Received: 2 October 2020 | Revised: 10 November 2020 | Accepted: 14 November 2020

DOI: 10.1002/jcla.23668

RESEARCH ARTICLE

WILEY

The prognostic value of general laboratory testing in patients with COVID-19

Zhihua Lv[1] | **Wei Wang**[2] | **Bin Qiao**[1] | **Xianghua Cui**[1] | **Yong Feng**[3,4] | **Lang Chen**[4,5] | **Qingfeng Ma**[6] | **Xinghui Liu**[7]

[1]Department of Clinical Laboratory, Renmin Hospital of Wuhan University, Wuhan, China

[2]Department of Clinical Laboratory, Wuhan Fourth Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, China

[3]Department of Medical Microbiology, Wuhan University School of Basic Medical Sciences, Wuhan, China

[4]Hubei Province Key Laboratory of Allergy and Immunology, School of Basic Medical Sciences, Wuhan University, Wuhan, China

[5]Department of Immunology, Wuhan University School of Basic Medical Sciences, Wuhan, China

[6]Department of Clinical Laboratory, Liyuan Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, China

[7]Department of Clinical Laboratory, Shanghai Gongli Hospital, The Second Military Medical University, Shanghai, China

Correspondence
Xinghui Liu, Department of Clinical Laboratory, Shanghai Gongli Hospital, the Second Military Medical University, Pudong New Area, Shanghai, China.
Email: syliuxh@163.com (X.L.)

Qingfeng Ma, Department of Clinical Laboratory, Liyuan Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, China.
Email: 2002ly0714@hust.edu.cn (Q.M.)

Lang Chen, Hubei Province Key Laboratory of Allergy and Immunology, School of Basic Medical Sciences, Wuhan University, Wuhan, Hubei, China
Email: 00008515@whu.edu.cn (L.C.)

Funding information
National Mega Project on Major Infectious Disease Prevention, Grant/Award Number: 2017ZX10103005; Outstanding Leaders Training Program of Pudong Health Bureau of Shanghai, Grant/Award Number: PWR12018-05; Key Disciplines Group Construction Project of Pudong Health Bureau of Shanghai, Grant/Award Number: PWZxq2017-15; National Natural Science Foundation of China, Grant/Award Number: 81672079

Abstract

Background: Lymphocyte count (LYM) of peripheral blood and some indices of general biochemical analysis had diagnostic and prognostic value for coronavirus disease 2019 (COVID-19), and the value of other remaining indices is rare.

Methods: A total of 94 patients with COVID-19 were enrolled at Renmin Hospital of Wuhan University. According to the severity of COVID-19, the patients were divided into three groups (moderate 49, severe 35, and critical 10), and 40 healthy cases were enrolled in the same period as healthy controls. The diagnostic and prognostic value of indices in peripheral blood cell count and general biochemical analysis was analyzed.

Results: Compared with healthy cases, the value differences in peripheral blood analysis in patients with COVID-19 were statistically significant ($p < 0.01$), the differences in LYM, neutrophil count (Neu), platelet count (PLT), and white blood cell count (WBC) were statistically significant among different severity of COVID-19 ($p < 0.05$). Compared with healthy cases, the differences in general biochemical results in patients with COVID-19 were statistically ˢignificant ($p < 0.01$), the value differences in direct bilirubin (DBIL), low-density lipoprotein cholesterol (LDL-Ch), and nitrogen (urea) were statistically significant among different severity of COVID-19 ($p < 0.05$). Neutrophil/lymphocyte ratio (NLR) had higher sensitivity and specificity for COVID-19 diagnosis.

Conclusions: Some indices of peripheral blood cell count and general biochemical analysis were valuable in discriminating COVID-19 and predicting severity and

Zhihua Lv, Wei Wang, and Bin Qiao contributed equally to this work.

adverse outcome of patients with COVID-19. For clinician, it is better to use more economical and easy-to-get indices to diagnose and predict the prognosis of COVID-19.

KEYWORDS

biochemical analysis, COVID-19, peripheral blood cell count, severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2)

1 | INTRODUCTION

The pandemic of COVID-19 is caused by SARS-CoV-2,[1] as of May 31, 2020, the COVID-19 has spread out all over the World, and over 6.0 million confirmed cases and more than 370,000 deaths were reported globally.[2] According to the published Diagnosis and Treatment Program of 2019 New Coronavirus Pneumonia (seventh trial version), COVID-19 patients are divided into four groups (mild, moderate, severe, and critical),[3] and the COVID-19 patients mainly died from respiratory failure, septic shock, and multiple organ dysfunction syndrome (MODS).[1-4]

Many parameters had used to auxiliary diagnosis and monitoring treatment of COVID-19. IL-6 and IL-10, acted as pro-inflammatory cytokines,[5] can be used as predictors for fast diagnosis of patients with higher risk of disease deterioration and help physicians correctly allocate patients at an early stage.[6] Some urine biochemical parameters are helpful to differentiate COVID-19 patients, and urine glucose and proteinuria can be used as effective markers to predict COVID-19 severity.[7] CRP, as a non-specific marker of inflammation, can reflect the severity of COVID-19 pneumonia in the early stage, and the level of plasma is useful for physicians to stratify patients for intense care unit transfer.[8,9] According to retrospective cohort study, higher lactate dehydrogenase (LDH) is associated with higher mortality of COVID-19 patients,[10] and 36% patients with COVID-19 had elevated D-dimer.[11] For peripheral blood analysis, severe COVID-19 patients tend to have lower LYM,[12,13] and the significant reduction in T-lymphocyte subsets was positively correlated with in-hospital mortality and severity following SARS-CoV-2 infection.[14] NLR, as an inflammatory marker, may indicate the condition of glucose metabolism and diabetic control level in type 2 diabetic subjects.[15] Elevated NLR is useful to auxiliary differentiate malign from benign thyroid nodules.[16] NLR was elevated in active ulcerative colitis and may be used as an activity parameter for ulcerative colitis.[17] Except for these parameters, many other parameters also can be easy to get from routine blood and biochemical analysis; meanwhile, numerous patients with COVID-19 were asymptomatic and severe SARS-CoV-2 infection.[18] In order to detect whether other indices from general laboratory testing have prognostic value in patients with COVID-19, and provide more evidence for clinical diagnosis and treatment, we investigated indices of peripheral blood analysis and biochemical analysis in COVID-19 patients.

2 | MATERIALS AND METHODS

2.1 | Study design and participants

This study was approved by the institutional ethics board of Renmin Hospital of Wuhan University (No. WDRY2020-K066), and participants signed informed consent forms.

All 94 patients with COVID-19 enrolled in this study were diagnosed with SARS-CoV-2 infection in Renmin Hospital (Wuhan University, China) from February 1 to February 9, 2020. According to the Diagnosis and Treatment Program of New Coronavirus Pneumonia (seventh trial version),[3] the case group was divided into three additional subgroups: moderate cases, including 24 males and 25 females, mean age 63.0 ± 12.5; severe cases: including 18 males and 17 females, mean age 62.1 ± 15.5; and critical cases: including 6 males and 4 females, mean age 60.1 ± 11.1. Other 40 healthy subjects (including 20 males and 20 females, mean age 62.25 ± 9.77) were selected as control group. There was no significant difference in terms of sex or age among the four groups ($p > 0.05$). The detailed criteria are listed as follows:

Moderate group: fever, respiratory tract symptoms, and pneumonia on imaging.

Severe group: Patients have any of the following conditions: respiratory distress, RR ≥ 30 times/minute; the oxygen saturation (SpO_2) ≤93% at rest; oxygen partial pressure (PaO_2)/oxygen concentration (FiO_2) in arterial blood ≤ 300 mmHg; and >50% lung imaging progress in the short term within 24–48 h.

Critical group: Patients have any of the following conditions: respiratory failure and mechanical ventilation required; shock; combining other organ failure, intensive care unit is needed.

2.2 | Method

Approximately 5~10 ml of peripheral blood was obtained with collection tube from the subjects in each group, serum samples were separated for serum general tests using ADVIA 2400 automatic biochemical analyzer (Siemens Healthcare, Germany) and matching kits, and the blood routine was tested by Sysmex XN900 multifunctional automatic blood cell analyzer (Sysmex Corporation, Kobe, Japan) and matching kits. All data were derived from the first test results upon admission.

2.3 | Statistical analysis

SPSS 22.0 statistical software was used for statistical analysis. Count data were analyzed by the chi-square test; distributed measurement data were expressed as the mean ± SD and were analyzed by t test between two samples normally; and non-normally distributed data are presented as medians with interquartile range (P25, P75) and were analyzed by the nonparametric Mann-Whitney *U* test or the Wilcoxon signed-rank test. A p value < 0.05 indicates statistical significance.

3 | RESULTS

3.1 | The results of peripheral blood cell count in COVID-19 patients and controls

Except for lymphocyte, in order to detect whether the other results of peripheral blood cell count are associated with COVID-19, we first compared the peripheral blood cell count results from COVID-19 patients and healthy cases. The values of hematocrit (HCT), hemoglobin (Hb), LYM, mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), mean corpuscular volume (MCV), Neu, and red blood cell count (RBC) between COVID-19 patients and healthy cases were statistically significant ($p < 0.01$), while there was no significance ($p > 0.05$) for PLT and WBC results between COVID-19 patients and healthy cases (Table 1).

3.2 | The results of blood biochemical analysis in COVID-19 patients and controls

To further examine whether more general biochemical results are associated with COVID-19, we compared general biochemical results from COVID-19 patients and healthy controls (Table 2). The differences in biochemical results, including albumin (ALB), alanine aminotransferase (ALT), aspartate aminotransferase (AST), DBIL, glutamyl transferase (GGT), glucose (Glu), high-density lipoprotein cholesterol (HDL-Ch), LDL-Ch, total bilirubin (TBIL), total cholesterol (TCh), total protein (TP), and uric acid (UA), were statistically significant ($p < 0.01$) between patients with COVID-19 and healthy controls; however, the differences in alkaline phosphatase (ALP), creatinine (Cr), and triglyceride (TG) between patients with COVID-19 and healthy controls were not statistically significant ($p > 0.05$).

3.3 | The prognostic value of peripheral blood cell count results in severity of COVID-19

Lymphocyte count, one result of peripheral blood cell count, was associated with the severity of COVID-19.[13,14] Next, we analyzed the associations of other peripheral blood cell count results with COVID-19 severity (Table 3). Among different severity of COVID-19, the differences in LYM, Neu, PLT, and WBC were statistically significant ($p < 0.05$), while the differences in HCT, Hb, MCH, MCHC, MCV, and RBC were not statistically significant ($p > 0.05$). After multiple comparisons, the results showed that the value of LYM and Neu in moderate cases had significant difference to severe and critical cases ($p < 0.05$), and the value of LYM, Neu, and WBC in severe cases had no significant difference to critical cases ($p > 0.05$). The difference in PLT was statistically significant ($p = 0.040$) between moderate and critical cases. Compared with moderate cases, the difference of WBC in severe cases was statistically significant ($p = 0.026$), and other results were not statistically significant between different severity ($p > 0.05$).

3.4 | The prognostic value of blood general biochemical results in severity of COVID-19

Besides D-dimer, CRP, and LDH, to further examine whether more general biochemical results are associated with COVID-19 severity, we compared general biochemical results from different severity of COVID-19 (Table 4). Among different severity of COVID-19, the differences in DBIL, LDL-Ch, and urea were statistically significant ($p < 0.05$), while the differences in ALB, ALP, ALT, AST, Cr, GGT, Glu, HDL-Ch, TBIL, TCh, TG, TP, and UA were not statistically significant

TABLE 1 The result difference in blood routine test

	COVID-19 ($n = 94$)	Health ($n = 45$)	z	p
HCT (L/L)	0.37 (0.34, 0.40)	0.44 (0.40, 0.46)	−7.312	<0.001
Hb (g/L)	129.50 (118.50, 137.00)	147.00 (135.25, 156.75)	−6.326	<0.001
LYM (10^9/L)	0.80 (0.54, 1.05)	2.16 (1.81, 2.57	−8.526	<0.001
MCH (pg)	30.60 (29.28, 31.33)	31.80 (30.73, 32.60)	−4.059	<0.001
MCHC (g/L)	346.00 (341.00, 352.00)	335.50 (332.00, 341.00	−5.053	<0.001
MCV (fL)	87.80 (84.50, 90.68)	93.85 (91.93, 95.60)	−6.89	<0.001
Neu (10^9/L)	5.06 (3.32, 8.18)	3.19 (2.58, 4.18)	−4.578	<0.001
PLT (10^9/L)	211.50 (156.50, 260.25)	227.50 (181.75, 273.00)	−1.145	0.25
RBC (10^{12}/L)	4.15 (3.97, 4.51)	4.65 (4.36, 4.96)	−4.452	<0.001
WBC (10^9/L)	6.57 (4.65, 9.51)	6.06 (5.16, 7.38)	−1.13	0.26

TABLE 2 The difference in blood biochemical result

	COVID-19 ($n = 94$)	Health ($n = 45$)	z	p
ALB (g/L)	35.30 (32.25, 39.25)	44.95 (44.10, 46.68)	−8.657	<0.001
ALP (U/L)	65.50 (57.00, 84.00)	73.40 (61.23, 90.40)	−1.524	0.13
ALT (U/L)	28.00 (19.75, 50.25)	21.00 (17.25, 29.75)	−2.866	<0.001
AST (U/L)	34.50 (26.00, 51.00)	23.50 (21.00, 27.00)	−5.069	<0.001
Cr (μmol/L)	61.00 (51.00, 72.25)	63.00 (52.25, 73.00)	−0.195	0.85
DBIL (μmol/L)	4.90 (3.30, 5.80)	3.05 (2.40, 4.25)	−4.275	<0.001
GGT (U/L)	37.00 (23.00, 64.25)	20.00 (15.00, 36.00)	−3.837	<0.001
Glu (mmol/L)	6.21 (5.53, 8.76)	4.83 (4.53, 5.23)	−5.898	<0.001
HDL-Ch (mmol/L)	0.88 (0.72, 0.98)	1.35 (1.19, 1.52)	−7.620	<0.001
LDL-Ch (mmol/L)	2.30 (1.83, 2.87)	3.05 (2.69, 3.39)	−4.860	<0.001
TBIL (μmol/L)	11.65 (8.68, 15.23)	11.60 (9.33, 14.63)	−0.071	<0.001
TCh (mmol/L)	3.68 (3.21, 4.19)	5.06 (4.55, 5.56)	−7.206	<0.001
TG (mmol/L)	1.25 (0.98, 1.63)	1.14 (0.95, 1.60)	−0.720	0.47
TP (g/L)	59.85 (55.95, 64.30)	72.55 (69.33, 74.88)	−8.414	<0.001
UA (μmol/L)	225.50 (182.75, 309.75)	297.00 (254.50, 350.50)	−3.654	<0.001
Urea (mmol/L)	5.50 (4.09, 7.90)	6.03 (5.41, 7.01)	−1.349	0.18

($p > 0.05$). After multiple comparisons, the results showed that the value of LDL-Ch in moderate and critical cases had significant difference ($p < 0.05$), and the value of LDL-Ch in severe cases had no significant difference to moderate and critical cases ($p > 0.05$). The differences in DBIL and urea were not statistically significant among different severity ($p > 0.05$).

3.5 | The evaluation of LYM, Neu, and NLR with ROC curve for diagnostic value of COVID-19

To evaluate the diagnostic value of LYM, Neu, and NLR in patients with COVID-19, ROC curves were drawn. For diagnosis of the COVID-19, the area under ROC curve of LYM, Neu, and NLR was 0.966, 0.750, and 0.930, respectively. The preoperative LYM value of 1.345×10^9/L was the optimal cutoff value for predicting COVID-19 (sensitivity = 90.4%, specificity = 92.5%), the preoperative Neu value of 4.37×10^9/L was the optimal cutoff value for predicting COVID-19 (sensitivity = 62.8%, specificity = 85.0%), and the preoperative NLR value of 2.010 was the optimal cutoff value for predicting COVID-19 (sensitivity = 93.6%, specificity = 87.5%) (Figure 1).

4 | DISCUSSION

Since the outbreak of COVID-19 in December 2019,[1] the pandemic has spread out all over the world, and confirmed cases worldwide have exceeded 6.0 million by May 30, 2020.[2] The pathogen of COVID-19 is a novel coronavirus (SARS-CoV-2),[19] the characteristics of patients with critical COVID-19 are acute respiratory distress syndrome (ARDS), septic shock, and multiple organ failure,[3] the critical COVID-19 is the main cause of high mortality, and the pandemic had caused more than 370,000 deaths.[2] SARS-CoV-2 is an RNA virus that can grow in epithelial cells, COVID-19 is mainly diagnosed through the detection of SARS-CoV-2 RNA by real-time

TABLE 3 The value of blood routine analysis in COVID-19

	Moderate ($n = 49$)	Severe ($n = 35$)	Critical ($n = 10$)	z	p
HCT (L/L)	0.37 (0.34, 0.39)	0.37 (0.34, 0.41)	0.36 (0.34, 0.40)	0.07	0.964
Hb (g/L)	128.00 (119.00, 136.50)	130.00 (117.00, 142.00)	129.00 (117.75, 134.75)	0.11	0.947
LYM (10^9/L)	1.00 (0.70, 1.21)	0.59 (0.42, 0.86)	0.69 (0.37, 0.85)	18.60	<0.001
MCH (pg)	30.40 (29.45, 31.45)	30.70 (29.10, 31.40)	29.20 (28.65, 30.78)	2.97	0.226
MCHC (g/L)	347.00 (0.34, 0.40)	345.00 (339.00, 351.00)	347.00 (339.50, 352.00)	0.82	0.665
MCV (fL)	88.40 (85.15, 91.40)	88.70 (84.50, 90.60)	84.55 (83.70, 87.83)	3.73	0.155
Neu (10^9/L)	4.42 (2.84, 5.99)	6.69 (4.18, 10.27)	9.69 (3.25, 12.46)	15.38	<0.001
PLT (10^9/L)	232.00 (182.00, 280.50)	205.00 (149.00, 258.00)	160.00 (109.75, 224.50)	7.14	0.028
RBC (10^{12}/L)	4.13 (3.97, 4.47)	4.24 (3.94, 4.92)	4.30 (3.95, 4.72)	1.00	0.607
WBC (10^9/L)	5.82 (4.40, 7.36)	7.76 (5.16, 12.04)	10.70 (4.63, 13.26)	9.71	0.008

TABLE 4 The value of blood biochemical result in COVID-19

	Moderate ($n = 49$)	Severe ($n = 35$)	Critical ($n = 10$)	z	p
ALB (g/L)	35.80 (32.45, 40.50)	35.30 (32.40, 37.90)	33.20 (29.20, 36.38)	3.50	0.174
ALP (U/L)	64.00 (56.50, 80.50)	67.00 (57.00, 90.00)	68.50 (56.75, 90.50)	0.82	0.664
ALT (U/L)	25.00 (16.00, 57.50)	29.00 (22.00, 46.00)	25.00 (18.75, 43.75)	0.36	0.835
AST (U/L)	33.00 (25.50, 54.00)	40.00 (30.00, 51.00)	32.50 (20.00, 51.50)	1.73	0.420
Cr (μmol/L)	60.00 (50.50, 68.50)	67.00 (51.00, 76.00)	71.50 (55.25, 102.25)	4.12	0.128
DBIL (μmol/L)	4.30 (3.15, 5.50)	5.30 (3.90, 6.80)	4.95 (3.70, 9.78)	6.04	0.049
GGT (U/L)	30.00 (20.50, 54.50)	41.00 (30.00, 64.00)	59.00 (32.00, 81.25)	4.61	0.100
Glu (mmol/L)	5.85 (5.51, 8.17)	6.39 (5.55, 8.96)	7.74 (5.98, 11.34)	2.53	0.283
HDL-Ch (mmol/L)	0.93 (0.79, 0.99)	0.80 (0.67, 0.99)	0.90 (0.72, 0.99)	2.84	0.242
LDL-Ch (mmol/L)	2.48 (2.03, 2.98)	2.17 (1.73, 2.76)	1.82 (1.41, 2.24)	10.39	0.006
TBIL (μmol/L)	11.30 (8.40, 14.65)	13.10 (9.20, 18.00)	11.60 (8.43, 23.95)	2.97	0.227
TCh (mmol/L)	3.81 (3.36, 4.38)	3.56 (3.13, 4.02)	3.28 (3.13, 3.88)	3.85	0.146
TG (mmol/L)	1.18 (0.99, 1.58)	1.33 (0.98, 1.67)	1.32 (0.84, 2.41)	0.78	0.676
TP (g/L)	60.90 (56.35, 64.00)	59.30 (55.80, 65.10)	59.15 (56.08, 61.75)	0.80	0.671
UA (μmol/L)	235.00 (187.50, 296.500)	226.00 (170.00, 327.00)	196.00 (179.25, 367.00)	0.35	0.840
Urea (mmol/L)	4.91 (3.84, 6.50)	6.30 (4.60, 8.60)	7.87 (3.49, 12.00)	6.34	0.042

reverse transcription-polymerase chain reaction (rRT-PCR).[20,21] rRT-PCR, affected by sampling, operation, and reaction system, is prone to get false-negative or false-positive results.

Facing the so complicated situation, to achieve the purpose of classifying and earlier treatment, clinicians need more laboratory indices to auxiliary diagnose COVID-19 and clarify its severity. Peripheral blood cell analysis confirmed that LYM was reduced in COVID-19 patients than those in non–COVID-19 patients,[22,23] low platelet count is associated with severity and mortality of patients with COVID-19,[24,25] then we investigated the relationship between other results of peripheral blood cell count and COVID-19, the results (Table 1) showed that the differences in HCT, Hb, MCH, MCHC, MCV, Neu, and RBC were statistically significant between COVID-19 patients and healthy cases except for LYM, and these indices also can be used to differentiate COVID-19 patients from healthy cases. For WBC and PLT, the value of distinguishing COVID-19 patients from healthy cases was low. SARS-CoV-2 may infect lymphocytes directly through ACE2 receptor on the surface of lymphocytes to cause lymphocytopenia[26]; lymphocytopenia was more prominent among higher severity patients with COVID-19.[27-29] Our investigation also showed that Neu, PLT, and WBC were also associated with the severity of COVID-19, LYM and Neu had the ability to identify severe and critical cases from COVID-19 patients, including WBC, and these indices could not be used to distinguish between severe and critical patients; compared with moderate patients, platelets of critical patients were decreased, and the result is consistent with reported study[24,25]; and WBC of severe patients was increased. The results indicate that multiple indices of peripheral blood cell analysis are useful for differentiating patients with COVID-19 from healthy cases, for differentiating the severity and mortality of COVID-19 patients, clinicians should pay attention that these indices are also useful, but the value is different.

Neutrophil/lymphocyte ratio, as an inflammatory marker, was used as an index of diabetic control level, active ulcerative colitis, and thyroid cancer.[15-17] In this study, ROC curve analysis confirmed that LYM, Neu, and NLR could be used as indices for distinguishing COVID-19 patients from healthy cases. The cutoff values of LYM and NLR were better for COVID-19 diagnosis and had higher diagnostic value. The sensitivity of Neu at the cutoff value was not high, if only Neu is used as a diagnostic indice, which may lead to missed diagnosis of patients with COVID-19. More importantly, those indices are easy to get and should be preferentially evaluated for auxiliary diagnosis of patients with COVID-19, especially under the heavy burden of medical care in each affected hospital.

Laboratories can provide many biochemical indices for clinicians to assess treatment effect and organ's function of patients. CRP, as one of the most serum acute-phase reaction proteins, usually increases in pulmonary diseases with inflammatory features.[30] CRP level was positively correlated with lung lesions in the early stage of COVID-19 and associated with COVID-19 severity.[8] Severe and critical patients with COVID-19 were commonly accompanied with acute myocardial injury, which was one reason of deaths, and increased troponin T (hs-TnT) was associated with adverse prognosis of COVID-19 patients.[31,32] Patients with COVID-19 had significantly higher AST, ALT, and LDH, and these indices had very good accuracy in predicting patients with COVID-19.[33,34] In this retrospective study, the results showed that many indices (including ALB, ALT, AST, DBIL, GGT, Glu, HDL-Ch, LDL-Ch, TBI, TCh, TP, and UA), except for CRP, TnT, and LDH, could be used to identify COVID-19 patients from healthy cases. Urea, Cr, and ALP had no difference between COVID-19 patients and healthy cases. The results indicated that COVID-19 patients usually accompanied by liver damage and metabolic disorders, and further confirmed that the infection of SARS-CoV-2 can lead to multiple organ damage[35]; the value of urea and Cr

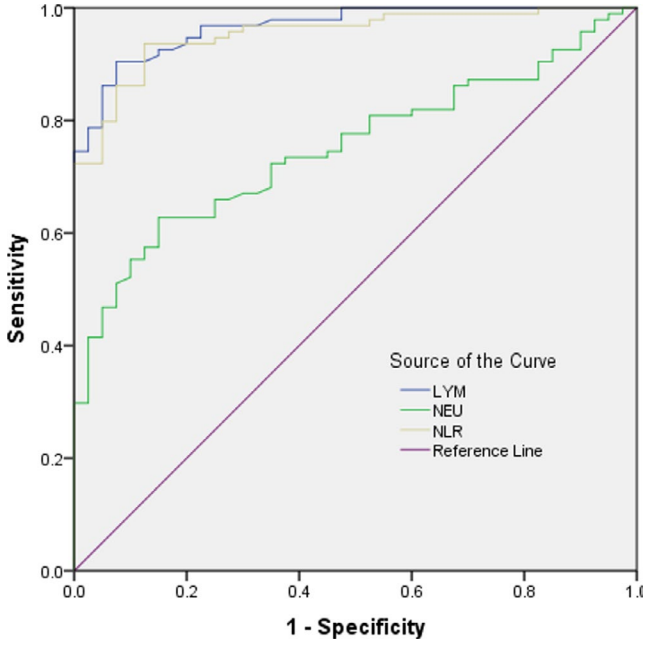

FIGURE 1 ROC curve for diagnosis of patients with COVID-19. Univariate logistic regression analysis was used to identify COVID-19 patients. Performance of ROC curves of LYM, Neu, and NLR for auxiliary diagnosis of patients with COVID-19

had no difference between COVID-19 patients and healthy cases, less than one third of the damage to kidney function may be the reason. The results also indicated that DBIL and urea had ability to distinguish severe and critical patients from moderate patients, and LDL-Ch could be used to differentiate severity of COVID-19. The findings of this study also suggested that DBIL, LDL-Ch, and urea can be used as severe and mortal predictors of COVID-19 patients.

5 | CONCLUSIONS

Our results suggested that some indices of peripheral blood cell analysis and general biochemical tests performed well in discriminating severity and predicting adverse outcome of COVID-19 patients. It is necessary to use more economical and easy-to-obtain indices of peripheral blood cell count and general biochemical analysis for clinician to diagnose and predict the prognosis of COVID-19; meanwhile, other indices with diagnostic and predictive value also should be applied as much as possible. According to the prevention and treatment guidelines of the Chinese health department, critical COVID-19 patients were mainly treated in three hospitals of Wuhan during pandemic, so the small number of cases used is a limitation of this study.

ACKNOWLEDGMENTS

We would like to acknowledge the research assistance received and help from Dr Zhu CL (Department of Clinical Laboratory, Renmin Hospital of Wuhan University, Wuhan 430060, Hubei, China).

CONFLICT OF INTEREST

We declare that we have no conflicts of interest.

ETHICAL APPROVAL

This study was approved by the institutional ethics board of Renmin Hospital of Wuhan University (No. WDRY2020-K066), and participants signed informed consent forms.

DATA AVAILABILITY STATEMENT

All datasets are available from the corresponding author upon request.

ORCID

Qingfeng Ma https://orcid.org/0000-0002-1676-3235

REFERENCES

1. Zhu N, Zhang W, Wang W, et al. A novel Coronavirus from patients with pneumonia in China, 2019. *N Engl J Med*. 2020;382(8):727-733.
2. Coronavirus disease (COVID-2019) situation reports. https://www.who.int/emergencies/diseases/novel-coronavirus-2019/situation-reports. Accessed 15 February 2020.
3. General Office of the National Health Committee of China, China Traditional Chinese Medicine Administration Office. Diagnosis and treatment plan of novel coronavirus pneumonia (seventh trial edition). 2020. http://www.nhc.gov.cn/yzygj/s7652m/202003/a31191442e29474b98bfed5579d5af95.shtml. Accessed 11 March 2020.
4. Li Q, Guan X, Wu P, et al. Early transmission dynamics in Wuhan, China, of novel coronavirus-infected pneumonia. *N Engl J Med*. 2020;382(3):1199-1207.
5. Scheller J, Chalaris A, Schmidt-Arras D, Rose-John S. The pro- and anti-inflammatory properties of the cytokine interleukin-6, BBA-Mol. *Cell Res*. 2011;1813(5):878-888.
6. Han H, Ma Q, Li C, et al. Profiling serum cytokines in COVID-19 patients reveals IL-6 and IL-10 are disease severity predictors. *Emerg Microbes Infect*. 2020;9(1):1123-1130.
7. Liu R, Ma Q, Han H, et al. The value of urine biochemical parameters in the prediction of the severity of coronavirus disease 2019. *Clin Chem Lab Med*. 2020;58(7):1121-1124.
8. Wang L. C-reactive protein levels in the early stage of COVID-19. *Med Mal Infect*. 2020;50(4):332-334.
9. Chen W, Zheng KI, Liu S, Yan Z, Xu C, Qiao Z. Plasma CRP level is positively associated with the severity of COVID-19. *Ann Clin Microbiol Antimicrob*. 2020;19(1):18.
10. Zhou F, Yu T, Du R, et al. Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: a retrospective cohort study. *Lancet*. 2020;395(10229):1054-1062.
11. Chen N, Zhou M, Dong X, et al. Epidemiological and clinical characteristics of 99 cases of 2019 novel coronavirus pneumonia in Wuhan, China: a descriptive study. *Lancet*. 2020;395(10223):507-513.
12. Qin C, Zhou L, Hu Z, et al. Dysregulation of immune response in patients with COVID-19 in Wuhan, China. *Clin Infect Dis*. 2020;71(15):762-768.
13. Liu Y, Liao W, Wan L, Xiang T, Zhang W. Correlation between relative nasopharyngeal virus RNA load and lymphocyte count disease severity in patients with COVID-19. *Viral immunol*. 2020. [Epub ahead of print].
14. Xu B, Fan CY, Wang AL, et al. Suppressed T cell-mediated immunity in patients with COVID-19: a clinical retrospective study in Wuhan, China. *J Infect*. 2020;81(1):e51-e60.

15. Duman TT, Aktas G, Atak BM, Kocak MZ, Erkus E, Savli H. Neutrophil to lymphocyte ratio as an indicative of diabetic control level in type 2 diabetes mellitus. *Afr Health Sci*. 2019;19(1):1602-1606.
16. Sit M, Aktas G, Erkol H, Yaman S, Keyif F, Savli H. Neutrophil to lymphocyte ratio is useful in differentiation of malign and benign thyroid nodules. *P R Health Sci J*. 2019;38(1):60-63.
17. Posul E, Yilmaz B, Aktas G, Kurt M. Does neutrophil-to-lymphocyte ratio predict active ulcerative colitis? *Wien Klin Wochenschr*. 2015;127(7-8):262-265.
18. Wells PM, Doores KJ, Couvreur S, et al. Estimates of the rate of infection and asymptomatic COVID-19 disease in a population sample from SE England. *J Infect*. 2020;S0163-4453(20):30653–30658.
19. World Health Organization, WHO Director-General's remarks at the media briefing. https://www.who.int/dg/speeches/detail. Accessed 11 February 2020.
20. Ishige T, Murata S, Taniguchi T, et al. Highly sensitive detection of SARS-CoV-2 RNA by multiplex rRT-PCR for molecular diagnosis of COVID-19 by clinical laboratories. *Clin Chim Acta*. 2020;507:139-142.
21. Kokkinakis I, Selby K, Favrat B, Genton B, Cornuz J. Performance du frottis nasopharyngé-PCR pour le diagnostic du Covid-19 - Recommandations pratiques sur la base des premières données scientifiques [Covid-19 diagnosis : clinical recommendations and performance of nasopharyngeal swab-PCR]. *Rev Med Suisse*. 2020;16(689):699-701.
22. Xu Z, Shi L, Wang Y, et al. Pathological findings of COVID-19 associated with acute respiratory distress syndrome. *Lancet Respir Med*. 2020;8(4):420-422.
23. Chan JF, Yuan S, Kok KH, et al. A familial cluster of pneumonia associated with the 2019 novel coronavirus indicating person-to-person transmission: a study of a family cluster. *Lancet*. 2020;395(10223):514-523.
24. Lippi G, Plebani M, Henry BM. Thrombocytopenia is associated with severe coronavirus disease 2019 (COVID-19) infections: a meta-analysis. *Clin Chim Acta*. 2020;506:145-148.
25. Jiang SQ, Huang QF, Xie WM, Lv C, Quan XQ. The association between severe COVID-19 and low platelet count: evidence from 31 observational studies involving 7613 participants. *Br J Haematol*. 2020;190(1):e29-e33.
26. Xu H, Zhong L, Deng J, et al. High expression of ACE2 receptor of 2019-nCoV on the epithelial cells of oral mucosa. *Int J Oral Sci*. 2020;12(1):8.
27. Guan WJ, Ni ZY, Hu Y, et al. 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.
28. Arentz M, Yim E, Klaff L, et al. Characteristics and outcomes of 21 critically Ill patients with COVID-19 in Washington State. *JAMA*. 2020;323(16):1612-1614.
29. Bhatraju PK, Ghassemieh BJ, Nichols M, et al. Covid-19 in critically Ill patients in the Seattle region-case series. *N Engl J Med*. 2020;382(21):2012-2022.
30. Marnell L, Mold C, Du Clos TW. C-reactive protein: ligands, receptors and role in inflammation. *Clin Immunol*. 2005;117(2):104-111.
31. Wei JF, Huang FY, Xiong TY, et al. Acute myocardial injury is common in patients with covid-19 and impairs their prognosis. *Heart*. 2020;106(15):1154-1159.
32. Shi S, Qin M, Shen B, et al. Association of cardiac injury with mortality in hospitalized patients with COVID-19 in Wuhan, China. *JAMA Cardiol*. 2020;5(7):802-810.
33. Mardani R, Ahmadi Vasmehjani A, Zali F, 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):e43.
34. Mo P, Xing Y, Xiao Y, et al. Clinical characteristics of refractory COVID-19 pneumonia in Wuhan, China. *Clin Infect Dis*. 2020;ciaa270.
35. Iwasaki M, Saito J, Zhao H, Sakamoto A, Hirota K, Ma D. Inflammation triggered by SARS-CoV-2 and ACE2 augment drives multiple organ failure of severe COVID-19: molecular mechanisms and implications. *Inflammation*. 2020;1-22.

How to cite this article: Lv Z, Wang W, Qiao B, et al. The prognostic value of general laboratory testing in patients with COVID-19. *J Clin Lab Anal*. 2021;35:e23668. https://doi.org/10.1002/jcla.23668