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Clinical and hematological characteristics of 88 patients with COVID-19

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Abstract

Introduction: To retrospectively analyze epidemiological, clinical and hematological characteristics of COVID-19 patients.

Methods: The demographic, symptoms, and physiological parameters of 88 patients were collected and analyzed. The performance of complete blood count (CBC) indexes for monitoring and predicting the severity of COVID-19 in patients was evaluated by analyzing and comparing CBC results among different COVID-19 patient groups.

Results: White blood cells (WBCs), the neutrophil percentage (Neu%), absolute neutrophil count (Neu#), and neutrophil-to-lymphocyte ratio (NLR) were significantly higher in the critical group than in the other three groups ($P < .05$), while the lymphocyte percentage (Lym%), monocyte percentage (Mon%), lymphocyte count (Lym#), and lymphocyte-to-monocyte ratio (LMR) were significantly lower in the critical group than in the other three groups ($P < .05$). WBCs, the Neu%, Neu#, NLR, and neutrophil-to-monocyte ratio (NMR) were significantly higher in the severe group than in the mild and moderate groups ($P < .05$), while the Lym% was significantly lower in the severe group than in the mild and moderate groups ($P < .05$). The Mon%, Lym#, and LMR were significantly lower in the severe group than in the moderate group ($P < .05$). Using receiver operating characteristic (ROC) curve analysis to differentiate severe and nonsevere patients, the areas under the curve (AUCs) for the NLR, Neu%, and Lym% were 0.733, 0.732, and 0.730, respectively. When differentiating critical patients from noncritical patients, the AUCs for the NLR, Neu%, and Lym% were 0.832, 0.831, and 0.831.

Conclusions: The NLR is valuable for differentiating and predicting patients who will become critical within 4 weeks after the onset of COVID-19.

KEYWORDS

BC-6800plus, clinical characteristics, COVID-19, hematology, neutrophil-to-lymphocyte ratio, novel coronavirus (SARS-Cov-2)

Hongmei Zhang and Xiaocui Cao contributed equally to this work.

1 | INTRODUCTION

An outbreak of novel coronavirus (COVID-19) occurred in December 2019, and it was recognized by the World Health Organization (WHO) on January 12, 2020. Patients initially presented with fever, dry cough, fatigue, and other symptoms. Within 1-2 weeks, they could progress to acute respiratory distress syndrome (ARDS), metabolic acidosis, and even shock, multiple organ failure and other fatal complications.[1,2,3] There is no specific therapy, and comprehensive support and symptomatic treatment are employed.[4] Patients with mild and moderate disease can recover quickly with appropriate medical interventions,[5] but the death rate of severe or critical patients, especially patients with underlying diseases and elderly patients, is higher.[6,7,8] As of May 10, 2020, 3 917 366 cases have been confirmed, and 274 361 patients have died, with a mortality rate of 7%.[9] In different countries, due to differences in pressure on the medical system and in prevention and control measures, the mortality rate is quite different, with rates of 5.91% (80 787/1 367 638), 10.06% (26 621/264 663), 14.53% (31 855/219 183), 13.95% (30 560/219 070), and 16.41% (34 306/209 070) in the United States, Spain, the UK, Italy and Russia, respectively. Therefore, indicators that can be used to evaluate the severity of the disease, monitor the treatment process and the clinical outcome and provide a clinical reference could provide information for targeted or preventive medication, which is expected to significantly reduce patient mortality and prevent further worsening of the epidemic.

CBCs are a convenient and effective laboratory examination. The purpose of this study was to review and analyze differences among CBC results of COVID-19 patients with different disease severity and how CBC results changed after disease onset to identify key indicators of disease progression and stage and to provide a basis for diagnosis and treatment basis for clinicians.

2 | MATERIALS AND METHODS

2.1 | Patients

All 88 patients reviewed in this study were hospitalized at the Central Hospital of Wuhan from January 28, 2020 to February 24, 2020. Most of the patients complained of fever or respiratory symptoms. Patient epidemiological information, including whether they had contact with suspected or confirmed patients in the 2 weeks before admission, was collected and recorded. Nasopharynx or pharynx swabs were collected from all patients before their admission to detect the virus. This study was approved by the hospital ethics committee. As this was a retrospective study, the Ethics Council gave approval to not obtain written informed consent from patients. All patients were diagnosed by virus nucleic acid testing with quantitative RT-PCR, and seven pneumonia viruses (influenza A virus antigen, influenza B virus antigen, respiratory syncytial virus antigen, adenovirus, human parainfluenza virus IgM antibody, *Mycoplasma pneumoniae* IgM antibody, and *Chlamydia pneumoniae* IgM antibody) were excluded with the colloidal gold method. There were 29 patients with moderate disease, 36 patients with severe disease, and 23 critical patients. As of the end of the investigation, 29 moderate patients improved and were discharged; 34 patients in the severe group improved and were discharged and 2 patients were transferred to other hospitals for further treatment; and 10 patients in the critical group improved and were discharged, 5 patients were transferred to other hospitals for further treatment, 2 patients remained in the hospital for treatment, and 6 patients died. The Guidelines for the Diagnosis and Treatment of Novel Coronavirus (2019-nCoV) Infection (trial version 7) released by the National Health Commission of the People's Republic of China was used as criteria for the diagnosis and differentiation of all patients.[3] Novel coronavirus pneumonia patients were classified according to the following clinical criteria: (1) mild type (mild clinical symptoms and no signs of pneumonia on imaging, (2) moderate type (fever, respiratory tract infection symptoms, and imaging findings of pneumonia), and (3) severe type (the occurrence of any of the following: (a) shortness of breath with a respiratory rate (RR) >30 times/min, (b) mean oxygen saturation of blood from the finger of <93% at rest, (c) arterial oxygen partial pressure (PaO2)/fraction of inspired oxygen (FiO2) ≤300 mm Hg (1 mm Hg = 0.133 kPa), or (d) pulmonary imaging showing that the focus had progressed more than 50% within 24-48 hours), and (4) critical (the occurrence of any of the following: (a) respiratory failure requiring mechanical ventilation, (b) shock; and (c) other organ failure requiring intensive care unit (ICU) treatment).

2.2 | Data records and assays

Patient epidemiological information was obtained from questionnaires that patients completed when they were admitted to the hospital, and patient symptoms, signs, medical history, and other data were obtained from patient descriptions and clinicians' records from consultations and physical examinations (hospital information system (HIS)). CBC results (BC-6800plus hematology analyzer, Mindray, Shenzhen, China) were collected from the laboratory information system (LIS). A total of 413 CBC test results were collected from 88 patients hospitalized in our hospital from January 28, 2020 to February 24, 2020, and these test results were classified according to the real-time condition and recovery of patients into 4 groups: 8 tests were collected from the mild group, 243 tests were collected from the moderate group, 113 tests were collected from the severe group and 49 tests were collected from the critical group for subsequent statistical analysis.

2.3 | Statistical analysis

Categorical variables are expressed as absolute numbers and percentages, and the R × C chi-square test was used for comparisons among multiple groups. CBC results were considered continuous variables and are expressed as the mean and standard deviation (SD). Variance analysis was used to compare multiple groups. The least significant difference (LSD) t test was used when the variance was

homogeneous, and Tamhane's T2 test was used when the variance was not homogenous. Statistical significance ($P < .05$) was determined by a two-tailed Student's *t* test with SPSS statistical software (version 19.0, SPSS Inc, Chicago IL).

3 | RESULTS

A summary of patient information is shown in Table 1; there were 45 male patients (26-89 years old) and 43 female patients (22-81 years old). The average age of patients in the severe and critical groups was significantly higher than that in the moderate group ($P < .05$). Eleven (12.5%) patients had contacted suspected patients in the past 2 weeks, and 7 (8.0%) had contacted confirmed patients. In regard to clinical symptoms, 71 (80.7%) patients had fever, 43 (48.9%) had asthenia, 32 (36.4%) had dry cough, 28 (31.8%) had expectoration, 21 (23.9%) had shivering and 15 (17.0%) had muscle pain, and there was no significant difference in symptoms in the different groups ($P > .05$). Among all patients, 33 (37.5%) had underlying diseases, of which hypertension (26.1%) and diabetes (12.5%) were the most common. There was no significant difference between the groups ($P > .05$).

A comparison of CBC results showed that as the disease progressed, WBCs, the Neu%, Neu#, NLR, NMR, and platelet-to-lymphocyte ratio (PLR) gradually increased, and there were significant differences among the four groups ($P < .05$). The Lym%, Mon%, Lym#, and LMR gradually decreased, and there were significant differences among the four groups ($P < .05$). Among these differences, WBCs, the Neu%, Neu#, and NLR were significantly higher in the critical group than the other three groups ($P < .05$), while the Lym%, Mon%,

TABLE 1 Epidemiological and clinical characteristics of patients with SARS-Cov-2 pneumonia

Characteristics	All patients	Moderate	Severe	Critical	*P* value
N	88	29	36	23	/
Demographic information					
Age, median (range) – y	55 (22-89)	37 (22-66)	58 (28-81)	66 (26-89)	.000
Male– no. (%)	45 (51.1%)	11 (37.9%)	17 (47.2%)	17 (73.9%)	.030
Female– no. (%)	43 (48.9%)	18 (62.1%)	19 (52.8%)	6 (26.1%)	
Exposure history within 2 wk – No.(%)					
Suspected patient contact within 2 wk	11 (12.5%)	8 (27.6%)	2 (5.6%)	1 (4.3%)	.014
Confirmed patient contact within 2 wk	7 (8.0%)	5 (17.2%)	2 (5.6%)	0	.034
Clinical symptoms – no. (%)					
Fever	71 (80.7%)	26 (89.7%)	27 (75.0%)	18 (78.3%)	.312
Fatigue	43 (48.9%)	14 (48.3%)	16 (44.4%)	13 (56.5%)	.662
Cough	32 (36.4%)	14 (48.3%)	11 (30.6%)	7 (30.4%)	.265
Expectorant	28 (31.8%)	9 (31.0%)	12 (33.3%)	7 (30.4%)	.967
Chills	21 (23.9%)	8 (27.6%)	9 (25.0%)	4 (17.4%)	.667
Muscle pain	15 (17.0%)	5 (17.2%)	7 (19.4%)	3 (13.0%)	.810
Diarrhea	11 (12.5%)	2 (6.9%)	7 (19.4%)	2 (8.7%)	.259
Headache	8 (9.1%)	0	6 (16.7%)	2 (8.7%)	.023
Dizziness	7 (8.0%)	2 (6.9%)	2 (5.6%)	3 (13.0%)	.591
Chest pain	5 (5.7%)	2 (6.9%)	1 (2.8%)	2 (8.7%)	.576
Stomach ache	4 (4.5%)	0	3 (8.3%)	1 (4.3%)	.160
RR> 30 bmp	2 (2.3%)	0	1 (2.8%)	1 (4.3%)	.422
Hypotension	1 (1.1%)	0	0	1 (4.3%)	.257
Underlying disease – no. (%)					
Any	33 (37.5%)	7 (24.1%)	13 (36.1%)	13 (56.5%)	.055
Hypertension	23 (26.1%)	5 (17.2%)	11 (30.6%)	7 (30.4%)	.412
Diabetes	11 (12.5%)	2 (6.9%)	3 (8.3%)	6 (26.1%)	.095
Cardiovascular diseases	8 (9.1%)	1 (3.4%)	3 (8.3%)	4 (17.4%)	.222
Cerebrovascular disease	5 (5.7%)	0	1 (2.8%)	4 (7.4%)	.018
Chronic kidney disease	4 (4.5%)	1 (3.4%)	1 (2.8%)	2 (8.7%)	.573
Cancer	3 (3.4%)	1 (3.4%)	1 (2.8%)	1 (4.3%)	.950

Note: $P < .05$ indicates that there were statistically significant differences among the groups.

Lym#, and LMR were significantly lower in the critical group than in the other three groups ($P < .05$). Additionally, WBCs, the Neu%, Neu#, NLR, and NMR were significantly higher in the severe group than in the mild and moderate groups ($P < .05$), while the Lym% was significantly lower in the severe group than in the mild and moderate groups ($P < .05$). The Mon%, Lym#, and LMR were significantly lower in the severe group than in the moderate group ($P < .05$), and the PLR was significantly higher in the severe group than in the mild group ($P < .05$) and was not significantly different in the severe and moderate groups ($P > .05$; Table 2). A grouped box plot for the parameters with significant differences in the analysis of variance described above (WBCs, the Neu#, Neu%, Lym#, Lym%, Mon%, NLR, LMR, NMR, and PLR) is shown in Supplement S1. Each parameter gradually increased or decreased as the disease progressed.

Next, CBC results of severe and critical patients (162 tests total, collectively referred to as the severe type) were considered the positive standard, CBC results of mild and moderate patients (251 tests total, collectively referred to as the nonsevere type) were considered the negative standard, and the ROC curve was used to analyze the diagnostic value of each CBC parameter for distinguishing the severe and nonsevere types (Figure 1A,B). The results showed that the AUCs of the NLR, Neu%, Lym% were the most valuable, with values of 0.733, 0.732, and 0.730, respectively. The sensitivity and specificity were 67.3% and 74.5% for the NLR, 69.1% and 68.9% for the Neu%, and 67.5% and 74.5% for the Lym% when the cut-off values were 5.92, 77.85% and 13.45%, respectively.

When CBC results of critical patients (49 tests, referred to as the critical type) were considered the positive standard, CBC results of the other patients (364 tests total, collectively referred to as the noncritical type) were considered the negative standard, and the ROC curve was used to analyze the diagnostic value of each CBC parameter for distinguishing the critical and noncritical types (Figure 1C,D), the results showed that the AUCs of the NLR, Neu%, Lym% were still the most valuable, with values of 0.832, 0.831, and 0.831, respectively. The sensitivity and specificity were 89.8% and 67.0% for the NLR, 91.8% and 65.7% for the Neu%, and 89.8% and 65.9% for the Lym%, respectively, when the cut-off values were 6.19, 79.55%, and 13.2%, respectively.

Based on the cut-offs of the above three parameters, the grouping accuracy of all the CBC results was evaluated, and the identification rate is shown in Table 3. When the cut-off values of the NLR, Neu%, and Lym% were 5.92%, 77.85%, and 13.45%, respectively, more critical and severe samples were identified. At the same time, when considering the time when the patients complained of fever, dry cough, dyspnea, chest distress, and other symptoms as day 0, we analyzed changes and trends in CBC results of moderate, severe, and critical patients (Figure 2). Within 26 days of disease onset, 62.2% (74/119) of Neu% results of the moderate group were below 77.85%, while 71.7% (66/92) of Neu% results of the critical group were above 77.85%. Additionally, 69.7% (83/119) of Lym% results were over 13.45% in the moderate group, while 71.7% (66/92) of Lym% results were under 13.45% in the critical group. Finally, 68.9% (82/119) of NLR results were under 5.92 in the moderate group, while 72.8% (67/92) of NLR results were over 5.92 in the critical group. Thus, among these parameters, the trend of the NLR was the most stable.

4 | DISCUSSION

This study described 88 COVID-19 patients hospitalized at our hospital from January 28, 2020 to February 24, 2020 and found that the average age of severe and critical patients was significantly higher than that of moderate patients ($P < .05$). This finding indicates that

TABLE 2 Multiple-group comparison of CBC results (ANOVA)

Para.	Total (N = 414)	Mild (N = 8)	Moderate (N = 243)	Severe (N = 113)	Critical (N = 49)	*F*	*P* value
WBC	7.31 ± 3.79	5.08 ± 2.14	6.68 ± 3.48	7.82 ± 4.15[a]	9.57 ± 3.53[a]	10.28	.000
Neu%	74.62 ± 12.86	61.48 ± 6.65	71.02 ± 12.64[a]	78.01 ± 11.31[a]	86.79 ± 6.01[a]	32.41	.000
Lym%	17.85 ± 10.61	27.41 ± 4.61	20.82 ± 10.53[a]	15.07 ± 9.38[a]	7.99 ± 4.69[a]	30.62	.000
Mon%	6.45 ± 2.7	7.54 ± 2.63	6.94 ± 2.72	6.1 ± 2.62[d]	4.7 ± 1.85[a]	11.37	.000
Neu#	5.75 ± 3.65	3.22 ± 1.67	5.02 ± 3.27	6.35 ± 3.96[a]	8.39 ± 3.37[a]	15.70	.000
Lym#	1.07 ± 0.56	1.36 ± 0.47	1.18 ± 0.55	0.98 ± 0.56[d]	0.7 ± 0.44[a]	12.82	.000
Mon#	0.43 ± 0.2	0.35 ± 0.1	0.42 ± 0.2	0.44 ± 0.23	0.43 ± 0.18	0.49	.690
NLR	8.06 ± 9.66	2.33 ± 0.62	5.98 ± 8.27[a]	9.55 ± 10.31[a]	15.84 ± 10.67[a]	18.19	.000
LMR	2.83 ± 1.62	3.97 ± 1.27	3.12 ± 1.62	2.59 ± 1.62[d]	1.72 ± 1[a]	13.43	.000
NMR	14.5 ± 9.3	8.97 ± 2.89	12.43 ± 7.26	16.5 ± 10.47[b]	21.03 ± 11.81b	16.44	.000
PLR	304.04 ± 356.91	178.41 ± 84.37	257.66 ± 174	327.5 ± 289.28[c]	500.47 ± 830.81[c]	7.11	.000

[a]Indicates significantly different from any of the other three groups;

[b]indicates significantly different from the mild and moderate groups;

[c]indicates significantly different from the mild group; and

[d]indicates significantly different from the moderate group.

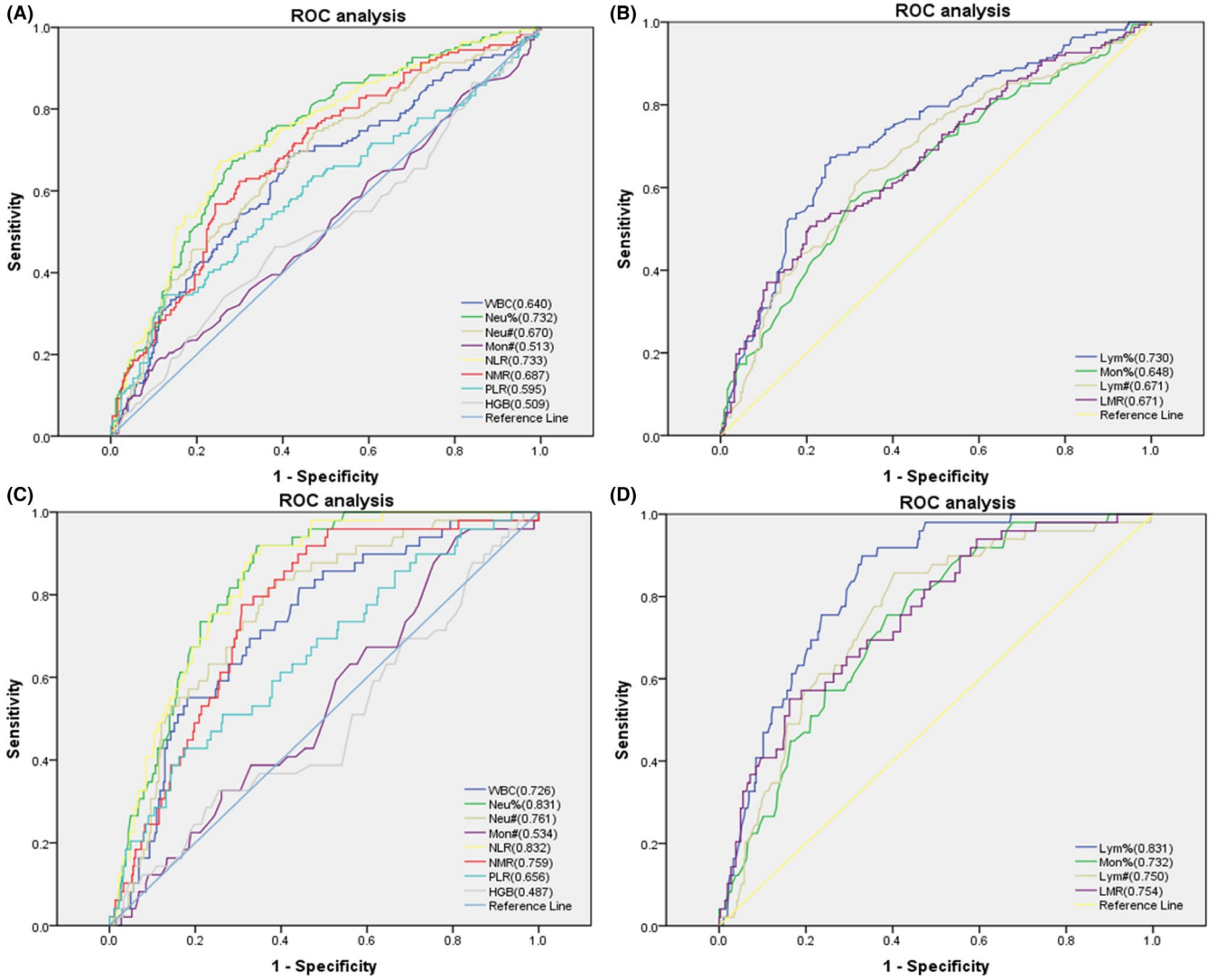

FIGURE 1 ROC analysis of CBC results. A-B: ROC analysis of CBC results of severe type and nonsevere type; C-D: ROC curve analysis of CBC results of critical type and noncritical type [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE 3 Comparison of screening rates of three CBC indexes at different cut-offs

Parameters	Mild (N = 8)	Moderate (N = 243)	Severe (N = 113)	Critical (N = 49)	Total (N = 413)
NLR ≥ 5.92 - no. (%)	0 (0%)	64 (26.3%)	64 (56.6%)	45 (91.8%)	173
NLR ≥ 6.19 - no. (%)	0 (0%)	61 (25.1%)	59 (52.2%)	44 (89.8%)	164
Neu%≥77.85% - no. (%)	0 (0%)	78 (32.1%)	67 (59.3%)	45 (91.8%)	190
Neu%≥79.55% - no. (%)	0 (0%)	66 (27.2%)	59 (52.2%)	45 (91.8%)	170
Lym%≤13.2% - no. (%)	0 (0%)	62 (25.5%)	62 (54.9%)	44 (89.8%)	168
Lym%≤13.45% - no. (%)	0 (0%)	64 (26.3%)	65 (57.5%)	44 (89.8%)	173

as the age of patients with SARS-Cov-2 increased, the disease was more serious. This observation is likely related to the decrease in the body's defenses that is caused by the deterioration of physiological and immune functions in elderly individuals.[6,7,8] In regard to data on underlying disease, it has been found that as the infection increases in severity, the proportion of individuals with underlying diseases has increased, which was also one of the main reasons for the disease severity in elderly individuals. The most common complications were hypertension (26.1%) and diabetes (12.5%), which is consistent with the current understanding of the disease.[6] The main clinical symptoms of patients in this study were fever (80.7%), weakness (48.9%), dry cough (36.4%), and expectoration (31.8%). Therefore, if patients have the above symptoms, they should be taken seriously and active measures such as self-isolation or medical treatment should be taken

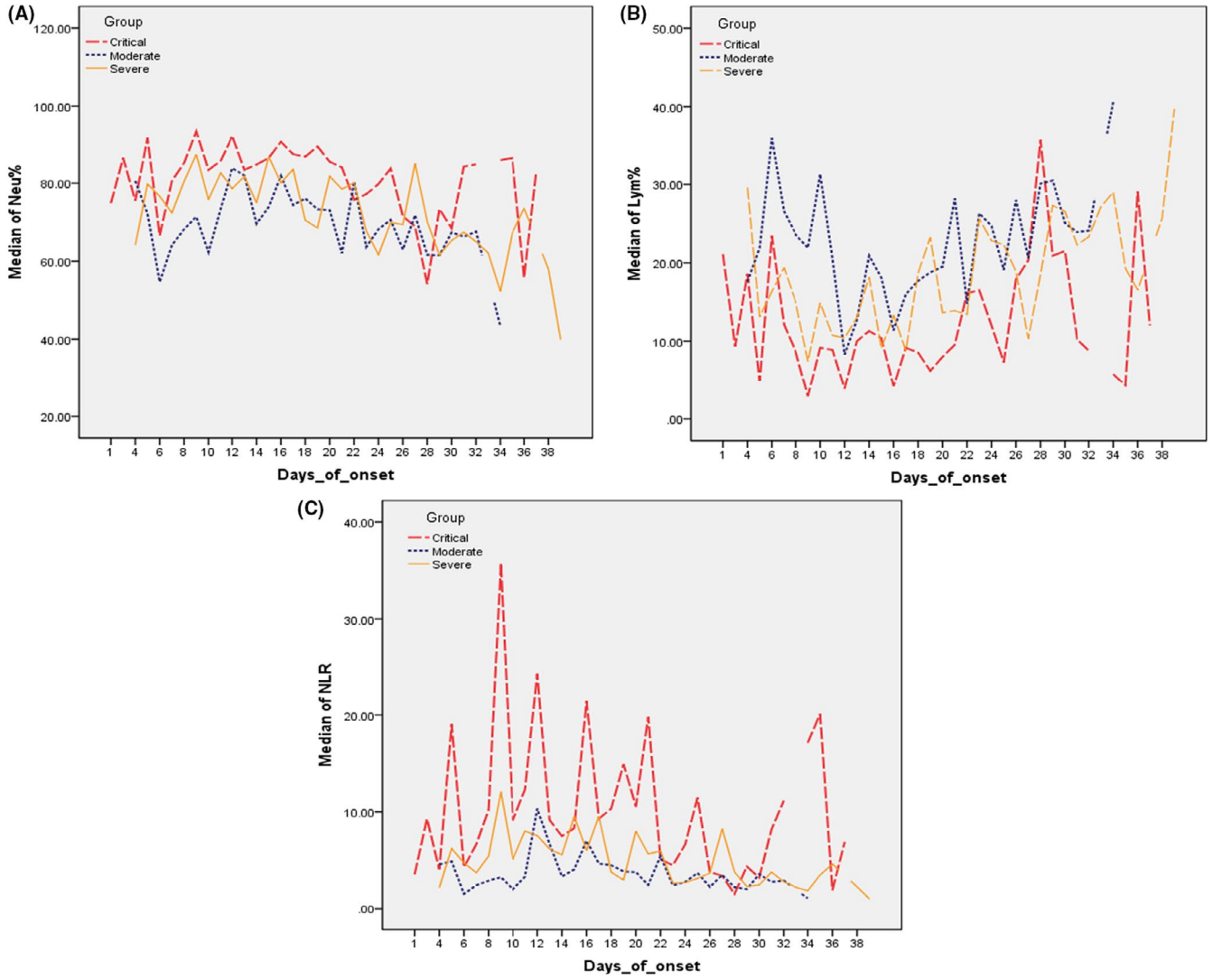

FIGURE 2 Trends in CBC results over time after disease onset [Colour figure can be viewed at wileyonlinelibrary.com]

to protect patients as well as the people around patients and to effectively prevent further expansion of the epidemic.

CBC results were divided into four groups, ranging from mild to critical, in this study according to the real-time condition of the patients. WBCs, the Neu%, and Mon% showed a significant upward trend ($P < .05$), while the Lym% showed a significant downward trend ($P < .05$) with the worsening of the disease. This also led to a significant increase in related parameters, the NLR, NMR, and PLR, and a significant decrease in the LMR. A study by Qin et al.[10] also showed that monitoring the NLR and lymphocyte subsets was helpful for screening early critical COVID-19, which is consistent with the findings of this study. Novel coronavirus, as an RNA virus that has not previously appeared in humans, has become well known, and the way through which the virus invades humans and the mechanism of infection are gradually becoming clear.[11] In the early stage of the disease, B lymphocytes secrete antibodies that directly combine with the virus and thus destroy the virus. T lymphocytes can engulf infected cells and thus eliminate the virus. In this process, a large number of lymphocytes are consumed, which may be the main reason for the decrease in lymphocytes.[12,13] Autopsy results showed early changes in acute lung injury during infection and diffuse alveolar injury with exudate, in which the inflammation was mainly lymphocytic, which also explains the decrease in lymphocytes.[14] This phenomenon was previously observed in severe acute respiratory syndrome (SARS) and Middle East respiratory syndrome (MERS) patients.[15,16] As the disease progresses, the organs that produce lymphocytes are also attacked or even destroyed by the virus. At the same time, the virus affects the release of immune factors and immune regulation. At the later stage of infection, COVID-19 patients may develop secondary bacterial infections.[17] Neutrophils are activated by the pathogen and release a large number of cytokines, chemokines, and various proteolytic enzymes to eliminate the pathogen. There is evidence that peripheral blood neutrophils in patients with severe bacterial infection are affected by cytokines, and neutrophil apoptosis is significantly inhibited, resulting in a significant increase in the number of peripheral blood neutrophils.[18,19] Because neutrophils are the main source of chemokines and cytokines and cytokine storms can

lead to ARDS, neutrophils are strongly related to the development of ARDS and critical illness.[20]

The diagnostic efficacy of blood cell indexes for differentiating severe and critical patients was analyzed. The results showed that the diagnostic efficacy of the NLR, Neu%, and Lym% was the greatest. When evaluating severe patients, the AUCs of the three indexes were 0.733, 0.732, and 0.730, respectively, and when the cut-off values were 5.92, 77.85, and 13.45%, the sensitivity and specificity were 67.3% and 74.5% for NLR, 69.1% and 68.9% for Neu and 67.5% and 74.5% for Lym, respectively. When examining critical patients, the AUCs of the three indexes were 0.832, 0.831, and 0.831, respectively, and when the cut-offs were 6.19, 79.55%, and 13.2%, the sensitivity and specificity were 89.8% and 67.0% for the NLR, 91.8% and 65.7% for the Neu%, and 89.8% and 65.9% for the Lym%, respectively. As a commonly used screening method in all medical institutions, the CBC needs to identify target patients as much as possible, and based on CBC results, laboratories or clinicians can make a comprehensive decision according to the patient's signs, symptoms, and other information. Therefore, detection methods should be highly sensitive.[21] Based on the results of this study, if a COVID-19 patient had an NLR over 5.92, a Neu% over 77.85%, and a Lym% lower than 13.45%, he/she was more likely to be or become a severe patient and therefore needed to be monitored by clinicians. Based on the relationship among the three parameters, we recommend using the NLR, as it was more stable and considered the characteristics of the Neu% and Lym%, to predict disease severity. Based on changes in the CBC after disease onset, the NLR has a good ability to differentiate patients who will become critical within 4 weeks after disease onset. The NLR is the ratio of neutrophils to lymphocytes in peripheral blood, and its clinical value in infectious diseases or inflammation has been gradually appreciated.[22,23,24] In the early stage of this epidemic, a study carried out by Beijing Ditan Hospital Affiliated to Capital Medical University[25] showed that if a patient had an NLR > 3.13 and was over 50 years old, he/she was more likely to develop severe disease, and intensive care should be considered as early as possible. This study also found that the NLR had a better differentiation value than other parameters for identifying patients who would become critical within 4 weeks after the onset of COVID-19. COVID-19 patients who have an NLR over 5.92 should receive special attention and be treated as soon as possible to resolve the condition.

It can be seen in diagram that the trend and change of Neu% and NLR values were higher in the critically ill group than in the moderate and severe groups, while the Lym% was lower in the critically ill group than in the moderate and severe groups. These data indicate that the disease severity of patients was positively correlated with Neu% and NLR values and negatively correlated with Lym% values. Notably, in the second week after disease onset, the Neu% and NLR in each group began to significantly increase, with the Neu% increasing by approximately 40% and the NLR increasing by approximately 200%. The Lym% also showed a significant decline, decreasing by approximately 70%. These results are consistent with the findings of Terpos et al,[26] which indicated that patients experienced a sharp increase in clinical manifestations, a significant decrease in lymphocytes, and a cytokine storm approximately 7-14 days after the onset of initial symptoms. In this study, neutrophils began to significantly increase in the second week after disease onset, which may have been caused by weakened immunity and bacterial infection after the viral infection. The production of a large number of cytokines and inflammatory mediators led to the inhibition of neutrophil apoptosis and an increase in the number of neutrophils in peripheral blood. Wang et al also found that the number of peripheral blood neutrophils in the COVID-19 death group significantly increased in the second week after onset and was significantly higher than that in the COVID-19 survival group.[27] Further decreases in lymphocytes may occur because of the increase in some cytokines, including IL-6, IL-2, and TNF-α, and may accelerate the apoptosis of lymphocytes. Additionally, the large amount of cytokine activation may also be related to the atrophy of lymphoid organs, which inhibits lymphocyte proliferation. In this study, the Neu%, Lym%, and NLR gradually recovered 3-4 weeks after disease onset, indicating that the treatment measures were effective. The Neu%, Lym%, and NLR could effectively reflect disease progression in COVID-19 patients.

To evaluate whether the cell morphology of patients with COVID-19 changed, the peripheral blood smear of one patient was observed under a microscope, as shown in Supplement S2. The results showed that some neutrophils exhibited toxic granules and vacuolation in the cytoplasm (Supplement S2A). Abnormal lymphocytes were occasionally seen. The morphology of the nucleus and cytoplasm was inconsistent. Irregular nuclei and abundant cytoplasm with a few dark, thick granules were present. Some lymphocytes appeared to have nucleoli (Supplement S2B-E). Mononuclear nuclei were irregular, and vacuolar degeneration was obvious (Supplement S2F). These results suggest that patients with COVID-19 develop abnormal morphology of neutrophils, lymphocytes, and monocytes after being invaded by the pathogen. This is consistent with the findings of Zini and Mitra.[28,29]

This small sample size study retrospectively analyzed the basic information and CBC results of 88 inpatients at our hospital in a single center. In view of the particular circumstances in our hospital's region, it is unclear whether the information gathered in this study is accurate and representative of other regions; therefore, the applicability of these results in other parts of the world needs to be further verified. A CBC is the most common and easy-to-obtain test item. We will further study the role of neutrophils and lymphocytes, as well as T-lymphocyte subsets, in the immune response to SARS-CoV-2 infection. We hope that by studying the characteristics of inpatients in this study, we can provide clinicians in other countries with more information on the characteristics of COVID-19 patients and potentially valuable information for timely and appropriate intervention in the diagnosis and treatment of this disease. This will help to control this epidemic, which endangers all humans.

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CONFLICT OF INTERESTS

The authors have no competing interests.

AUTHOR CONTRIBUTION

Man Kong and Panwen He has access to all data in this study and is responsible for the integrity of the data and the accuracy of the data analysis. Hongmei Zhang and Xiaocui Cao were responsibility for the research content, experimental design and obtain the ethical approval. Xiaoli Mao and Lifeng Huang took responsibility for data collection and data accuracy. Shiyao Pan and Jin Li were in charge of the statistical analysis. Hongmei Zhang and Xiaocui Cao were in charge of the manuscript draft. Zhongxin Lu contributed to critical revision of the manuscript. All authors reviewed and approved the final version.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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