RESEARCH ARTICLE

OPEN ACCESS

Received: 09.11.2020

Accepted: 12.12.2020

Published: 07.01.2021

Citation: Attiyah SM, Elsayed HM, Al-Mughales JA, Moharram AB, Abdel-Fattah M (2020) Critical cases of COVID-19 patients can be predicted by the biomarkers of complete blood count. Indian Journal of Science and Technology 13(48): 4739-4745. <https://doi.org/10.17485/IJST/v13i48.2033>

* **Corresponding author.**

Tel: 00966562052341
hodaelsayed71@yahoo.com

Funding: None

Competing Interests: None

Copyright: © 2020 Attiyah et al. This is an open access article distributed under the terms of the [Creative Commons Attribution License](https://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Published By Indian Society for Education and Environment ([iSee](https://www.indjst.org/))

ISSN

Print: 0974-6846

Electronic: 0974-5645

Critical cases of COVID-19 patients can be predicted by the biomarkers of complete blood count

Sama M Attiyah¹, Hoda M Elsayed^{2*}, Jamil A Al-Mughales³, Ahmed B Moharram⁴, Mohamed Abdel-Fattah^{5,6}

1 Assistant professor of immunology and cardiology, Biology Department, Faculty of Sciences and Arts, Al Kamel Branch, University of Jeddah, Jeddah, Saudi Arabia

2 Assistant professor of immunology and parasitology, Biology Department, Faculty of Sciences and Arts, Al Kamel Branch, University of Jeddah, Jeddah, Saudi Arabia.
Tel.: 00966562052341

3 Assistant professor of immunology, consultant diagnostic immunologist, head of the clinical immunology services, King Abdu Azizi hospital

4 Chief Data Scientist & Evolutionary Artificial Intelligence Expert, master's in information systems [AI & DSS] / MBA [DSS] / IS Diploma, Germany-Berlin

5 Department of Epidemiology, Faculty of Public Health & Health Informatics, Umm AL Qura University, Saudi Arabia

6 Research and Development Department, VACSERA, Egypt

Abstract

Background: The confirmatory test for COVID-19 relies on the virus levels in the patients and sampling methods. Besides, there is no definitive description of the role of diagnostic lab parameters in the analysis of positive cases yet. **Objective:** To investigate the positive COVID-19 cases by screening out hematological biomarker for detection of disease severity and progression. **Methods:** Data of 110 confirmed COVID-19 cases at King Abdulaziz hospital were analyzed, 42 (38.2%) of the cases were treated in ICU. All variables' means and variances were compared between two groups (non-severe patients and severe) using statistical analysis. **Results:** ICU and non-ICU positive cases rates were 38.2% and 61.8% respectively. Out of COVID-19 patients, 60% showed lymphopenia and neutrophilia ($P < 0.025$) and Eosinopenia (60.9%). Furthermore, low levels of MCH and hemoglobin were observed in 96.4% and 90%, respectively. At a significance level of 5%, statistical tests showed a statistically significant difference between groups under investigation in both the mean value and variance for lymphocyte, neutrophils, platelet, and WBCs variables. **Conclusions:** The analysed variables can be used for predicting patients with positive COVID-19 cases. Lymphocytes and neutrophils were much helpful in monitoring disease severity and infection progression. Moreover, these results encourage considering data as a useful, rapid, and easy way to arrive at a decision of disease severity.

Keywords: CBC; Laboratory biomarker; COVID-19; Lymphopenia; Eosinopenia

1 Introduction

Two highly pathogenic human coronaviruses had been triggered major epidemics over the last 20 years, Severe Acute Respiratory Syndrome (SARS, 2003), and Middle East Respiratory Syndrome (MERS, 2014)⁽¹⁾. Many unexplained cases of pneumonia by the newly identified SARS-CoV-2 were recorded in Wuhan, China on 31 December 2019⁽²⁾. It expands and reaches all over the world creating a global health crisis. There is clear heterogeneity in the pathogenic severity of COVID-19 from asymptomatic to serious cases according to WHO 2020⁽³⁾. Peripheral white cell differential may be a systemic inflammatory response predictor and is commonly examined as useful indicator of viral pneumonia patients⁽⁴⁾. As such biomarkers are required to identify patients' severity, recent studies have shown correlations between COVID-19 disease and different hematological test results^(5,6). These studies have shown that biomarkers in the standard CBC parameters can estimate the development of that infectious disease⁽⁷⁻⁹⁾.

COVID-19 clinical diagnoses are principally relying on the identification of nucleic acid of the viruses in the laboratory, which are influenced by the virus levels in patients and by methods of sampling. There are also false-negative observations^(10,11). Several recent articles have shown the clinical and epidemiologic features of COVID-19 patients, but there is minimal laboratory evidence for contaminated patients. Our research aimed to study different hematological parameters of positive RT-PCR cases for COVID-19 to provide a basis to use these parameters for diagnosis and as a prognostic indicator for patients' severity.

2 Methods

2.1 Study design

Our retrospective study on laboratory CBC parameters comprised one hundred and ten positive COVID-19 cases and were divided into ICU and non-ICU patients' groups. All were confirmed using reverse transcription-polymerase chain reaction (RT-PCR Abbott company, USA) in King Abdulaziz hospital. The study was approved by the hospital's Ethics Committee (Reference NO. 301020). Demographic parameters (age, gender, ethnicity, mortality) and laboratory assessments of complete blood count of the patients were obtained exclusively from the Laboratory Information System (phoneix) in King Abdulaziz hospital. Patients with complete data, including 68 non-severe and 42 critical cases (ICU group), were randomly selected. The patients grouped into severe and non-severe COVID-19 according to the interim guidance of the World Health Organization⁽¹²⁾. Whole venous blood samples have been collected on BD EDTA tube and CBC profile analysis has been performed on Sysmex xn-10 and Sysmex xn-20 analyzer (JAPAN).

2.2 Statistical analysis

The statistical analysis, reporting, and graphical representation were done using the following packages: pandas 1.0.5, numpy 1.18.5, hypothesis 5.18.3, IPython 7.16.1, pandas_datareader, scipy 1.5.0, and matplotlib 3.2.2. The data-processing environment was Jupyter 2.1.5 with python 3.7.7.final.0 64-bit on an Intel Core i7-4710HQ. Operating system Microsoft Windows 10 64-bit. A significance level (α) of 5% was used as a maximum accepted p-value to reject the null hypothesis. And as we are measuring the difference in both directions (positive and negative) p-value is compared to 2.5%.

3 Results

The characteristics of demographics and hematological laboratory findings between patients in ICU and non-ICU groups were reported in Table 1. A total of 110 adult patients (≥ 18 years old) with a confirmed diagnosis of COVID-19, 69 (62.7%) were male patients while 41 (37.3%) were female patients. Percentage of Saudi Arabian ethnicity patients were 32 (29.1%), while that of the other ethnicities patients (non-Saudi) were 78 (70.9%).

Table 1. Comparisons of Blood profile parameters at admission between ICU and non-ICU patients

	ICU patients (n= 42) (38.2%)		NON-ICU patients (n= 68) (61.8 %)		(n = 110)
Gender	Male	Female	Male	Female	
no. of patients	33 (78.6%)	9 (21.4%)	36 (52.9%)	32 (47.1%)	
Mortality	15	4	1	-	20 (18.2%)
Ethnicity					
Saudi Arabian	13	2	3	14	32 (29.1%)
Others	20	7	33	18	78 (70.9%)

Continued on next page

Table 1 continued

Age					
< 39	4	2	8	11	25 (22.7%)
40-59	9	3	20	14	46 (41.8%)
> 60	20	4	8	7	39 (35.5%)
Blood profile					
Hb					
Low	30	8	15	12	65 (59.1%)
Normal	3	1	21	20	45 (40.9%)
MCH					
< 32	31	9	34	32	106 (96.4%)
32-36	2	-	2	-	4 (3.6%)
Platelets					
< 150	4	-	7	2	13 (11.8%)
150-450	28	8	29	30	95 (86.4%)
> 450	1	1	-	-	2 (1.8%)
WBCs					
< 4.5	1	-	6	10	17 (15.4%)
4.5 – 11.5	11	5	26	20	62 (56.4%)
> 11.5	21	4	4	2	31 (28.2%)
Neutrophils					
< 50	-	-	5	7	12 (10.9%)
50-70	1	4	14	13	32 (29.1%)
> 70	32	5	17	12	66 (60%)
Lymphocytes					
< 20	32	7	17	10	66 (60%)
20-45	1	2	16	17	36 (32.7%)
> 45	-	-	3	5	8 (7.3%)
Monocytes					
< 2	4	1	-	-	5 (4.5%)
2-11	28	7	30	28	93 (84.5%)
> 11	1	1	6	4	12 (11%)
Eosinophils					
< 1	21	6	20	20	67 (60.9%)
1-3	9	3	16	8	36 (32.7%)
> 3	3	-	-	4	7 (6.4%)

Note: (a) Data includes Saudi Arabian residents and non-Saudi. Non-Saudi have been included as “Others” under ethnicity.

(b) Normal range of White Blood Cell (WBC) is 4.5- 11.5 K/uL, Mean Cell Hemoglobin(MCH) is 32-36 pg, platelets are 150- 450 K/uL, Neutrophils % is 50-70, Lymphocytes % is 20-45, Monocytes % is 2-11 and Eosinophils % is 1-3.

Most of the positive patients underwent blood routine examinations on admission had peripheral blood system anomalies. The rate of anemia of 90.5% of ICU patients compared to 39.7% of non-ICU patients has been observed. Moreover, 96.4% and 90% of all COVID-19 patients presented a low value of MCH and hemoglobin level, respectively regarding the reference range. The increase of neutrophils count percentage was obvious within 88.1% of ICU patients. More important, we found that 92.8% among ICU patients showed significantly decreased lymphocyte counts and 60.9% of the patients showed eosinopenia. Our study showed normal platelet counts with 95 (86.4%) among COVID-19 patients. Moreover, among ICU patients, 19 deaths had occurred, equivalent to a mortality rate of 45%.

Table 2 shows the statistical measures of the continuous variables and both p-values test. A null hypothesis H_0 of no significant difference in the mean value for each continuous variable between the two groups was tested using Welch's t-Test.

Another set of F-Tests was also conducted with a null hypothesis of equality invariance (Table 3). For the significance of mean value differences between the two groups, results show that the null hypothesis is rejected for Age, Hb, Lymphocyte, Monocyte, Neutrophils, Platelet, and WBCs. This indicates a statistically significant difference between the two groups in both the mean value and variance for Lymphocyte, Neutrophils, Platelet, and WBCs variables (Figures 1 and 2).

Table 2. Continuous variables statistical measures

	Mean	S.D.	Min	Max
Age	52.54	16.94	19.00	94.00
Eosinophils	0.87	1.16	0.00	5.00
Hb	12.05	2.63	5.50	17.90
Lymphocyte	19.68	13.07	1.80	51.80
MCH	27.87	2.60	20.00	35.20
Monocyte	6.61	3.39	0.90	17.20
Neutrophils	70.85	14.69	37.20	93.30
Platelet	259.15	103.95	105.00	535.00
WBCs	8.98	5.08	1.68	25.66

Table 3. The baseline characteristics variable statistical measures and tests' results of covid-19 patients in the study subject

	ICU 42 (38.18%)			None-ICU 68 (61.82%)			t-Test p-value	F-Test p-value
	Mean	Std	Median	Mean	Std	Median	ICU vs None-ICU	
Age	58.048	16.233	61.00	49.132	16.574	46.50	0.0067<0.025*	0.4503 >0.025**
Eosinophils	0.807	1.193	0.15	0.913	1.152	0.50	0.6473>0.025	0.3926 >0.025**
Hb	10.769	2.425	10.75	12.847	2.452	13.00	0.0000<0.025*	0.4769 >0.025**
Lymphocyte	9.848	7.045	7.10	25.759	12.231	24.90	0.0000<0.025*	0.0001 <0.025
MCH	28.005	2.199	28.00	27.787	2.831	28.45	0.6525>0.025	0.0420 >0.025**
Monocyte	5.150	3.191	4.35	7.510	3.218	7.40	0.0003<0.025*	0.4853 >0.025**
Neutrophils	79.933	10.358	82.60	65.237	14.198	65.75	0.0000<0.025*	0.0160 <0.025
Platelet	306.071	120.729	300.00	230.176	80.164	215.00	0.0006<0.025*	0.0014 <0.025
WBCs	13.077	4.983	13.12	6.453	3.119	5.81	0.0000<0.025*	0.0003 <0.025

Symbol (*) denote to that the difference between the means of ICU and None-ICU are statistically significance at level of significance $\alpha=0.05\%$ for all variables. Otherwise are not significant using T test.

Symbol (**) denote to that the data of ICU and None-ICU are statistically homogeneous (i.e. their variances are statistically equaling) at level of significance $\alpha=0.05\%$ for all variables. Otherwise are not homogeneous using F test.

Fig 1. Histogram and kernel density estimation for variables with significant statistical difference in both mean and variance

Fig 2. Histogram and kernel density estimation for variables with significant statistical difference in mean value only

4 Discussion

Early diagnosis of COVID-19 is critical for the optimal management of infected patients to control viral spread. The standard test for COVID-19 remains RT-PCR to detect viral RNA from swap samples, although it is specific but lacks sensitivity^(13–15). Complete blood count (CBC) is a routine test during initial biological assessment of patients and it is well-known that the COVID-19 pandemic has significantly challenged the international laboratory hematology community⁽¹⁶⁾.

In the current study, male gender was estimated to be dominant among studied population which is consistent with previous literatures^(17,18). Moreover, it could be detected as a high-risk factor in COVID-19 infection where males were almost three times higher than females in the severity and mortality of the disease, furthermore, most of the patients are non-Saudi ethnicity.

Our study aimed to investigate the applicable thresholds for 110 CBC profiles to identify the factors that may affect COVID-19 progression. Our study revealed that the patients in the intensive care unit for COVID-19 showed significant changes in several parameters: a high percentage of neutrophil, low count of eosinophils, and lymphopenia comparing to mild cases. This finding is primarily suggested that these factors can be considered as prognostic biomarkers to predict severe COVID-19.

The current study showed a lymphopenia in 60% of the study participants and 92.8% in ICU patients only. It is the most significant trend of the disease progression across all parameters with a critical and clear pattern and in the same line with previous reports that stated low lymphocytes and high percentage of neutrophils in most patients^(8,19). Also, Huang C et al. (2020) have showed that lymphopenia is a common finding in patients with COVID-19⁽²⁰⁾. Similarly, Sun et al. showed lower lymphocytes, and a higher PLR in patients with COVID-19 compared to controls⁽²¹⁾. On the other hand, it was shown in different studies that COVID-19 positive patients had lymphopenia associated with the disease prognosis^(21,22).

Our study showed elevated neutrophils count in 60% of participants and 88.1 % in ICU patients which in consistent with the study done by Fan BE and his colleagues, 2020 that showed a significant correlation in neutrophils count among ICU patients compared with non-ICU group⁽²¹⁾.

The small part of WBCs, the eosinophils, were shown to have different functions, such as antiviral activity and immunoregulation. It has been reported in studies that eosinopenia was detected in COVID-19 patients^(23–25). Other study evaluated 10 COVID-19 patients showed that their eosinophil values were low on admission and changed normal after complete recovery⁽²⁶⁾. In the current study, eosinopenia was detected in 60.9% which could be used as a tool in COVID-19 prognosis.

Li Q et al. (2020) have showed that there was no difference in RBC and hemoglobin levels in COVID-19 patients compared to controls⁽²⁷⁾. On the reciprocal, our study showed that 90 % of the studied population were anemic, moreover mean corpuscular volume (MHC) was decreased in 96.4%. Although, it is not yet fully known whether COVID-19 affects erythrocytes or not, this finding could suggest that it may affect to some extent RBCs system.

Outcomes in the intensive care unit mortality of the study suggested unusually high ICU mortality rates (45%). The mortality rates varied significantly amongst different countries such as 17% in united states⁽²⁸⁾, 25.6% in china⁽²⁹⁾ and 48.8% in Italy⁽³⁰⁾, this could be explained due to high aged non-Saudi ethnicity patients' rate (70.9%) participated in our study.

Although the number of our study population (n=110) may be seemed to be inadequate, there many previous studies that comprised small number of patients on comparing with ours such as, 41 COVID-19 patients confirmed infection⁽³¹⁾,

61 COVID-19 ICU patients⁽¹⁷⁾, 67 COVID-19 patients from Singapore⁽²²⁾, 75 COVID-19 mild to severe patients⁽³²⁾ and 99 patients in a descriptive study in Wuhan⁽²⁵⁾.

Based on two facts, first is the negative indications for RT-PCR testing alone as the principle way for infection controlling⁽³³⁾, second is WHO expectation that the second wave of COVID-19 will be more severe than the first one⁽³⁴⁾, our findings may play a crucial role to identify severe cases rapidly in the second wave and parameters based on CBC can be a useful tool for predicting prognosis of COVID-19. Much more, CBC tests able to be a practical and efficient method to screen large populations with low cost and less time, which may lead to enhance the management of second wave COVID-19 infection.

5 Conclusion

Based on the present study findings, older age, gender, anemia, lymphopenia, eosinopenia, and high neutrophils count could be used for predicting positive COVID-19 cases. Most important, a high incidence of lymphopenia and elevated neutrophils count were obvious and associated with ICU patients and act as a prognostic indicator for patients' severity. Moreover, these results encourage physicians to consider CBC parameters as useful, rapid, and easy factors to predict the severity of COVID-19 patients.

Limitation

Our retrospective study was done in a single center and as a result the sample size sample was limited due to logistic problems and administrative acceptance of a large number of patients that need more processing time, so a multiple centers prospective research is recommended. Also, since this study was conducted on blood laboratory parameters, patients were not constantly tracked for all clinical manifestations. Also, unfortunately the available acceptance was limited for hematological laboratory results only.

Declaration of competing interest

The authors declared that there is no conflict of interest.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Acknowledgements

Authors would like to thank Ehab A. Aloqbi, specialist, King Abdu Azizi hospital lab for his help in collecting data during the preparation of the manuscript.

References

- 1) Hui D, A Z. Severe acute respiratory syndrome: historical, epidemiologic, and clinical features. *Infect Dis Clin N Am*. 2019;p. 869–889. Available from: <https://doi.org/10.1016/j.idc.2019.07.001>.
- 2) Lu R, Zhao X, Li J, Niu P, Yang B, Wu H, et al. Genomic characterisation and epidemiology of 2019 novel coronavirus: implications for virus origins and receptor binding. *Lancet*. 2020;395:565–574. Available from: [https://doi.org/10.1016/S0140-6736\(20\)30251-8](https://doi.org/10.1016/S0140-6736(20)30251-8).
- 3) WHO China Joint Mission, Report of the WHO-China Joint Mission on Coronavirus Disease 2019 (COVID-19). 2019. Date accessed March 1, 2020. Available from: <https://www.who.int/docs/default-source/coronaviruse/>.
- 4) Ying H, Deng Q, He B, Pan Y, Wang F, Sun H, et al. The prognostic value of preoperative NLR, d-NLR, PLR and LMR for predicting clinical outcome in surgical colorectal cancer patients. *Med Oncol*. 2014;31(12). Available from: <https://doi.org/10.1007/s12032-014-0305-0>.
- 5) Emanuel EJ, et al. Fair allocation of scarce medical resources in the time of Covid19. *N Engl J Med*. 2020. Available from: <https://doi.org/10.1056/NEJMs2005114>.
- 6) Guan W, et al. Clinical characteristics of coronavirus disease 2019 in China. *N Engl J Med*. 2020. Available from: <https://doi.org/10.1056/NEJMoa2002032>.
- 7) Ognibene A, et al. Elevated monocyte distribution width in COVID-19 patients: The contribution of the novel sepsis indicator (2020). 2020. Available from: <https://doi.org/10.1016/j.cca.2020.06.002>.
- 8) Qu R, Ling Y, Zhang YH, et al. Platelet-to-lymphocyte ratio is associated with prognosis in patients with coronavirus disease-19. *J Med Virol*. 2020. Available from: <https://doi.org/10.1002/jmv.25767>.
- 9) Sun S, et al. Abnormalities of peripheral blood system in patients with COVID-19 in Wenzhou. China. 2020. Available from: <https://doi.org/10.1016/j.cca.2020.04.024>.
- 10) Chan JF, Yuan S, Kok KH, To KK, Chu H, Yang J. A familial cluster of pneumonia associated with the novel coronavirus indicating person-to-person transmission: a study of a family cluster. *Lancet*. 2020;395:514–523. Available from: [https://doi.org/10.1016/s0140-6736\(20\)30154-9](https://doi.org/10.1016/s0140-6736(20)30154-9).
- 11) Huang Y, Tu M, Wang S, Wang S, Chen S, Zhou W. Clinical characteristics of laboratory confirmed positive cases of SARS-CoV-2 infection in Wuhan, China: a retrospective single center analysis. *Travel Med Infect*. 2020. Available from: <https://doi.org/10.1016/j.tmaid.2020.101606>.

- 12) World Health Organization. Clinical management of severe acute respiratory infection when Middle East respiratory syndrome coronavirus (MERS-CoV) infection is suspected: interim guidance. 2019. Available from: <https://apps.who.int/iris/handle/10665/178529>.
- 13) Ai T, Yang Z, Hou H, Zhan C, Chen C, Lv W, et al. Correlation of Chest CT and RT-PCR testing for Coronavirus disease 2019 (COVID-19) in China: A report of 1014 cases. *Radiology*. 2020;296(2):E32–E40. Available from: <https://dx.doi.org/10.1148/radiol.2020200642>.
- 14) Kim H, Hong H, Yoon SH. Diagnostic performance of CT and reverse transcriptase-polymerase chain reaction for coronavirus disease 2019: a meta-analysis. *Radiology*. 2020;17.
- 15) Yang Y, Yang M, Shen C, Wang F, Yuan J, Li J. 2020. Available from: <https://doi.org/10.1101/2020.02.11.20021493>.
- 16) Frater JL, Zini G, d'Onofrio G, Rogers HJ. COVID-19 and the clinical hematology laboratory. *International Journal of Laboratory Hematology*. 2020;42(S1):11–18. Available from: <https://dx.doi.org/10.1111/ijlh.13229>.
- 17) Katipoğlu B, Sönmez LÖ, Vatansev H, Yüce N, Sabak M, Szarpak L, et al. Can hematological and biochemical parameters fasten the diagnosis of COVID-19 in emergency departments? *Disaster and Emergency Medicine Journal*. 2020. Available from: <https://dx.doi.org/10.5603/demj.a2020.0039>.
- 18) Fu J, Kong J, Wang W, et al. The clinical implication of dynamic neutrophil to lymphocyte ratio and D-dimer in COVID-19: A retrospective study in Suzhou China. *Thromb Res*. 2020;192:3–8.
- 19) Mardani R, Vasmehjani A, Zali A, Gholami F, A, Nasab M, et al. Laboratory Parameters in Detection of COVID-19 Patients with Positive RT-PCR; a Diagnostic Accuracy Study. *Arch Acad Emerg Med*. 2020;8(1):43.
- 20) Huang C, et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. *The Lancet*. 2020;395:497–506.
- 21) Yang AP, Liu JP, Tao WQ, et al. The diagnostic and predictive role of NLR, d-NLR and PLR in COVID-19 patients. *Int Immunopharmacol*. 2020;84.
- 22) Fan B, Chong V, Chan S, Lim G, Lim K, Tang, et al. Hematologic parameters in patients with COVID-19 infection (2020); available at Hematologic parameters in patients with COVID-19 infection. . Available from: groupedeveillecovid.fr.
- 23) Suna S, Caib X, Wang H, He G, Lin Y, Lu B, et al. Abnormalities of peripheral blood system in patients with COVID-19 in Wenzhou, China. *Clinica Chimica Acta*. 2020;507:174–180.
- 24) Lindsley AW, Schwartz JT, Rothenberg ME. Eosinophil responses during COVID-19 infections and coronavirus vaccination. *Journal of Allergy and Clinical Immunology*. 2020;146(1):1–7. Available from: <https://dx.doi.org/10.1016/j.jaci.2020.04.021>.
- 25) Chen R, Sang L, Jiang M, Yang Z, Jia N, Al ET. Longitudinal hematologic and immunologic variations associated with the progression of COVID-19 patients in China. *Journal of Allergy and Clinical Immunology*. 2020;146:89–100.
- 26) Liu F, Xu A, Zhang Y, Xuan W, Yan T, Pan K, et al. Patients of COVID-19 may benefit from sustained Lopinavir-combined regimen and the increase of Eosinophil may predict the outcome of COVID-19 progression. *International Journal of Infectious Diseases*. 2020;95:183–191. Available from: <https://dx.doi.org/10.1016/j.ijid.2020.03.013>.
- 27) Li Q, Ding X, Xia G, Chen H, Chen F. Eosinopenia and elevated C-reactive protein facilitate triage of COVID-19 patients in fever clinic: a retrospective case-control study. *EClinical Medicine*. 2020;23.
- 28) Kim L, Garg S, O'Halloran A, Whitaker M, Pham H, Anderson EJ, et al. Risk Factors for Intensive Care Unit Admission and In-hospital Mortality Among Hospitalized Adults Identified through the US Coronavirus Disease 2019 (COVID-19)-Associated Hospitalization Surveillance Network (COVID-NET). *Clinical Infectious Diseases*. 2020. Available from: <https://dx.doi.org/10.1093/cid/ciaa1012>.
- 29) Guan WJ, Ni ZY, Hu Y. China medical treatment expert group for Covid-19. Clinical characteristics of coronavirus disease 2019 in China. *N Engl J Med*. 2020;382(18):1708–1720.
- 30) Grasselli G, Greco M, Zanella A. Risk Factors Associated with Mortality Among Patients With COVID-19 in Intensive Care Units in Lombardy, Italy. *JAMA Internal Medicine*. 2020;180(10):1345–1355.
- 31) Huang C, Wang Y, Li X, et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan. *China Lancet*. 2020;395:497–506.
- 32) Fu J, Kongd J, Wange W, Wub M, Yaob L, Wangc Z, et al. The clinical implication of dynamic neutrophil to lymphocyte ratio and Ddimer in COVID-19: A retrospective study in Suzhou China. *Thrombosis Research*. 2020;192:3–8.
- 33) Lippi G, Simundic AM, Plebani M. Potential preanalytical and analytical vulnerabilities in the laboratory diagnosis of coronavirus disease 2019 (COVID-19). *Clinical Chemistry and Laboratory Medicine (CCLM)*. 2020;58(7):1070–1076. Available from: <https://dx.doi.org/10.1515/cclm-2020-0285>.
- 34) WHO speaks at the European Parliament on the COVID-19 response. .