma glucose ≥ 126 mg/dl [12]. Antidiabetic medications before hospitalization and during hospitalization were recorded from electronic medical record system. Cases with hemoglobin A1c (HbA1C) levels > 7% were classified as poorly controlled while those with ≤ 7% were regarded as well-controlled.

Laboratory values of patients in the first 24 h of admission to hospital were evaluated. Complete blood count analysis was performed using UniCel DxH 800 hematology analyzer (Beckman Coulter, Miami, FL, USA). Glucose, creatinine, alanine aminotransferase (ALT), aspartate aminotransferase (AST), ferritine, uric acid, C-reactive protein (CRP), and lipid parameters were measured by enzymatic methods using an AU5800 autoanalyzer (Beckman Coulter, High Wycombe, UK). For high-sensitive troponin I (hs-TNI) procalcitonin, ADVIA Centaur XP immunoassay analyzer (Siemens Healthineers, Erlangen, Germany) was used. Prothrombin time (PT) and activated partial prothrombin time (APTT), fibrinogen, and d-dimer were measured by CS 2500 ACL coagulation analyzer system (Sysmex Corporation, Kobe, Japan), and hemoglobin A1c (HbA1C) were analyzed by autoanalyzer HPLC variant II (Bio-Rad Laboratories, CA, USA). Diagnosis of COVID-19 was confirmed by real-time polymerase chain reaction (RT-PCR) (Bio-Speedy COVID-19 RT-qPCR, Bioeksen R&D Technologies Ltd., İstanbul).

Continuous variables were presented as mean ± standart deviation (SD) or median and interquartile range (IQR). Categorical variables were expressed as frequencies and percentages (%). Chi-square test was applied to compare categorical variables and Student-*t* test and Mann–Whitney *U* test were used for the comparison of continuous variables. For more than two-group comparisons of continuous variables, ANOVA was used. $P < 0.05$ was considered statistically significant. Statistical analysis was performed with the SPSS 24 statistical software.

Results

A total of 341 hospitalized patients with COVID-19 confirmed by RT-PCR and/or chest imaging suggestive of COVİD-19 infection were retrospectively included in this study. Among these patients, 120 cases (35.2%) had diabetes mellitus, and 221 did not have diabetes. The demographic and clinical characteristics of patients with and without diabetes are shown in Table 1.

Laboratory values, treatments, and clinical outcomes are shown in Table 2. Although the percentage of patients that need oxygen treatment was significantly higher in the diabetic 61 (51.2%) compared to non-diabetic group 65 (29.4%) ($p = 0.001$), the need for invasive mechanical ventilation was similar. According to clinical staging, the percentage of patients with severe disease was higher in the diabetic group ($n = 57$) 47.5% compared to non-diabetic group ($n = 61$) 27.8% ($p = 0.001$). The median duration of hospitalization in the diabetic group was 8 days [IQR 6–11.5] that was significantly higher than the non-diabetic group 7 days [IQR 5–10] ($p = 0.009$). The mortality rate was similar between the diabetic and non-diabetic individuals.

Table 1 Clinical characteristics of hospitalized COVID-19 patients

	Diabetes (120)	Non-diabetes (221)	*p*-value
Age (median, IQR)	60 (49–71)	49 (36–62)	0.001
Sex (M/F) (*n*)	62/58	124/97	0.302
Fever (*n*)%	76 (63.9%)	132 (60%)	0.880
Cough (*n*)%	60 (50.8%)	103 (46.6%)	0.644
Dyspnea (*n*)%	38 (32%)	65 (29.7%)	0.660
Fatigue (*n*)%	36 (30.1%)	58 (26.2%)	0.445
Myalgia (*n*)%	60 (50.8%)	103 (46.6%)	0.644
Taste/smell loss (*n*)%	5 (3.8%)	4 (1.6%)	0.291
Sore throat (*n*)%	16 (13.1%)	24 (11%)	0.553
Chest pain (*n*)%	4 (3.2%)	2 (0.8%)	0.165
Hypertension (*n*)%	84 (70.5%)	75 (33.8%)	0.001
CVD (*n*)%	30 (25.4%)	25 (11.6%)	0.001
Pulmonary disease (*n*)%	11 (9.0%)	15 (6.8%)	0.470
CKD (*n*)%	12 (9.8%)	82 (3.7%)	0.02
CLD (*n*)%	1 (0.9%)	2 (0.8%)	0.929
Thyroid disease (*n*)%	7 (5.7%)	16 (7.3%)	0.580
Rheumatic disease (*n*)%	2 (1.6%)	2 (0.9%)	0.551

P values indicate differences between diabetes and non-diabetes patients; $P < 0.05$ was considered statistically significant

CVD cardiovascular disease, *CKD* chronic kidney disease, *CLD* chronic liver disease

The percentage of patients that need oxygen treatment or invasive mechanical ventilation was similar between well-controlled and poorly controlled diabetic groups (Table 3).

Discussion

In this retrospective study that included 341 patients, we evaluated the clinical characteristics, laboratory parameters, and clinical outcomes of patients with COVID-19 infection. All these parameters were compared between COVID-19 patients with diabetes mellitus and without diabetes mellitus. Also we evaluated them in both well-controlled and poorly controlled diabetic subgroups.

Recent data propose that patients with diabetes, hypertension, and cardiovascular disease are more prone to COVID-19 infection. In a meta-analysis that included 46,248 COVID-19 patients, the prevalence of diabetes, hypertension, and cardiovascular disease were 8%, 17%, and 5%, respectively [2, 5]. However in an Italian study, the prevalence of diabetes was 35% [5, 14]. Likewise, in our study cohort, the prevalence of diabetes, hypertension, and cardiovascular disease were 35.2%, 46.5%, and 15.8%, respectively. The difference from the results of the above-mentioned meta-analysis might be explained by that, in our hospital generally COVID-19 patients with comorbidities were hospitalized.

In case of clinical features of COVID-19 infection such as dry cough, fever, dyspnea, chest pain, sore throat, headache, fatigue, myalgia, and loss of smell and taste, diabetic and non-diabetic patients were similar [3, 15]. Also, in our study, these symptoms were similar between diabetics and non-diabetics.

Diabetic patients with COVID-19 were found to have higher neutrophil and leucocyte and decreased lymphocyte count in previous studies. It was suggested that these findings might result from that diabetic patients had more severe viral infection and were more susceptible to bacterial infections [4, 15]. Also, inflammatory markers such as CRP and erythrocyte sedimentation rate were more pronounced in diabetic patients [9, 10]. In consistence with these findings, in our study, we observed higher neutrophil and leucocyte counts and CRP levels in diabetic patients. In addition, we found increased ferritine levels that was again the result of severe infection and increased fibrinogen levels that might reflect the hypercoagulable state that might be derived from systemic activation of coagulation cascade due to the severe viral infection [5, 16].

While in some studies diabetes mellitus was found to be associated with more severe or critical COVID-19 infection [5, 8], other studies found that odds ratio for severe COVID-19 infection was not higher in diabetic patients compared to non-diabetic [2, 5, 10]. In diabetes mellitus, in addition to usual mechanisms such as impaired neutrophil chemotaxis and phagocytosis, some specific factors were proposed to be responsible for severe COVID-19 infection: increased ACE-2 expression, increased furin which is a type-1 membrane-bound protease and involved in the entry of coronaviruses into the cell, impaired T-cell function, and increased ınterleukin-6 (IL-6) [5]. The higher rate of severe disease in patients with diabetes was attributed to higher incidence of complications and coexistence of other comorbidities, especially obesity and hypertension. Even, further analysis revealed that diabetic patients without these comorbidities were also more susceptible to severe disease and death compared to on-diabetics [10]. In our study, we found that the percentage of patients with severe disease was higher in diabetic group compared to non-diabetic group. However, in contrast to previous findings, after excluding the patients with hypertension and/or cardiovascular disease in diabetic group, we found no difference between the two groups in terms of clinical outcomes. This might be explained by that, in our study we did not evaluate obesity which would affect the results.

The data about the mortality of diabetic patients with COVID-19 is conflicting. Whereas it was reported to be higher in some studies [17–19], it was similar between diabetics and non-diabetics in other studies [7, 20]. Whereas mortality rate was reported to be around 2%, in our study it was 1.1%. This can be explained by the mean lower age in our study population [7, 20].

Table 2 Laboratory findings, treatments, and clinical outcomes of hospitalized COVID-19 patients

	Diabetes (120)	Non-diabetes (221)	*p*-value
WBC 10^3/μL (median, IQR)	7.40 (5.25–10.40)	7 (5.20–8.80)	0.739
Neutrophil, 10^3/μL (median, IQR)	4.85 (3.62–8.17)	4.30 (3.00–6.10)	0.016
Lymphocyte, 10^3/μL (median, IOR)	1.40 (1.00–1.90)	1.40 (1.00–2.10)	0.308
Platelet 10^3/Ul (median, IQR)	23 (188.75–318.75)	205 (161.00–253.00)	0.001
Hemoglobin, g/dL (median, IQR)	12.65 (11.12–14.37)	13.70 (12.50–14.90)	0.001
Procalcitonin, μg/L (median, IQR)	0.06 (0.01–0.31)	0.03 (0.01–0.08)	0.818
PTR, second (median, IQR)	12.60 (12.00–13.10)	12.50 (11.80–13.50)	0.553
APTT, second (median, IQR)	25.30 (23.30–27.20)	24.80 (23.90–27.70)	0.155
CRP, mg/L (median, IQR)	40.45 (7.45–101.55)	12.90 (4.90–52.95)	0.001
LDH, U/L (median, IQR)	243 (184–309.50)	251 (203.50–299.0)	0.774
Ferritin, g/L (median, IQR)	175.10 (67.50–409.7)	98.0 (55.0–241.0)	0.010
Fibrinogen mg/dL (median, IQR)	427.60 (341.1–518.6)	368.6 (280.60–444.1)	0.011
D-dimer, μg/L (median, IQR)	640 (430–1410)	610 (310–1200)	0.760
Troponin, ng/L (median, IQR)	2.83 (0.17–10.56)	2.50 (0.19–5.50)	0.137
Antibiotic therapy (*n*)%	94 (78.60%)	157 (70.90%)	0.071
Anti-viral therapy (*n*)%	69 (57.90%)	122 (55.20%)	0.168
Chloroquine therapy (*n*)%	110 (92.10%)	209 (94.90%)	0.394
Oxygen inhalation (*n*)%	61 (51.20%)	65 (29.40%)	0.001
Invasive MV therapy (*n*)%	12 (9.80%)	11 (4.90%)	0.068
Severe disease (*n*)%	57 (47.50%)	61 (27.80%)	0.001
Hospital stay, day (median, IQR)	8 (6.0–11.50)	7 (5.0–10.0)	0.009
Death (*n*)%	2 (4.20%)	2 (2.80%)	0.479

P values indicate differences between diabetes and non-diabetes patients; $P < 0.05$ was considered statistically significant

WBC white blood cell, *PTR* prothrombin time, *APTT* activated partial thromboplastin time, *CRP* C-reactive protein, *LDH* lactate dehydrogenase, *MV* mechanical ventilation

Recently, the clinical outcomes of well-controlled and poorly controlled diabetic patients with COVID-19 were also evaluated. Zhu et al. reported that well-controlled diabetic patients had lower death rate, compared with poorly controlled diabetics [21]. However, CORONADO study and Raoufi et al. found no association between HbA1C and death rate [11, 22]. The authors suggested that, these inconsistent results might arise from that acute viral infections lead to decreased insulin sensitivity and increased fasting plasma glucose levels even in diabetic patients with HbA1C < 7%. In our study, we also found no difference in terms of clinical outcomes in well-controlled vs. poorly controlled diabetic patients. This might suggest that diabetes with other comorbidities is associated with severe COVID-19 infection irrespective of glycemic control.

This study had limitations; since the data were collected retrospectively from electronic medical records of our hospital, information about the body mass index was absent. However, the large sample size was the strength of the study.

Table 3 Clinical characteristics, laboratory parameters, and treatments of the diabetic patients with COVID-19

	Well-controlled diabetes (30)	Poorly controlled diabetes (90)	*p*-value
Age (median, IQR)	56 (49.25–70.25)	61 (48–72)	0.925
Sex (male/female) (*n*)	14/16	48/42	0.567
Hypertension (*n*)%	23 (77.80%)	59 (65.90%)	0.249
CVD (*n*)%	7 (22.20%)	24 (26.80%)	0.874
CKD (*n*)%	3 (11.10%)	9 (10.70%)	0.452
Pulmonary disease (*n*)%	3 (11.0%)	6 (7.30%)	0.584
WBC 10^3/μL (median, IQR)	7.15 (4.57–10.20)	7.50 (5.90–12.30)	0.912
Neutrophil, 10^3/μL (median, IQR)	4.25 (2.62–8.10)	5.20 (3.70–9.20)	0.950
Lymphocyte, 10^3/μL (median, IQR)	1.40 (1.00–1.77)	1.30 (0.90–2.00)	0.644
Platelet 10^3/μL (median, IQR)	215 (166–303)	244 (194.25–352.25)	0.503
Hemoglobin, g/dL (median, IQR)	13.0 (11.10–14.50)	12.60 (11.25–13.95)	0.847
Procalcitonin, μg/L (median, IQR)	0.03 (0.01–0.06)	0.08 (0.04–0.24)	0.886
PTR, second (median, IQR)	12.60 (12.10–13.70)	12.60 (12.10–13.10)	0.048
APTT, second (median, IQR)	26.10 (23.90–27.20)	24.70 (22.80–27.40)	0.027
CRP, mg/L (median, IQR)	11 (2.45–136.37)	40.10 (7.31–112.60)	0.667
LDH, U/L (median, IQR)	259 (201.25–450.75)	231 (199–295.0)	0.183
Ferritin, g/L (median, IQR)	115.01 (31.50–450)	211.40 (75.30–450.0)	0.268
Fibrinogen mg/dL (median, IQR)	423.4 (341.7–506.0)	441.60 (379.1–529.4)	0.846
D-dimer, μg/L (median, IQR)	450 (420–1520)	660 (445–1375)	0.686
Troponin, ng/L (median, IQR)	3.02 (0.01–11.12)	4.49 (0.02–12.94)	0.537
Antibiotic therapy (*n*)%	25 (85.20%)	69 (76.80%)	0.626
Anti-viral therapy (*n*)%	23 (77.40%)	52 (58.20%)	0.268
Chloroquine (*n*)% therapy	27 (92.60%)	82 (91.50%)	0.259
Oxygen inhalation (*n*)%	17 (55.60%)	42 (46.30%)	0.556
Invasive MV therapy (*n*)%	3 (11.10%)	10 (11.0%)	0.452
Severe disease (*n*)%	17 (55.60%)	42 (46.30%)	0.556
Hospital stay, day (*n*)%	8 (6.0–11.0)	9 (6.0–16.0)	0.006
Death (*n*)%	1 (3.70%)	3 (4.10%)	0.693

P values indicate differences between well-controlled diabetes and poorly controlled diabetes patients; $P < 0.05$ was considered statistically significant

CVD cardiovascular disease, *CKD* chronic kidney disease, *WBC* white blood cell, *PTR* prothrombin time, *APTT* activated partial thromboplastin time, *CRP* C-reactive protein, *LDH* lactate dehydrogenase, *MV* mechanical ventilation

Conclusions

In conclusion, patients with diabetes were more susceptible to COVID-19 infection and the infection was more severe in patients with diabetes compared to patients without diabetes. However, the mortality rate was similar between diabetic and non-diabetic group. Diabetic COVID-19 patients without other comorbidities were not prone to severe infection. Considering the patients with diabetes mellitus, clinical outcomes were similar between well-controlled and poorly controlled diabetic subgroups. Patients with diabetes and comorbidities, apart from the glycemic control, should receive intensive monitoring and disease management.

Declarations

Ethics approval The study was approved by the local ethics committee of Tepecik Research and Training Hospital (Decision Date: 25.01.2021; Decision No: 82021/01–13).

Conflict of interest The authors declare no competing interests.

References

1. Conway J, Gould A, Westley R et al (2020) Characteristics of patients with diabetes hospitalised for COVID-19 infection-a brief case series report. Diabetes Res Clin Pract 169:108460. https://doi.org/10.1016/j.diabres.2020.108460
2. Yang J, Zheng Y, Gou X et al (2020) Prevalence of comorbidities and its effects in patients infected with SARS-CoV-2: a systematic review and meta-analysis. Int J Infect Dis 94:91–95. https://doi.org/10.1016/j.ijid.2020.03.017
3. Zhang N, Wang C, Zhu F et al (2020) Risk factors for poor outcomes of diabetes patients with COVID-19: a single-center, retrospective study in early outbreak in China. Front Endocrinol 11:571037. https://doi.org/10.3389/fendo.2020.571037
4. Guo W, Li M, Dong Y et al (2020) Diabetes is a risk factor for the progression and prognosis of COVID-19. Diabetes Metab Res Rev 31:e3319. https://doi.org/10.1002/dmrr.3319
5. Singh AK, Gupta R, Ghosh A, Misra A (2020) Diabetes in COVID-19: prevalence, pathophysiology, prognosis and practical considerations. Diabetes Metabolic Syndrome 14:303–310. https://doi.org/10.1016/j.dsx.2020.04.004
6. Wang D, Hu B, Hu C et al (2020) Clinical characteristics of 138 hospitalized patients with 2019 novel coronavirus-ınfected pneumonia in Wuhan. China JAMA 323:1061–1069. https://doi.org/10.1001/jama.2020.1585
7. Wu C, Chen X, Cai Y et al (2020) Risk factors associated with acute respiratory distress syndrome and death in patients with coronavirus disease 2019 pneumonia in Wuhan. China JAMA 180:934–943. https://doi.org/10.1001/jamainternmed.2020.0994
8. Chen Y, Gong X, Guo J (2020) Effects of hypertension, diabetes and coronary heart disease on COVID-19 diseases severity: a systematic review and meta-analysis (preprints). https://doi.org/10.1101/2020.03.25.20043133
9. Hussain A, Bhowmik B, do Vale Moreira NC (2020) COVID-19 and diabetes: knowledge in progress. Diab Res Clin Pract 162:108142. https://doi.org/10.1016/j.diabres.2020.108142
10. Akbariqomi M, Hosseini MS, Rashidiani J et al (2020) Clinical characteristics and outcome of hospitalized COVID-19 patients with diabetes: a single-center, retrospective study in Iran. Diabetes Res Clin Pract 169:108467. https://doi.org/10.1016/j.diabres.2020.108467
11. Raoufi M, Khalili S, Mansouri M et al (2020) Well-controlled vs poorly-controlled diabetes in patients with COVID-19: are there any differences in outcomes and imaging findings? Diabetes Res Clin Pract 166:108286. https://doi.org/10.1016/j.diabres.2020.108286
12. World Health Organization (2020_ Clinical management of COVID-19: interim guidance. 27. https://www.apps.who.int/iris/handle/10665/332196. (Access date: 24 Apr 2021)
13. Cordon-Cardo C, Pujadas E, Wajnberg A et al (2020) COVID-19: staging of a new disease. Cancer Cell 38:594–597. https://doi.org/10.1016/j.ccell.2020.10.006
14. Onder G, Rezza G, Brusaferro S (2020) Case-fatality rate and characteristics of patients dying in relation to COVID-19 in Italy. JAMA 323:1775–1776. https://doi.org/10.1001/jama.2020.4683
15. Huang C, Wang Y, Li X et al (2020) Clinical features of patients infected with 2019 novel coronavirus in Wuhan. China Lancet 395(10223):497–506. https://doi.org/10.1016/S0140-6736(20)30183-5
16. Yan Y, Yang Y, Wang F et al (2020) Clinical characteristics and outcomes of patients with severe covid-19 with diabetes. BMJ Open Diabetes Res Care 8:e001343. https://doi.org/10.1136/bmjdrc-2020-001343
17. Guan WJ, Ni ZY, Hu Y et al (2020) Clinical characteristics of coronavirus disease 2019 in China. N Engl J Med 382:1708–1720. https://doi.org/10.1056/NEJMoa2002032
18. Yang X, Yu Y, Xu J et al (2020) Clinical course and outcomes of critically ill patients with SARS-CoV-2 pneumonia in Wuhan, China: a single-centered, retrospective, observational study. Lancet Respir Med 8:475–481. https://doi.org/10.1016/S2213-2600(20)30079-5
19. Chen T, Wu D, Chen H et al (2020) Clinical characteristics of 113 deceased patients with coronavirus disease 2019: retrospective study. BMJ 31(368):m1295. https://doi.org/10.1136/bmj.m1091
20. Zhou F, Yu T, Du R et al (2020) Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: a retrospective cohort study. Lancet 28:395(10229):1038. https://doi.org/10.1016/S0140-6736(20)30566-3
21. Zhu L, She ZG, Cheng X et al (2020) Association of blood glucose control and outcomes in patients with COVID-19 and preexisting type 2 diabetes. Cell Metab 31(6):1068–1077.e3. https://doi.org/10.1016/j.cmet.2020.04.021
22. Cariou B, Hadjadj S, Wargny M et al (2020) CORONADO investigators. Phenotypic characteristics and prognosis of inpatients with COVID-19 and diabetes: the CORONADO study. Diabetol 63:1500–1515. https://doi.org/10.1007/s00125-020-05180-x