Disease and Diagnosis

Dis Diagn. 2023; 12(3):118-123

doi 10.34172/ddj.2023.471

Original Article

Evaluation of Laboratory Diagnostic Markers in Diabetic Patients With COVID-19

Hasan Maredi[1], Naser Kamyari[2], Maryam Ban[3], Khadijeh Kanani[4], Sara Mobarak[5], Esmat Radmanesh[6*]

[1]Student Research Committee, Abadan University of Medical Sciences, Abadan, Iran
[2]Department of Public Health, School of Health, Abadan University of Medical Sciences, Abadan, Iran
[3]School of Nursing, Abadan University of Medical Sciences, Abadan, Iran
[4]Clinical Research Development Unit, Taleghani Educational Hospital, Abadan University of Medical Sciences, Abadan, Iran
[5]Department of Infectious Diseases, School of Medicine, Abadan University of Medical Sciences, Abadan, Iran
[6]Department of Physiology, Abadan University of Medical Sciences, Abadan, Iran

Abstract

Background: Diabetes mellitus is the most common chronic metabolic disorder that increases both susceptibility and mortality rates in patients with the coronavirus disease 2019 (COVID-19). We conducted a study on diabetic patients with COVID-19 to investigate the relationship between laboratory indicators and peripheral oxygen saturation (SPO_2).

Materials and Methods: In this analytical-cross-sectional study, the required information of diabetic patients with COVID-19 admitted to Taleghani educational hospital in Abadan from March 20, 2020 to March 19, 2021 was obtained by referring to the hospital information system of Abadan University of Medical Sciences and patient files.

Results: Two hundred patients were studied, of which 88 (44%) were men and 112 (56%) were women. The mean age of the studied patients was 60.57 ± 14.84. Among all the investigated markers, blood urea nitrogen (BUN), serum glutamate oxalate transaminase (SGOT), serum glutamic-pyruvic transaminase (SGPT), erythrocyte sedimentation rate (ESR), C-reactive protein (CRP), lactate dehydrogenase (LDH), and respiratory rate (RR) were higher than the normal range, while SPO_2 was lower than the normal range. Based on the linear regression analysis results, a significant relationship was observed between the decrease in SPO_2 of patients with disease outcome, duration of hospitalization in the intensive care unit ($P<0.001$), RR ($P<0.001$), mean corpuscular volume (MCV) ($P=0.02$), CRP + 3 ($P=0.002$), platelet (PTT) ($P=0.03$), alkaline phosphatase (ALP) ($P=0.002$), and LDH ($P=0.003$).

Conclusion: The results showed that some laboratory diagnostic markers were higher than the normal range, while SPO_2 was lower than the normal range. Moreover, a significant relationship was found between SPO_2 index and disease outcome, duration of hospitalization in intensive care unit (ICU), and some diagnostic markers of the liver, inflammation, and coagulation.

Keywords: Renal markers, Diabetes, SPO_2

***Correspondence to**
Esmat Radmanesh,
Emails:
esmatradmanesh33@gmail.com, e.radmanesh@abadanums.ac.ir

Received: December 26, 2022, **Accepted:** February 12, 2023, **ePublished:** May 3, 2023

Introduction

The prevalence of diabetes has been steadily increasing over the past few decades. Diabetes, a chronic metabolic disease, occurs when the pancreas does not produce enough insulin, or the body cannot effectively use the produced insulin. It is characterized by an increase in blood glucose levels (1,2). Diabetes is the seventh leading cause of death in the United States and one of the leading causes of death in Iran (3). It is increasing among working-age people in developing countries as well as elderly people in developed countries (4).

Patients with diabetes are more susceptible to viral and bacterial infections, and one of these infections affecting the respiratory system is the pandemic coronavirus disease 2019 (COVID-19) (5). Corona disease is a disease caused by the acute respiratory syndrome of the coronavirus 2, which causes significant mortality in humans. Obesity, old age, hypertension, and diabetes significantly increase the risk of hospitalization and death in these patients (6). Diabetes is a serious risk factor for progression to acute respiratory distress syndrome and mortality in hospitalized patients with COVID-19 (7). So far, the COVID-19 disease has infected more than 603 million people worldwide and more than 7 million people in Iran (8).

There is a relationship between COVID-19 and

© 2023 The Author(s). This is an open access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

diabetes in that diabetes is associated with an increased risk of severe COVID-19, and on the other hand, sudden diabetes and severe metabolic complications of diabetes such as diabetic ketoacidosis have been observed in patients with COVID-19 (9). The most important mechanisms that cause immune system dysfunction in diabetics are reduced chemotaxis, reduced production of interleukins in response to infection, immobility of polymorphonuclear leukocytes, and reduced phagocytic activity (10-12).

Diabetes mellitus is associated with increased severity of COVID-19 and increased mortality; accordingly, diabetes-related complications (e.g., cardiovascular disease and chronic kidney disease) increase COVID-19 mortality. In addition to paying attention to clinical findings and the relationship between COVID-19 and diabetes, Paraclinical evaluations in these patients are necessary and valuable. Paraclinical examinations play an important role in the diagnosis, treatment, and evaluation of the patient's condition; therefore, laboratory tests should be done on them (13-17).

Since coronavirus 2 has the ability and potential to damage various vital organs such as the liver and kidneys, the analysis of various clinical and laboratory markers such as renal, liver, biochemical, hematologic, and inflammatory markers makes the performance of these organs better evaluated and avoids damage to these organs. Accordingly, this study was conducted on diabetic patients with COVID-19 to investigate the relationship between peripheral oxygen saturation (SPO2) and laboratory indicators such as renal, liver, biochemical, hematologic, and inflammatory markers.

Materials and Methods

The current research is a cross-sectional analytical study in which the information on 200 hospitalized diabetic patients with COVID-19 was obtained from March 20, 2020 to March 19, 2021 by referring to the hospital information system of Taleghani educational hospital in Abadan, Iran. The age range of patients was 13 to 96 years. The information included hematologic factors, including lymphocytes, white blood cells, red blood cells, mean corpuscular volume (MCV), mean corpuscular hemoglobin, mean corpuscular hemoglobin concentration, platelets, coagulation factors (prothrombin time, partial thromboplastin time [PTT], and international normalized ratio), liver factors (alkaline phosphatase [ALP], total bilirubin, direct bilirubin, lactate dehydrogenase [LDH], serum glutamate oxalate transaminase [SGOT], and serum glutamic-pyruvic transaminase [SGPT]), and renal factors such as blood urea nitrogen (BUN), creatinine (Cr), serum sodium, and serum potassium. Information was sorted based on gender, age, and date of admission, and then duplicate data was removed, and the information was recorded in Excel software.

The inclusion criteria in this study included diabetic patients with COVID-19 who were admitted to Taleghani educational hospital in Abadan, Iran, and information about their laboratory diagnostic markers such as liver, kidney, cardiac, and coagulation markers was available in hospital information system. Patients with nasopharyngeal swabs positive for severe acute respiratory syndrome coronavirus 2 in reverse transcription polymerase chain reaction and with fasting blood sugar above 120 mg/dL were included. If this information was incomplete or unavailable, these patients were excluded from the study.

To describe the data, mean and standard deviation were used for quantitative variables, and frequency and percentage were used for qualitative variables. Further, the normality of quantitative variables was checked using the Kolmogorov-Smirnov test. Multiple linear regressions were also run to check the correlation between variables and the SPO_2 index. Then, data analysis was done via SPSS version 24 software, and $P>0.05$ was considered statistically significant.

Results

Demographic Findings of the Diabetic Patients With COVID-19

Of the 200 studied diabetic patients with COVID-19, 88 were men (44%), and 112 (56%) were women. The mean age of the studied patients was 60.57 ± 14.84 within the range of 13 to 96. Hypertension in 58 people (29%), kidney disease in 14 people (7%), heart disease in 27 people (13.5%), and lung disease in 11 people (5.5%) were reported in these patients (Table 1).

Laboratory and Clinical Markers in Diabetic Patients with COVID-19

Among the renal markers, the mean BUN in diabetic patients was higher than the normal range (22.76 ± 15.15 mg/dL). SGOT (50.7 ± 58.49) and SGPT (42.2 ± 49.32 IU/L) were higher than the normal range in this group of patients. Furthermore, C-reactive protein (CRP) + 1, CRP + 2, and CRP + 3 were reported in 53 (26.5%), 59 (29.5%), and 34 (17%) diabetic patients with COVID-19, respectively. The means of fasting blood sugar (FBS) (253.94 ± 125.34), LDH (606.45 ± 257.91), erythrocyte sedimentation rate (ESR) (56.72 ± 26.51), and respiratory rate (RR) (21.68 ± 3.24) were also observed higher than normal in diabetic patients with COVID-19. Moreover, the mean SPO_2 of the patients was lower than the normal range (93.01 ± 6.57%), as depicted in Table 1.

Relationship Between SPO_2 and the Laboratory and Clinical Markers in Diabetic Patients with COVID-19

The findings obtained from the linear regression analysis showed that the SPO2 level of diabetic patients with COVID-19 has a significant relationship with the

Table 1. Demographic, Laboratory, and Clinical Characteristic of Patients (N = 200)

Variable		Mean or N	SD or %
Age, year† (Mean ± SD): 60.57 ± 14.84	≤ 50	43	21.5%
	51–70	109	54.5%
	≥ 71	48	24.0%
Gender	Male	88	44.0%
	Female	112	56.0%
Blood pressure	Yes	58	29.0%
Renal disease	Yes	14	7.0%
Heart disease	Yes	27	13.5%
Lung disease	Yes	11	5.5%
Seizure	Yes	0	0.0%
FBS (mg/dL)†		253.94	125.34
BUN (mg/dL)†		22.76	15.15
Cr (mg/dL)†		1.35	1.28
Na (mmol/L)†		136.04	3.94
K (mmol/L)†		4.40	0.51
ALP (U/L)†		230.11	91.32
LDH (U/L)†		606.45	257.91
Total bilirubin (mg/dL)†		0.97	2.57
Direct bilirubin (mg/dL)†		0.26	0.12
SGOT (IU/L)†		50.70	58.49
SGPT (IU/L)†		42.20	49.32
PT (s)†		12.42	2.14
PTT (s)†		33.01	7.29
INR†		1.05	0.22
ESR (mm/h)†		56.72	26.51
CRP	Negative	54	27.0%
	1+	53	26.5%
	2+	59	29.5%
	3+	34	17.0%
WBC (/mm3)†		8.83	4.05
RBC (million/mm3)†		4.53	0.71
MCV (μm³)†		82.09	6.83
MCH (pg/cell)†		27.41	2.84
MCHC (Hb/cell)†		31.88	1.71
PLT (mm³)†		251.63	87.00
RR†		21.68	3.24
SPO_2†		93.01	6.57
SBP†		122.09	14.99

Note. SD, Standard deviation; FBS, Fasting blood sugar; BUN, Blood urea nitrogen; Cr, Creatinine; Na, Sodium; K, Potassium; ALP, Alkaline phosphatase; LDH, Lactate dehydrogenase; SGOT, Serum glutamate oxalate transaminase; SGPT, Serum glutamic-pyruvic transaminase; PT, Prothrombin time; PTT, Partial thromboplastin time; INR, International normalized ratio; ESR, Erythrocyte sedimentation rate; CRP, C-reactive protein; WBC, White blood cell; RBC, Red blood cell; MCV, Mean corpuscular volume; MCH, Mean corpuscular hemoglobin; MCHC, Mean corpuscular hemoglobin concentration; PLT, Platelet; RR, Respiratory rate; SPO2, Peripheral oxygen saturation; SBP, Systolic blood pressure.
†Variable with normal distribution.

outcome of their death. Hence, according to the estimated regression coefficient, the mean SPO_2 in patients who died was 2.774 units less than that in diabetic patients with COVID-19 who recovered ($P = 0.019$). Further, with increasing age, the mean SPO_2 decreased by 0.023 units, and the mean SPO2 in men was 0.073 units less than that in women.

In general, among other investigated factors, the relationship of SPO_2 patients with outcome variables, duration of hospitalization in the intensive care unit ($P < 0.001$), RR ($P < 0.001$), MCV ($P = 0.02$), CRP + 3 ($P = 0.002$), PTT ($P = 0.03$), ALP ($P = 0.002$), and LDH ($P = 0.003$) was statistically significant. In this regard and according to the estimated regression coefficients, for each unit increase in SPO_2, the mean of ALP and LDH decreased by 0.01 and 0.004, respectively. The mean of SPO_2 in patients with CRP + 3 was 1.796 units less than that in those with negative CRP. Further, for each unit increase in SPO_2, the mean MCV, RR, and PTT decreased by 0.074, 0.82, and 0.067, respectively. For each SPO_2 unit increase, the duration of hospitalization in the intensive care unit was also shortened by 0.419 days (Table 2).

Discussion

Out of the 200 diabetic patients with COVID-19 in this study, the majority were in their 5th and 6th decades of life (54.5%). Hypertension was reported as the most common disease associated with these patients and was observed in more than a quarter of patients. Further, a significant relationship was found between SPO_2 and disease outcome, duration of hospitalization in ICU, RR, MCV, CRP + 3, LDH, ALP, and PTT. Among the renal markers, the mean BUN in diabetic patients was higher than the normal range. Likewise, SGOT and SGPT were higher than the normal range in this group of patients. CRP + 1, CRP + 2, and CRP + 3 were also reported in 53 (26.5%), 59 (29.5%), and 34 (17%) patients with diabetes, respectively. The mean FBS, LDH, ESR, and RR were also higher than normal in these patients. Conversely, the mean SPO_2 of the patients was lower than the normal range.

In the cohort study by Wu et al in 2020 on diabetes, there was a significant difference in CRP, gender, and common symptoms (e.g., fever, cough, shortness of breath, and fatigue). In diabetic patients with COVID-19 compared to non-diabetic patients, the numbers of white blood cells, neutrophils, D-dimer, and LDH in diabetic COVID-19 patients were not significant (18). In the present study, CRP + 3 and LDH increased in diabetic patients with COVID-19.

The cohort study of Bruce Bode et al in 2020 revealed that uncontrolled diabetes or hyperglycemia occurs frequently among hospitalized patients with COVID-19. In addition, the COVID-19 patients with diabetes/uncontrolled hyperglycemia had a longer length of hospitalization, and

Table 2. The Association between SPO_2 and Laboratory Diagnostic Factors in the Linear Regression Model

Variable	Unstandardized		Standardized	t	*P*	95.0% CI for B	
	B	SE	Beta			Lower	Upper
Age, year	-0.02	0.01	0.05	-1.37	0.17	-0.01	0.05
Gender (male)	-0.07	0.49	-0.00	-0.14	0.88	-1.05	0.90
Outcome (died)	-2.77	1.1	-0.13	-2.37	0.02	-5.08	-0.46
Blood pressure (yes)	0.67	0.62	0.04	1.08	0.28	-0.55	1.89
Renal problem (yes)	2.65	1.55	0.10	1.71	0.09	-0.40	5.70
Heart problem (yes)	0.63	0.77	0.03	0.82	0.41	-0.89	2.16
Lung problem (yes)	-0.45	1.02	-0.01	-0.44	0.66	-2.46	1.56
FBS (mg/dL)	.00	0.00	0.06	1.52	0.13	-0.00	0.00
BUN (mg/dL)	-0.01	0.03	-0.03	-0.49	0.62	-0.07	0.04
Cr (mg/dL)	-0.02	0.24	-0.00	-0.08	0.93	-0.50	0.46
Na (mmol/L)	.01	0.06	0.01	0.25	0.80	-0.11	0.14
K (mmol/L)	-0.29	0.51	-0.02	-0.58	0.56	-1.31	0.71
ALP (U/L)	-0.01	0.00	-0.13	-3.15	0.002	-0.01	-0.00
LDH (U/L)	-0.00	00.00	-0.14	-2.99	0.003	-0.00	-0.00
Total bilirubin (mg/dL)	0.06	0.09	0.02	0.76	0.45	-0.10	0.24
Direct bilirubin (mg/dL)	-0.46	1.98	-0.01	-0.23	0.81	-4.37	3.45
SGOT (IU/L)	-0.01	0.01	-0.13	-1.27	0.20	-0.04	0.00
SGPT (IU/L)	0.00	0.01	0.05	0.54	0.58	-0.02	0.03
PT (s)	0.03	0.15	0.01	0.23	0.81	-0.26	0.33
PTT (s)	-0.06	0.03	-0.07	-2.14	0.03	-0.13	-0.00
INR	-0.20	1.52	-0.01	-0.13	0.89	-3.20	2.79
ESR (mm/hr)	0.00	0.01	-0.00	-0.01	0.98	-0.02	0.023
CRP(1+)¶	0.11	0.70	0.00	0.16	0.87	-1.27	1.50
CRP(2+)¶	0.12	0.71	0.01	0.17	0.86	-1.28	1.53
CRP(3+)¶	-1.79	0.58	-0.10	-3.08	0.002	-2.94	-0.64
WBC (/mm3)	-0.05	0.09	-0.03	-0.55	0.58	-0.23	0.13
RBC (million/mm^3)	0.43	0.43	0.04	0.99	0.32	-0.42	1.28
MCV (μm^3)	-0.07	0.03	-0.07	-2.31	0.02	-0.13	-0.01
MCH (pg/cell)	0.16	0.14	0.07	1.12	0.26	-0.12	0.45
MCHC (Hb/cell)	0.09	0.15	0.02	0.60	0.55	-0.21	0.39
PLT (mm^3)	0.00	0.00	0.01	0.27	0.78	-0.05	0.00
RR	-0.82	0.10	-0.40	-7.83	<0.001	-1.02	-0.61
SBP	-0.03	0.02	-0.07	-1.65	.10	-0.06	0.00
Fever (yes)	-0.69	0.51	-0.05	-1.35	00.18	-1.72	0.32
Cough (yes)	-0.21	0.65	-0.01	-0.32	0.74	-1.51	1.08
Shortness of breath (yes)	-0.41	0.59	-0.02	-0.69	0.49	-1.59	0.76
Sore throat (yes)	1.24	0.76	0.06	1.62	0.10	-0.26	2.74
ICU care (yes)	-1.99	1.83	-0.10	-1.08	0.28	-5.60	1.62
Duration of ICU, day	-0.42	0.09	-0.22	-4.35	<0.001	-0.61	-0.23

Note. SPO2, Peripheral oxygen saturation; CI, Confidence interval; SE, Standard error; FBS, Fasting blood sugar; BUN, Blood urea nitrogen; Cr, Creatinine; Na, Sodium; K, Potassium; ALP, Alkaline phosphatase; LDH, Lactate dehydrogenase; SGOT, Serum glutamate oxalate transaminase; SGPT, Serum glutamic-pyruvic transaminase; PT, Prothrombin time; PTT, Partial thromboplastin time; INR, International normalized ratio; ESR, Erythrocyte sedimentation rate; CRP, C-reactive protein; WBC, White blood cell; RBC, Red blood cell; MCV, Mean corpuscular volume; MCH, Mean corpuscular hemoglobin; MCHC, Mean corpuscular hemoglobin concentration; PLT, Platelet; RR, Respiratory rate; SBP, Systolic blood pressure; ICU, Intensive care unit.
¶ref level: negative.

their mortality was more significant and higher than that of patients without diabetes/uncontrolled hyperglycemia (19). In the present study, the mean FBS in hospitalized diabetic coronary patients was observed to be higher than the normal range. Furthermore, low SPO_2 increased the risk of death of patients by 2.7 times.

In the research by Javanian et al in 2020, CRP in patients with COVID-19 was significantly higher (20). In the present study, CRP + 1, CRP + 2, and CRP + 3 were also reported in 53 (26.5%), 59 (29.5%), and 34 (17%) diabetic patients with COVID-19 and low SPO_2 significantly increased CRP + 3.

In the study by Alguwaihes et al in 2020, 68.3% of the total examined patients with COVID-19 were men, their mean age was reported to be 55 years, and diabetes significantly increased the death rate of patients (21). In the present study, 54.5% of people were in the age range of 50 to 70 years, and low SPO_2 increased the risk of death of patients by 2.7 times. Additionally, with increasing age, the mean SPO_2 decreased by 0.023 units, and the mean SPO_2 in men was 0.073 units less than that in women.

In a study by Cheng et al in 2020 in Wuhan, China, an increase in serum creatinine and BUN was reported in 14.4 and 13.1% of patients with COVID-19, respectively (22). This result is in line with the result of the present study in which the mean BUN in diabetic patients with COVID-19 was higher than the normal range.

In the study by Fox et al in 2021, 47% of all examined patients with COVID-19 had diabetes and had higher inflammatory markers such as CRP and LDH compared to others, and only age was reported as an independent risk factor for the death of patients (23). In our study, LDH and CRP + 3 significantly increased in diabetic patients with COVID-19, and the SPO_2 level of diabetic patients with COVID-19 had a significant relationship with the outcome of their death. Moreover, with increasing age, the mean SPO_2 decreased.

In another study by Hammad and Alseoudy in 2021, 118 diabetic patients with COVID-19 were studied, of which 54 (45.8%) were men and 64 (54.2%) were women. SGPT increased significantly in men compared to women, while SGOT exhibited no significant difference. Further, BUN and Cr did not increase significantly in both genders (24). In our study, the mean of SGPT, SGOT, and BUN was higher than the normal range.

The results of a study by Wang et al in 2020 showed that ESR and CRP increase in diabetic patients with COVID-19 (25). In the present study, the mean ESR was also higher than normal in diabetic patients with COVID-19.

Conclusion

The results indicated that some laboratory diagnostic markers (e.g., liver, kidney, and inflammation) were higher than the normal range, while SPO_2 was lower than the normal range. Moreover, a significant relationship was found between SPO_2 index and disease outcome, duration of hospitalization in ICU, and some diagnostic markers of the liver, inflammation, and coagulation. Therefore, it is critical to pay attention to these markers in the diagnosis and treatment of coronary patients with diabetes. However, this requires further studies. It is suggested that larger control case designs be implemented to compare laboratory marker indicators in patients with and without diabetes suffering from COVID-19 to determine the independent risk factors affecting the death of this group of patients while comparing these indicators.

Acknowledgments

The authors gratefully acknowledge the Ethics Committee of Abadan University of Medical Sciences and Clinical Research Development Unit of Taleghani Educational Hospital, Abadan University of Medical Sciences.

Authors' Contribution

Conceptualization: Esmat Radmanesh, Hasan Maredi.
Data curation: Naser Kamyari, Hasan Maredi.
Formal analysis: Naser Kamyari.
Investigation: Hasan Maredi, Khadijeh Kanani.
Methodology: Esmat Radmanesh, Hasan Maredi, Maryam Ban, Sara Mobarak.
Project administration: Esmat Radmanesh.
Supervision: Esmat Radmanesh.
Writing–original draft: Esmat Radmanesh, Hasan Maredi.
Writing–review & editing: Esmat Radmanesh, Maryam Ban, Naser Kamyari.

Competing Interests

The authors declare no conflict of interests.

Ethical Approval

This study was approved by the Ethics Committee of Abadan University of Medical Sciences (Ethical code: IR.ABADANUMS.REC.1399.178).

Funding

This study did not receive any grant.

References

1. NCD Risk Factor Collaboration (NCD-RisC). Worldwide trends in diabetes since 1980: a pooled analysis of 751 population-based studies with 4.4 million participants. Lancet. 2016;387(10027):1513-30. doi: 10.1016/s0140-6736(16)00618-8.
2. World Health Organization (WHO). Diabetes. Available from: https://www.who.int/health-topics/diabetes. Accessed May 30, 2020.
3. American Diabetes Association. Diagnosis and classification of diabetes mellitus. Diabetes Care. 2010;33(Suppl 1):S62-9. doi: 10.2337/dc10-S062.
4. Ugwueze CV, Ezeokpo BC, Nnolim BI, Agim EA, Anikpo NC, Onyekachi KE. COVID-19 and diabetes mellitus: the link and clinical implications. Dubai Diabetes Endocrinol J. 2020;26(2):69-77. doi: 10.1159/000511354.
5. Muniyappa R, Gubbi S. COVID-19 pandemic, coronaviruses, and diabetes mellitus. Am J Physiol Endocrinol Metab. 2020;318(5):E736-E41. doi: 10.1152/ajpendo.00124.2020.

6. Selvin E, Juraschek SP. Diabetes epidemiology in the COVID-19 pandemic. Diabetes Care. 2020;43(8):1690-4. doi: 10.2337/dc20-1295.
7. https://www.worldometers.info/coronavirus.
8. Chee YJ, Ng SJH, Yeoh E. Reply to comments on Letter to the Editor - Diabetic ketoacidosis precipitated by COVID-19 in a patient with newly diagnosed diabetes mellitus. Diabetes Res Clin Pract. 2020;166:108305. doi: 10.1016/j.diabres.2020.108305.
9. Wang T, Du Z, Zhu F, Cao Z, An Y, Gao Y, et al. Comorbidities and multi-organ injuries in the treatment of COVID-19. Lancet. 2020;395(10228):e52. doi: 10.1016/s0140-6736(20)30558-4.
10. Casqueiro J, Casqueiro J, Alves C. Infections in patients with diabetes mellitus: a review of pathogenesis. Indian J Endocrinol Metab. 2012;16(Suppl1):S27-36. doi: 10.4103/2230-8210.94253.
11. Erener S. Diabetes, infection risk and COVID-19. Mol Metab. 2020;39:101044. doi: 10.1016/j.molmet.2020.101044.
12. Geerlings SE, Hoepelman AI. Immune dysfunction in patients with diabetes mellitus (DM). FEMS Immunol Med Microbiol. 1999;26(3-4):259-65. doi: 10.1111/j.1574-695X.1999.tb01397.x.
13. Holman N, Knighton P, Kar P, O'Keefe J, Curley M, Weaver A, et al. Risk factors for COVID-19-related mortality in people with type 1 and type 2 diabetes in England: a population-based cohort study. Lancet Diabetes Endocrinol. 2020;8(10):823-33. doi: 10.1016/s2213-8587(20)30271-0.
14. Grasselli G, Zangrillo A, Zanella A, Antonelli M, Cabrini L, Castelli A, et al. Baseline characteristics and outcomes of 1591 patients infected with SARS-CoV-2 admitted to ICUs of the Lombardy region, Italy. JAMA. 2020;323(16):1574-81. doi: 10.1001/jama.2020.5394.
15. Yang J, Zheng Y, Gou X, Pu K, Chen Z, Guo Q, et al. Prevalence of comorbidities and its effects in patients infected with SARS-CoV-2: a systematic review and meta-analysis. Int J Infect Dis. 2020;94:91-5. doi: 10.1016/j.ijid.2020.03.017.
16. Zhu L, She ZG, Cheng X, Qin JJ, Zhang XJ, Cai J, et al. Association of blood glucose control and outcomes in patients with COVID-19 and pre-existing type 2 diabetes. Cell Metab. 2020;31(6):1068-77.e3. doi: 10.1016/j.cmet.2020.04.021.
17. Barron E, Bakhai C, Kar P, Weaver A, Bradley D, Ismail H, et al. Associations of type 1 and type 2 diabetes with COVID-19-related mortality in England: a whole-population study. Lancet Diabetes Endocrinol. 2020;8(10):813-22. doi: 10.1016/s2213-8587(20)30272-2.
18. Wu X, Wang T, Zhou Y, Liu X, Zhou H, Lu Y, et al. Different laboratory abnormalities in COVID-19 patients with hypertension or diabetes. Virol Sin. 2020;35(6):853-6. doi: 10.1007/s12250-020-00296-1.
19. Bode B, Garrett V, Messler J, McFarland R, Crowe J, Booth R, et al. Glycemic characteristics and clinical outcomes of COVID-19 patients hospitalized in the United States. J Diabetes Sci Technol. 2020;14(4):813-21. doi: 10.1177/1932296820924469.
20. Javanian M, Bayani M, Shokri M, Sadeghi-Haddad-Zavareh M, Babazadeh A, Yeganeh B, et al. Clinical and laboratory findings from patients with COVID-19 pneumonia in Babol North of Iran: a retrospective cohort study. Rom J Intern Med. 2020;58(3):161-7. doi: 10.2478/rjim-2020-0013.
21. Alguwaihes AM, Al-Sofiani ME, Megdad M, Albader SS, Alsari MH, Alelayan A, et al. Diabetes and COVID-19 among hospitalized patients in Saudi Arabia: a single-centre retrospective study. Cardiovasc Diabetol. 2020;19(1):205. doi: 10.1186/s12933-020-01184-4.
22. Cheng Y, Luo R, Wang K, Zhang M, Wang Z, Dong L, et al. Kidney disease is associated with in-hospital death of patients with COVID-19. Kidney Int. 2020;97(5):829-38. doi: 10.1016/j.kint.2020.03.005.
23. Fox T, Ruddiman K, Lo KB, Peterson E, DeJoy R 3rd, Salacup G, et al. The relationship between diabetes and clinical outcomes in COVID-19: a single-center retrospective analysis. Acta Diabetol. 2021;58(1):33-8. doi: 10.1007/s00592-020-01592-8.
24. Hammad MO, Alseoudy MM. The sex-related discrepancy in laboratory parameters of severe COVID-19 patients with diabetes: a retrospective cohort study. Prim Care Diabetes. 2021;15(4):713-8. doi: 10.1016/j.pcd.2021.05.002.
25. Wang Z, Du Z, Zhu F. Glycosylated hemoglobin is associated with systemic inflammation, hypercoagulability, and prognosis of COVID-19 patients. Diabetes Res Clin Pract. 2020;164:108214. doi: 10.1016/j.diabres.2020.108214.