Cancer Management and Research

Dovepress

open access to scientific and medical research

Open Access Full Text Article

ORIGINAL RESEARCH

Clinical Features and Short-Term Outcomes in COVID-19-Infected Patients with Cancer

This article was published in the following Dove Press journal:
Cancer Management and Research

Yong Wang[1,*]
Ben-Jie Shan[1,*]
Xia-Bo Shen[2,*]
Chang-Cheng Zheng[3]
Jin-Quan Wang[4]
Gui-Ling Li[5]
Yue-Yin Pan[1]

[1]Department of Medical Oncology, The First Affiliated Hospital of USTC, Division of Life Sciences and Medicine, University of Science and Technology of China, Hefei, Anhui Province 230001, People's Republic of China; [2]Department of Breast Medical Oncology, Cancer Hospital of the University of Chinese Academy of Sciences (Zhejiang Cancer Hospital), Hangzhou 311200, People's Republic of China; [3]Department of Hematology, The First Affiliated Hospital of USTC, Division of Life Sciences and Medicine, University of Science and Technology of China, Hefei 230001, People's Republic of China; [4]Department of Intensive Care Medicine, The First Affiliated Hospital of USTC, Division of Life Sciences and Medicine, University of Science and Technology of China, Hefei 230036, People's Republic of China; [5]Cancer Center, Union Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan 430022, People's Republic of China

*These authors contributed equally to this work

Background: Coronavirus disease 2019 (COVID-19) is an infectious disease that has been spreading very fast worldwide. Up to now, there is scarce information regarding the clinical features and short-term outcomes of infected patients with cancer.

Methods: We performed a retrospective study in Wuhan Union Hospital from Feb 14, 2020, to Mar 15, 2020, China. Data were retrieved including demographic and clinical features, laboratory findings, and outcome data. Patients were classified into the discharged group and undischarged group by the 4-week outcomes from admission. Difference analysis and correlation analysis were performed between the two groups.

Results: A total of 37 patients were enrolled in the study, including 27 cancer survivors in routine follow-up. Breast cancer (18.9%) was the most frequent cancer type, and common symptoms included cough (54.1%), fever (48.6%), and fatigue (27%). Lymphocytopenia and hypoproteinemia were much frequent in patients who had received chemotherapy, radiotherapy, or surgery within the past month. However, the concentration of D-dimer (median: 3.75 vs 0.43, P =0.010) and fibrin degradation products (median: 23.60 vs 1.80, P =0.002) were evidently increased in this population compared with cancer survivors. At the end of follow-up, 83.8% of the enrolled patients were discharged. Among the discharged, women (48.6%) and cancer survivors (67.6%) showed better short-term outcomes. The elevated level of FDP was significantly higher in the undischarged group (median: 21.85 vs 2.00, P =0.049). The proportion of CD3-positive lymphocyte cells and CD4-positive lymphocytes was correlated with short-term outcomes.

Conclusion: Peripheral lymphocyte subset (CD3-positive and CD4-positive) on admission as a novel biomarker had a potential association with early efficacy. Cancer survivors in routine follow-up would achieve better short-term outcomes. COVID-19 patients with cancer should gain more attention and close monitoring.

Keywords: COVID-19, cancer patients, short-term outcomes, lymphocyte subsets, fibrin degradation product

Correspondence: Yue-Yin Pan
Department of Medical Oncology, The First Affiliated Hospital of USTC, Division of Life Sciences and Medicine, University of Science and Technology of China, Hefei 230001, People's Republic of China
Email panyueyin@ustc.edu.cn

Gui-Ling Li
Cancer Center, Union Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan 430022, People's Republic of China
Email lgl6714@163.com

Introduction

Coronavirus disease 2019 (COVID-19) is an infectious disease caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), which was first identified in December 2019 in Wuhan, the capital of Hubei province, China.[1] On Mar 11, 2020, the WHO declared COVID-19 a global pandemic, its first such designation since declaring H1N1 influenza a pandemic in 2009. In contrast to severe acute respiratory system coronavirus (SARS) and Middle East respiratory syndrome coronavirus (MERS), COVID-19 was far more transmissible, with each new infected case producing an average of 2.68 new secondary cases.[2] As a global

submit your manuscript | www.dovepress.com
DovePress
http://doi.org/10.2147/CMAR.S279564

pandemic, it has been spreading very fast and has already invaded China and the rest of the world within 3 months period.

By Jun 4, 2020, more than 6.39 million cases have been reported, subsequently resulting in more than 383,872 deaths across 216 countries and territories. More than 2.87 million people have recovered.[3] In the early stages of this pneumonia, severe acute respiratory infection symptoms occurred, with some patients rapidly developing acute respiratory distress syndrome (ARDS), acute respiratory failure, and other serious complications.

Recent studies indicated that patients with cancer might be a vulnerable group, which had a higher risk of COVID-19 infection and a poorer prognosis than individuals without cancers.[4–6] It was reported that the fatality rate reached 5.6% among cancer patients compared with 2.3% in the general population.[7] Thus, more intensive attention should be paid to patients with cancer for avoiding rapid deterioration.

Unfortunately, information is scarce at present regarding the clinical features of patients with cancer and short-term outcomes. In this study, we did a comprehensive exploration of 37 cancer patients with confirmed 2019-nCoV pneumonia admitted to Wuhan Union Hospital. This study aimed to indicate if there was a potential relationship between clinical features and short-term outcomes.

Patients and Methods

Study Population

From Feb 14, 2020, to Mar 15, 2020, we performed a retrospective study in Wuhan Union Hospital, Tongji Medical College of Huazhong University of Science and Technology in China. This hospital prescribed by the local government was one of the designated treatment units for COVID-19 patients. The diagnosis of COVID-19 was confirmed according to WHO guidelines,[8] complemented by the Seventh Revised Trial Version of the COVID-19 Diagnosis and Treatment Guidance (2020) of China.[9] Patients previously diagnosed with cancer were enrolled from Feb 14, 2020, to Feb 17, 2020, in this study. The final date of follow-up was Mar 14, 2020. Before infected with the COVID-19, the patients all had well-controlled tumors with a performance score of 0–1. The patients admitted to the hospital were in severe condition (dyspnea, respiratory frequency ≥30/minute, blood oxygen saturation ≤93%, PaO2/FiO2 ratio <300, and/or lung infiltrates >50% of the lung field within 24–48 hours) or critical condition (respiratory failure requiring mechanical ventilation, shock or other organ failure that requires intensive care).

Laboratory Test

Routine blood examinations were complete blood count, coagulation profile, liver function, cellular immunity, and serum cytokines. Laboratory features of patients with cancer at admission were collected. The concentrations of interleukin-2 (IL-2), IL-4, IL-6, IL-10, and tumor necrosis factor α (TNF-α) were assessed in serum samples using a fully automated analyzer by chemiluminescence immunoassay method.

Data Collection

Data were retrieved from the electronic medical records using a standardized data collection form, including demographic and clinical features, laboratory findings, and outcome data. Meanwhile, lymphocyte subsets and cytokines of all patients were detected by flow cytometry on the first-day admission. Two researchers (BS and YW) independently reviewed the data collection forms to double-check the data collected. The researchers also directly inquired with patients or their families to ascertain the epidemiological and symptom data, which were not available from electronic medical records.

Study Definitions

All patients with cancer admission to hospital were divided into stable status group and unstable status group. Twenty-seven patients in stable status were cancer survivors in routine follow-up after primary anti-cancer therapy. Ten patients in unstable status were defined as a condition that patients had received chemotherapy, radiotherapy, or surgery within the past month. According to the short-term outcomes till March 15, 2020 (4 weeks from admission), patients were classified into two groups: discharged group and undischarged group. Thirty-one patients were classified into the discharged group when they meet all the following criterion: (1) Significant improved symptoms; (2) No fever for at least three days; (3) Obvious absorption of inflammation in pulmonary imaging (by CT-imaging); (4) Negative results for at least two consecutive tests of SARS-CoV-2 nucleic acid. Six patients who did not meet the discharge standard were classified into the undischarged group. Two patients died because of respiratory failure caused by pneumonia. Additionally, the patients who died in the hospital till the

end of the follow-up date were classified into the undischarged group.

Statistical Analysis

For descriptive analysis, continuous variables were expressed as median (IQR) and compared with the Mann–Whitney *U*-test; categorical variables were presented as number (%) and compared by $\chi 2$ test or Fisher's exact test in different groups. All statistical analysis was performed using SPSS software (version 26.0). A two-side *P*-value <0.05 was considered statistically significant.

Results

Baseline Characteristics

Thirty-seven COVID-19-infected patients with cancer were enrolled in this study. The median (IQR) age of patients was 66 (60.5–73.5) years old. 51.4% of patients were male. As presented, more than 70% of the patients had comorbidities, and 13.5% even had two or more comorbidities. The most common comorbidities included chronic cardiovascular disease (45.9%), diabetes (16.2%), and chronic pulmonary disease (5.4%). Breast cancer was the most frequent type of cancer (18.9%) in this study. There were 3 patients (8.1%) with dual primary tumors. The most common symptoms on admission were cough (54.1%), fever (48.6%), and fatigue (27%), followed by dyspnea (24.3%) and oppression in the chest (16.2%). In addition, headache, diarrhea, and chest pain were less common (<10%). The median (IQR) time from onset to the hospital was 14 days (8–17.5 days). By the cut-off date, 31 (83.8%) patients had been discharged, 4 (10.8%) patients still remained in hospital and 2 (5.4%) were dead. Demographic and clinical details are shown in Table 1.

Laboratory Findings

Compared with the stable group, the lymphocyte count (median: 1.42 vs 0.56, *P* =0.031) and platelet count (median: 235.5 vs 135, *P* =0.015) of patients were significantly decreased in the unstable group. On the contrary, the concentration of D-dimer (median: 0.43 vs 3.75, *P* =0.010) and fibrin degradation products (median: 1.80 vs 23.60, *P* =0.002) were evidently increased in the unstable group. In addition, serum total protein levels (median: 64.80 vs 63.10, *P* =0.048) and albumin levels (median: 38.05 vs 32.40, *P* =0.002) were observed to be lower in the unstable group at the time of admission. Moreover, the counts of CD4-positive and CD8-positive lymphocytes which play an important role in antiviral immunity[10,11] had no significant difference in the stable and unstable group ($P \geq 0.05$). The level of other markers showed no evident difference between the stable and unstable groups, including related indicators of the cytokine storm ($P \geq 0.05$). Notably, the IL-6 level of most patients in plasma exceeded the upper limit of normal value in both the stable group and the unstable group. The comparisons between stable and unstable groups are shown in Table 2.

Clinical Features and Short-Term Outcomes

As described in Table 3, in this study, 83.8% of the enrolled COVID-19-infected patients with cancer were discharged. Male patients were observed to have a higher risk of staying in the hospital than females, and female patients were cured all after 4-week treatment (the undischarged rates: 31.6% vs 0, *P* =0.020). Patients in the stable group showed a better short-term outcome in compassion with those in the unstable group (the discharged rates: 96.2% vs 60.0%, *P* =0.015). Besides, patients in the discharged group more likely had symptoms of cough at the onset of illness. The concentration of fibrin degradation products was significantly lower in the discharged group in comparison to the undischarged (median: 2.00 vs 21.85, *P* =0.049). The increased level of IL-6 was more prominent in the undischarged group, but there was no statistically significant (median: 12.66 vs 34.74, *P* =0.061).

In addition, we analyzed the plasma proportion of lymphocyte subsets (Figure 1). Compared to discharged patients, patients in the undischarged group had a significantly lower proportion of CD3-positive and CD4-positive lymphocytes (p=0.007 and p=0.003, respectively). The proportion of CD8-positive lymphocytes and CD4-positive/CD8-positive ratio was negatively correlated with short-term outcomes.

Discussion

In our study, the clinical characteristics of 37 cancer patients with laboratory-confirmed COVID-19 from the single-center were described. Breast cancer was the most frequent type. Consistent with the general population, cancer patients presented similar clinical features with cough, fever, and fatigue as the most common onset symptoms. Notably, few patients developed intestinal signs and symptoms (eg, diarrhea), whereas about

Table 1 Demographic, Baseline Clinical Characteristics, and Clinical Outcomes of 37 COVID-19-Infected Cancer Patients Admitted to Wuhan Union Hospital (Feb. 14–March 14, 2020)

	All Patients (n=37), N (%)
Age (years)	66 (60.5–73.5)
Gender	
Male	19 (51.4%)
Female	18 (48.6%)
Comorbidity	
Chronic cardiovascular disease	17 (45.9%)
Diabetes	6 (16.2%)
Chronic pulmonary disease	2 (5.4%)
Chronic liver disease	1 (2.7%)
Two or more comorbidities	5 (13.5%)
Tumor Type	
Breast cancer	7 (18.9%)
Lung cancer	3 (8.1%)
Gastric cancer	3 (8.1%)
Hematological malignancy	3 (8.1%)
Prostatic cancer	3 (8.1%)
Cervical cancer	3 (8.1%)
Thyroid carcinoma	3 (8.1%)
Bladder cancer	3 (8.1%)
Liver cancer	3 (8.1%)
Dual primary malignancies	3 (8.1%)
Others	5 (13.5%)
Symptoms at onset of illness	
Cough	20 (54.1%)
Fever	18 (48.6%)
Fatigue	10 (27%)
Dyspnea	9 (24.3%)
Oppression in chest	6 (16.2%)
Headache	2 (5.4%)
Diarrhea	1 (2.7%)
Chest pain	1 (2.7%)
Onset of symptom to admission	14 (8–17.5)
Clinical outcome	
Discharged form hospital	31 (83.8%)
Remained in hospital	4 (10.8%)
Death	2 (5.4%)

Note: Data are median (IQR) or n/N (%), where N is the total number of patients with available date.

20–25% of patients with MERS-Cov or SARS-CoV infection had diarrhea.[12] Most patients have mild manifestations and excellent short-term outcomes, although the feature of COVID-19 partially bears resemblance to SARS and MERS.[12–14]

Compared with patients in the stable group, lymphopenia was more common in unstable patients with SARS-CoV-2 infection, suggesting that SARS-CoV-2 consumed many immune cells and inhibits the body's cellular immune function. At the same time, hypoproteinemia occurred much more frequently in the unstable group, which was considered to be a major consequence of nutritional deterioration in cancer patients. Additionally, the counts of platelet values in the unstable group were lower, whereas the levels of D-dimer and FDP were higher in the stable group. It was reported that D-dimer were higher in COVID-19 patients with cancer.[15] Our results thus confirmed similar findings that coagulation disorders in the rapidly growing cancer population may appear as a consequence of tumor growth, chemotherapy, radiotherapy, or due to surgical trauma.[16]

The 4-week discharged rate was high among COVID-19 patients with cancer in our study. Patients who were female and had the symptom of cough were seen more frequently in the discharged group. Several studies showed that lung cancer patients with infected COVID-19 were more likely to progress more rapidly.[17] Almost half of the cancer patients in the unstable group were in the undischarged group, and they showed poor short-term outcomes. It might be due to those patients who underwent chemotherapy or surgery in the past month were more susceptible to respiratory pathogens and more likely to suffer severe pneumonia. It appears that breast cancer patients, with better lung function and endurance, are more likely to benefit from the treatment.

To be noticed, significant differences were found in laboratory findings between the discharged and undischarged group. In our enrolled patients, the undischarged patients revealed significantly higher FDP levels. It was reported that the circulation of free thrombin, uncontrolled by natural anticoagulants, can activate platelets, stimulate fibrinolysis, and affect prognosis.[18] A previous study identified the levels of fibrin-related markers (D-dimer and FDP) moderately or markedly elevated in all deaths with COVID-19.[15] This evidence and our findings implied that abnormal coagulation results had the potential to evaluate prognosis, especially short-term outcomes.

Among COVID-19 patients with cancer, the discharged patients had a higher level of CD3-positive and CD4-positive lymphocytes than undischarged cases. Our results demonstrated that T lymphocyte subset provided an important defense against COVID-19, which was consistent with the alteration in SARS and MERS.[19,20] The alteration in the subsets would enhance immune system

Table 2 Laboratory Findings of 37 COVID-19-Infected Patients with Cancer on Admission to Hospital (Feb.14–Mar 14, 2020)

	Stable Status (N=27)	Unstable Status (N=10)	P value
Neutrophils (×10^9 per L; normal range 1·8–6·3)	3.83 (2.98–4.67)	4.37 (2.68–8.56)	0.599
Lymphocytes (×10^9 per L; normal range 1·1–3.2)	1.42 (1.17–1.61)	0.56 (0.41–0.64)	0.031*
Platelets (×10^9 per L; normal range 125–350)	235.5 (175.8–303.8)	135 (51.5–248)	0.015*
D-dimer (μg per L; normal range 0·0–1·5)	0.43 (0.26–1.44)	3.75 (0.41–8.99)	0.010*
FDP (ug per mL; normal range <5)	1.80 (1.45–3.75)	23.60 (7.60–86.40)	0.002*
TP (g per L; normal range 64–83)	64.80 (62.05–71.50)	63.10 (51.20–67.70)	0.048*
Alb (g per L; normal range 35–55)	38.05 (34.58–41.72)	32.40 (28.95–36.43)	0.002*
CD3+T lymphocytes (%; normal range 58.17–84.22)	72.43 (63.92–82.49)	65.83 (58.45–81.81)	0.847
CD4+T lymphocytes (%; normal range 25.34–51.37)	43.82 (38.26–52.00)	44 (28.30–61.33)	0.996
CD8+T lymphocytes (%; normal range 14.23–38.95)	21.09 (17.49–26.32)	20.18 (15.66–31.00)	0.632
CD4+/CD8+ (normal range 0.41–0.72)	2.08 (1.17–2.69)	2.47 (1.12–4.31)	0.443
IL2 (pg per mL; normal range 0.10–4.10)	2.81 (2.16–4.27)	2.47 (2.10–3.35)	0.240
IL4(pg per mL; normal range 0.10–3.20)	2.36 (1.53–3.48)	1.96 (1.55–3.73)	0.762
IL6(pg per mL; normal range 0.10–2.90)	12.29 (6.39–65.82)	34.29 (21.10–46.56)	0.063
IL10(pg per mL; normal range 0.10–5.00)	4.49 (2.59–5.07)	3.39 (2.50–5.29)	0.816
TNF-a (pg per mL; normal range 0.10–23.00)	4.19 (2.49–7.29)	2.18 (2.01–3.60)	0.151

Notes: Data are median (IQR). P values comparing patients with cancer in stable and unstable status are from $\chi 2$, Fisher's exact test, or Mann–Whitney *U*-test. A two-side P value <0.05 was considered statistically significant. *P<0.05. The stable status was defined as a condition that patients had received chemotherapy or surgery within the past month. Patients in unstable status were cancer survivors in routine follow-up after primary anti-cancer therapy.

Table 3 The Clinical Features and Short-Term Outcomes of COVID-19-Infected Patients with Cancer

	Discharged (n=31)	Undischarged (n=6)	P value
Age, Median (IQR), Years	66 (61–74)	68.5 (35.75–74.3)	0.710
Gender			0.020*
Male	13 (35.1%)	6 (8.1%)	
Female	18 (48.6%)	0	
State			0.015*
Stable	25 (67.6%)	1 (2.7%)	
Unstable	6 (16.2%)	4 (10.8%)	
Cough	20 (54.1%)	0	0.005*
Fever	15 (40.5%)	3 (8.1%)	0.942
Fatigue	7 (18.9%)	3 (8.1%)	0.313
Dyspnea	7 (18.9%)	3 (8.1%)	0.317
Onset of symptom to admission	10 (7.5–14)	15 (8–21)	0.281
Neutrophils (×10^9 per L; normal range 1·8–6·3)	3.83 (2.92–4.66)	5.01 (3.31–11.77)	0.175
Lymphocytes (×10^9 per L; normal range 1·1–3.2)	1.19 (0.78–1.57)	0.88 (0.52–1.80)	0.766
Platelets (×10^9 per L; normal range 125–350)	177 (108.5–257.8)	221 (156–297.5)	0.368
D-dimer (μg per L; normal range 0·0–1·5)	0.63 (0.29–1.57)	1.69 (0.30–11.74)	0.264
FDP (ug per mL; normal range <5)	2.00 (1.50–4.55)	21.85 (2.97–102.3)	0.049*
TP (g per L; normal range 64–83)	57.1 (45.7–67.1)	65.0 (62.6–70.3)	0.132
ALB (g per L; normal range 35–55)	34.6 (26.0–38.2)	37.1 (33.3–40.9)	0.128
IL-2 (pg per mL; normal range 0.10–4.10)	3.20 (2.20–4.18)	2.47 (2.14–2.99)	0.259
IL-4 (pg per mL; normal range 0.10–3.20)	1.70 (1.34–2.84)	2.58 (1.53–3.81)	0.210
IL-6 (pg per mL; normal range 0.10–2.90)	12.66 (6.01–22.68)	34.74 (18.32–59.51)	0.061
IL-10 (pg per mL; normal range 0.10–5.00)	4.05 (2.51–5.11)	3.16 (2.63–6.15)	0.957
TNF-a (pg per mL; normal range 0.10–23.00)	3.55 (2.46–5.78)	2.22 (1.87–3.79)	0.099

Notes: Data are median (IQR) or n/N (%), where N is the total number of patients with available data. P values are comparing the discharged group and the undischarged group from Mann–Whitney *U*-test (continuous variables), $\chi 2$ test (categorical variables), or Fisher's exact test (categorical variables). P < 0.05 was considered statistically significant. *P<0.05

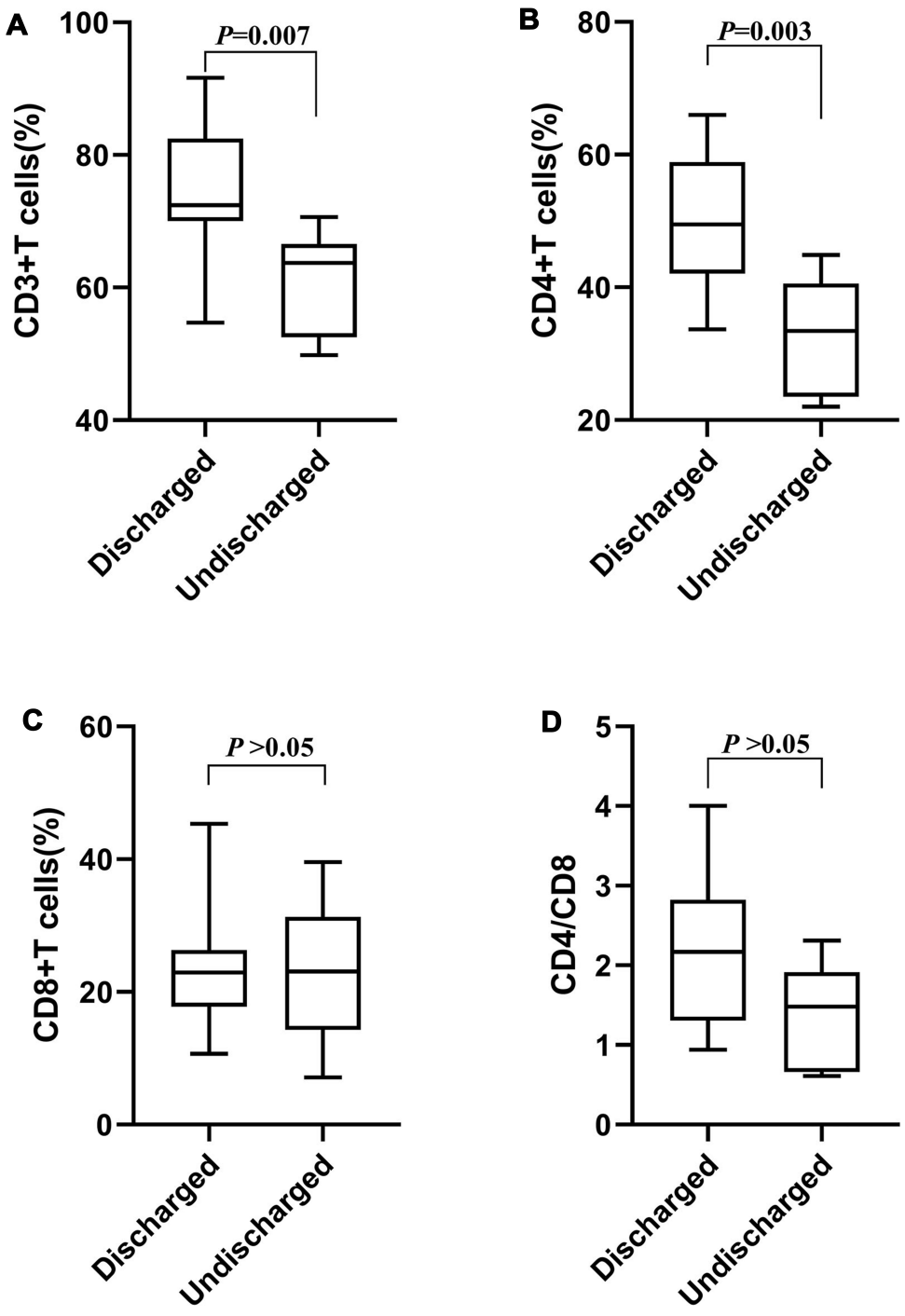

Figure 1 Comparison of peripheral lymphocyte subsets on admission between discharged patients and undischarged patients in included patients. Figure shows the plasma proportion of CD3+ lymphocytes (**A**), CD4+ lymphocytes (**B**), CD8+ lymphocytes (**C**), and CD4+/CD8+ (**D**). Differences between the discharged group and undischarged group were significant for CD3+ lymphocyte (**A**), CD4+ lymphocyte (**B**).

function.[21] CD3-positive and CD4-positive lymphocytes were all statistically higher in patients who had a fast recovery. Similarly, recent studies also showed that lymphocyte subsets (CD4-positive and CD8-positive) counts reflected the disease severity and predicted the clinical outcomes in COVID-19 patients.[22,23] Wang et al[23] reported that lymphocyte subsets, especially decreased CD8-positive lymphocytes, might be a potential predictor for poor clinical efficacy. However, there was no significant relationship between CD8-positive lymphocytes and short-term outcomes in our study. The reason for this remained unclear, it might be related that excessive

activation of CD4-positive lymphocytes, not exhaustion of CD8-positive lymphocytes, enhanced host antiviral immunity, and eventually predicted better outcomes.[24] Generally, among the differentially expressed functional molecules, cytotoxic immunity was attributed to antiviral processes and short-term outcomes in cancer patients.[25] We found that the cytotoxic immune function, particularly CD4-positive lymphocytes, might be a reliable indicator for early recovery.

Moreover, we noted that patients infected with COVID-19 also had initially increased secretion of IL-6. It was probably suggested that the cytokine storm was associated with unstable status because of the systemic immunosuppressive state caused by the malignancy and anticancer treatments. Wong CK et al[26] showed that the increased level of IL-6, IFN-γ was associated with the inflammatory-induced pulmonary injury. Our study illustrated that there was no significant difference in cytokines between the discharged group and the undischarged group. Interestingly, we noted that most patients in the two groups had a higher concentration of IL-6, suggesting that this marker may have a potential role in the disease evolution.[27] Further evidence is urgently needed to assess the efficacy.

Our study has several limitations. First, this was a retrospective study that was conducted at a single center, the sample size was small, and the follow-up period was short. Second, there was a deficiency in the detailed mechanisms of the immune molecules. Third, all patients received standard treatments, therapeutic factors might confound the short-term outcomes. A larger sample size of clinical studies and more effort should be made to elucidate the outcomes of cancer patients.

Conclusion

This study innovatively demonstrated that peripheral lymphocyte subset (CD3-positive and CD4-positive) on admission as a novel biomarker had a potential association with early efficacy. And cancer survivors in routine follow-up would achieve better short-term outcomes. COVID-19 patients with cancer should gain more attention and close monitoring.

Data Sharing Statement

The datasets used in this study are available from the corresponding author upon reasonable request, any data intended for sharing will be de-identified.

Ethics Statement

This study has been approved by the Ethics Committee of Wuhan Union Hospital (Ethical review [2020] No. 0272), and all relevant personal exempts from informed consent due to the particularity of the disease outbreak.

Funding

This study was supported by the Key Research and Development Projects from Science and Technology Department of Anhui Province (1704a0802148 and 1804h08020259), the Fundamental Research Funds for the Central Universities (WK9110000058), the Natural Science Foundation of Anhui Province (1908085MH260) and the Hefei Municipal Independent Innovation Policy "Borrowing and Transferring" Project (J2018Y01).

Disclosure

The authors declare no conflicts of interest in this work.

References

1. Zhou P, Yang X-L, Wang X-G, et al. A pneumonia outbreak associated with a new coronavirus of probable bat origin. *Nature*. 2020;579(7798):270–273. doi:10.1038/s41586-020-2012-7
2. Wu JT, Leung K, Leung GM. Nowcasting and forecasting the potential domestic and international spread of the 2019-nCoV outbreak originating in Wuhan, China: a modelling study. *Lancet*. 2020;395 (10225):689–697. doi:10.1016/S0140-6736(20)30260-9
3. WHO. Rolling updates on coronavirus disease (COVID-19); 2015. https://www.who.int/emergencies/diseases/novel-coronavirus-2019. Accessed Jun 4, 2020.
4. Dong S, Luo C, Hu X, et al. Expert Consensus for Treating Cancer Patients During the Pandemic of SARS-CoV-2. *Front Oncol*. 2020;10:1555. doi:10.3389/fonc.2020.01555
5. Huang Q, Hu S, Ran FM, et al. Asymptomatic COVID-19 infection in patients with cancer at a cancer-specialized hospital in Wuhan, China – preliminary results. *Eur Rev Med Pharmacol Sci*. 2020;24 (18):9760–9764.
6. Liang W, Guan W, Chen R, et al. Cancer patients in SARS-CoV-2 infection: a nationwide analysis in China. *Lancet Oncol*. 2020;21 (3):335–337. doi:10.1016/S1470-2045(20)30096-6
7. Wu Z, McGoogan JM. Characteristics of and important lessons from the coronavirus disease 2019 (COVID-19) outbreak in China: summary of a report of 72 314 cases from the Chinese Center for Disease Control and Prevention. *JAMA*. 2020;323(13):1239. doi:10.1001/jama.2020.2648
8. WHO. Clinical management of severe acute respiratory infection when novel coronavirus (nCoV) infection is suspected: interim guidance; 2020. https://www.who.int/publications-detail/clinical-management-of-severe-acute-respiratory-infection-when-novel-coronavirus-(ncov)-infection-is-suspected. accessed March 27, 2020.
9. National Health Commission of the People's Republic of China. Chinese management guideline for COVID-19 (version 7.0); 2020. http://www.nhc.gov.cn/yzygj/s7653p/202003/46c9294a7dfe4cef80dc7f5912eb1989/files/ce3e6945832a438eaae415350a8ce964.pdf. accessed March 27, 2020.
10. Whitmire JK, Ahmed R. Costimulation in antiviral immunity: differential requirements for CD4+ and CD8+ T cell responses. *Curr Opin Immunol*. 2000;12(4):448–455. doi:10.1016/S0952-7915(00)00119-9

11. Jansen J, Gerlach T, Elbahesh H, Rimmelzwaan GF, Saletti G. Influenza virus specific CD4+ and CD8+ T cell mediated immunity induced by infection and vaccination. *J Clin Virol*. 2019;119:44–52. doi:10.1016/j.jcv.2019.08.009
12. Assiri A, Al-Tawfiq JA, Al-Rabeeah AA, et al. Epidemiological, demographic, and clinical characteristics of 47 cases of Middle East respiratory syndrome coronavirus disease from Saudi Arabia: a descriptive study. *Lancet Infect Dis*. 2013;13(9):752–761. doi:10.1016/S1473-3099(13)70204-4
13. Huang C, Wang Y, Li X, et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. *Lancet*. 2020;395 (10223):497–506. doi:10.1016/S0140-6736(20)30183-5
14. Lee N, Hui D, Wu A, et al. A major outbreak of severe acute respiratory syndrome in Hong Kong. *N Eng J Med*. 2003;348 (20):1986–1994.
15. Tian J, Yuan X, Xiao J, et al. Clinical characteristics and risk factors associated with COVID-19 disease severity in patients with cancer in Wuhan, China: a multicentre, retrospective, cohort study. *Lancet Oncol*. 2020;21(7):893–903. doi:10.1016/S1470-2045(20)30309-0
16. Kvolik S, Jukic M, Matijevic M, Marjanovic K, Glavas-Obrovac L. An overview of coagulation disorders in cancer patients. *Surg Oncol*. 2010;19(1):e33–e46. doi:10.1016/j.suronc.2009.03.008
17. Dai M, Liu D, Liu M, et al. Patients with cancer appear more vulnerable to SARS-CoV-2: a multicenter study during the COVID-19 outbreak. *Cancer Discov*. 2020;10(6):783–791.
18. Kitchens CS. Thrombocytopenia and thrombosis in disseminated intravascular coagulation (DIC). *ASH Educ Program Book*. 2009;2009(1):240–246.
19. Peiris J, Lai S, Poon L, et al. Coronavirus as a possible cause of severe acute respiratory syndrome. *Lancet*. 2003;361 (9366):1319–1325. doi:10.1016/S0140-6736(03)13077-2
20. Wong RS, Wu A, To K, et al. Haematological manifestations in patients with severe acute respiratory syndrome: retrospective analysis. *BMJ*. 2003;326(7403):1358–1362. doi:10.1136/bmj.326.7403.1358
21. Li T, Qiu Z, Zhang L, et al. Significant changes of peripheral T lymphocyte subsets in patients with severe acute respiratory syndrome. *J Infect Dis*. 2004;189(4):648–651. doi:10.1086/381535
22. Liu Z, Long W, Tu M, et al. Lymphocyte subset (CD4+, CD8+) counts reflect the severity of infection and predict the clinical outcomes in patients with COVID-19. *J Infect*. 2020.
23. Wang F, Nie J, Wang H, et al. Characteristics of peripheral lymphocyte subset alteration in COVID-19 pneumonia. *J Infect Dis*. 2020;221(11):1762–1769. doi:10.1093/infdis/jiaa150
24. Moro-García MA, Mayo JC, Sainz RM, Alonso-Arias R. Influence of inflammation in the process of T lymphocyte differentiation: proliferative, metabolic, and oxidative changes. *Front Immunol*. 2018;9:339.
25. Zheng H-Y, Zhang M, Yang C-X, et al. Elevated exhaustion levels and reduced functional diversity of T cells in peripheral blood may predict severe progression in COVID-19 patients. *Cell Mol Immunol*. 2020;1–3.
26. Wong C, Lam C, Wu A, et al. Plasma inflammatory cytokines and chemokines in severe acute respiratory syndrome. *Clin Exp Immunol*. 2004;136(1):95–103. doi:10.1111/j.1365-2249.2004.02415.x
27. Liu J, Li S, Liu J, et al. Longitudinal characteristics of lymphocyte responses and cytokine profiles in the peripheral blood of SARS-CoV-2 infected patients. *EBioMedicine*. 2020;55:102763. doi:10.1016/j.ebiom.2020.102763