

Dynamic changes in clinical and CT characteristics of COVID-19 cases with different exposure histories: a retrospective study

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Abstract

Background: To assess the dynamic changes in clinical and CT characteristics of COVID-19 patients with different epidemiology histories.

Methods: Fifty-three discharged COVID-19 patients were enrolled at Beijing Youan Hospital, Capital Medical University, from Jan 21 to Mar 10, 2020. Spearman correlation analysis was performed between CT scores and laboratory indicators. Patients were divided into Wuhan (lived in/or traveled to Wuhan, 30 cases) and nonWuhan group (close contacts or unknown exposure, 23 cases). The CT and laboratory findings were compared between and within groups during the clinical process.

Results: Fever (88.7%), cough (64.2%), fatigue (34%), and abnormal laboratory indicators, including lymphopenia, reduced albumin, albumin/globulin (A/G), and elevated C-reactive protein (CRP), were mainly observed. Subpleural ground-glass opacities (86.8%) were usually detected at admission. The CT scores were highly correlated with lymphocytes, CRP, albumin, and A/G at initial and follow-ups (all $p<0.05$). Four days after admission, most patients (66.7% Wuhan, 47.8% nonWuhan) showed progression, and the CT scores of Wuhan significantly increased ($p=0.015$). Eight days after admission, the vast majority of patients (69.2% Wuhan, 100% nonWuhan, $p=0.006$) presented improvement, and the CT scores of nonWuhan were significantly lower than Wuhan ($p=0.006$). Pneumonia was completely absorbed in most patients 2-4 weeks after discharge.

Conclusions: CT plays a crucial role in early diagnosis and monitoring changes in COVID-19. Lymphocytes, CRP, albumin, and A/G are expected to predict disease severity and prognosis. Viral pathogenicity in non-endemic areas may be weaker than core-infected areas. Lung lesions can disappear around 4 weeks after discharge in most patients.

Background

In December 2019, there was an outbreak of novel viral pneumonia in Wuhan, China, which was proved to be associated with severe acute respiratory syndrome-related coronavirus 2 (SARS-CoV-2)[1] and later named by World Health Organization (WHO) as the corona virus disease (COVID-19). COVID-19 initially affected mainly the person who worked or lived around the Huanan seafood market (Wuhan, China)[2, 3]. Then, the number of infected individuals soared and rapidly spread across all over the country. According to the statistics of the National Health Commission of the People's Republic of China (NHC), up to 10 March 2020, the number of confirmed cases reached 80,754[4]. The patients included mainly the residents, the traveler from the affected areas, close contacts, and medical personnel, and the older age, higher sequential organ failure assessment (SOFA) score, and higher level of d-dimer are the potential risk factors[5]. At the same time, COVID-19 cases appeared and continuously increased in foreign countries. Italy, South Korean, and Iran might be the next potential areas for the outbreak[4, 6].

Epidemiological history, clinical manifestations, laboratory tests, chest CT and reverse transcription-polymerase chain reaction (RT-PCR) assay are the major diagnostic components according to the

guidance of NHC[7]. The CT scan also plays a more role in the evaluation of the disease progression. Several cases with the CT features of COVID–19 had been reported[8–13]. Chest CT of most COVID–19 cases (> 70%) showed ground glass opacities with consolidation and interstitial and/or interlobular septal thickening. Recently, the clinical, laboratory and chest CT characteristics between severe and non-severe COVID–19 patients had been compared[14, 15]. But the information on the dynamic changes in relationships between laboratory data and imaging were still limited. Discussion and analysis of these relationships will ultimately benefit the diagnosis, treatment, and monitoring of COVID–19. Additionally, Xu et al indicated that compared to the COVID–19 cases from Wuhan, the symptoms of patients outside of Wuhan are relatively mild[16]. We also found similar facts that patients who are residents of Wuhan or have recent Wuhan travel history, usually showed more prominent CT abnormalities, and progressed in short-term follow-up. The dynamic changes in clinical and CT characteristics of patients from non-endemic or core-infected areas are unclear.

The purpose of this study was to analyze the dynamic change in relationships between laboratory findings and chest CT manifestation of patients with COVID–19, and to explore the clinical, imaging characteristics and outcome in patients with different epidemiology.

Methods

Patients

The ethics committees of Beijing Youan Hospital, Capital Medical University, approved this retrospective study, which involved no risk for subjects. The written informed consent was waived. All COVID–19 patients were enrolled from Beijing Youan Hospital, Capital Medical University, which is one of the designated hospitals for treating COVID–19 patients in Beijing. Inclusion criteria included: (a) confirmed by the RT-PCR assay for SARS-CoV-2, which was performed before admission at the Center for Disease Control (CDC), Beijing, China; (b) at least one CT follow-up during hospitalization; (c) has been discharged as of Mar 10, 2020; (d) at least one CT follow-up after discharge as of Mar 10, 2020. Exclusion criteria included: (a) influenza A (H1N1, H7N9) and other common bacterial or viral pneumonia; (b) age < 14 years old. A total of 53 patients were included from Jan 21, 2020 to Mar 10, 2020. The study flow diagram was presented in Figure 1. Patients were further divided into 2 groups based on different epidemiological history (Wuhan group: lived in/or traveled to Wuhan recently, 30 cases; nonWuhan group: close contacts or unknown exposure, 23 cases).

Clinical data collection

Epidemiological, clinical, and laboratory data were obtained from electronic medical records. Detailed clinical information included demographics, current medical history, epidemiological history, past history, symptoms and signs, treatment measures, days of admission. The disease onset date was defined as the day when the symptoms were noticed. Treatment measures for non-severe patients included

symptomatic supportive care (ibuprofen, lianhua qingwen capsule, liver protection treatment, correct hypoalbuminemia), antiviral therapy (lopinavir/ritonavir). Lianhua qingwen capsule is a Traditional Chinese Medicine (TCM) formula, which has antiviral and anti-inflammatory effects and is used to treat respiratory tract infectious diseases in China[17]. Treatment measures for severe patients included symptomatic supportive care, antiviral therapy, oxygen support, respiratory support, antibiotic therapy, and corticosteroid therapy. Laboratory tests included white blood cell (WBC), lymphocytes (LYM), percentage of LYM (%LYM), neutrophil (NEUT), percentage of NEUT (%NEUT), C-reactive proteins (CRP), procalcitonin (PCT), alanine aminotransferase (ALT), aspartate aminotransferase (AST), albumin (ALB), globulin (GLOB), albumin/globulin ratio (A/G), glomerular filtration rate (eGFR), creatine kinase (CK), influenza antibody tests, and RT-PCR assay for SARS-CoV-2.

CT image acquisition

The initial CT examinations of all patients were obtained on the day of admission. The median duration from disease onset to CT scan of Wuhan and nonWuhan cases were 4.5 days (IQR, 3.8–6.3) and 5 days (IQR, 4.0–7.0) respectively. All chest CT scans were performed with a 256-section scanner (Brilliance iCT, Philips Healthcare, Cleveland, OH) without the use of intravenous contrast. The CT examination parameters were as follows: 120 kV; automatic tube current (100 mA–400 mA); iterative reconstruction technique; detector collimation, 128×0.625mm; section thickness, 5 mm; rotation time, 0.4 second; pitch, 0.914; matrix, 512×512; and breath-hold during end-inspiration. Two windows were used: lung window (window width, 1500 HU; window level, −500 HU) and mediastinal window (window width, 350 HU; window level, 50 HU). All follow-up images were obtained by using the same protocol as that of the initial scans. The median duration from initial CT to the first follow-up CT scan was 4 days (IQR, 4.0–5.0), and all patients, including Wuhan group 30 cases and nonWuhan group 23 cases, underwent the first follow-up. The median duration from initial CT to the second follow-up CT scan was 8 days (IQR, 7.7–10.0), and 46 patients (26 Wuhan, 20 nonWuhan) underwent the second follow-up. Seven patients with mild CT abnormalities were discharged without the second follow-up because the results of first follow-up showed that the lesions were absorbed obviously. As of 10 Mar 2020, 45 patients (25 Wuhan cases and 20 nonWuhan cases) had been followed up for about 2 weeks after discharge, and 18 patients (12 Wuhan and 6 nonWuhan) had been followed up for around 4 weeks. Ten of these patients (7 Wuhan and 3 nonWuhan) were followed up for both 2 and 4 weeks after discharge.

Review of CT images

In the condition of blindness to patients' clinical information, all CT images were reviewed independently by three radiologists (R. L., C. J., and H. L.) with approximately 9 to 32 years of experience in thoracic CT imaging. A final decision was based on consensus opinion when there was a discrepancy.

The CT images were evaluated for the following features: (1) the presence of ground-glass opacification (GGO) (defined as increased lung attenuation with no obscuration of the underlying vascular

architecture), patch shadowing (defined as increased lung attenuation obscuring the underlying vessels) or consolidation; (2) the subpleural or non-subpleural location; (3) the extent of involvement of lung, which was assessed independently for each of five lobes. Each lung lobe was evaluated and assigned a score, based on the following: score of 0 when no involvement, score of 1 when less than 25% involvement, score of 2 when 26% - 50% involvement; score of 3 when 51% - 75% involvement and score of 4 when 76% or more involvement. The total score was the summation of each lobe score (maximal score 20), which provided the extent of overall lung involvement. Similar evaluation methods had been reported[9]. The CT scores of lung involvement were also obtained in the follow-ups during hospitalization. The progression or improvement of the disease over time was assessed based on the extent and the density change of lung opacities on CT images.

Statistical analysis

The Shapiro-Wilk (S-W) test was used to assess the normality of continuous variables. Normally distributed data were presented as means (standard deviation, SD) and were compared between different groups with independent two samples *t*-test. Non-normally distributed data were presented as median (interquartile ranges, IQR) and were compared with the Mann-Whitney U test. Paired *t*-test or two related samples Wilcoxon signed ranks test was used to evaluate the differences of variables between the initial and follow-ups examination. Categorical variables were described as frequency rates or percentages and were compared using χ^2 or Fisher's exact test between groups, if appropriate. Spearman correlation was performed for continuous and categorical variables. Two-sided p values less than 0.05 were considered statistically significant. All analyses were performed with the use of IBM SPSS Statistics version 20.0 (IBM, Armonk, NY, USA).

Results

Demographic and clinical characteristics

The demographic and clinical characteristics were shown in Table 1. The 53 patients included 31 (58.5%) women and 22 (41.5%) men, and the mean age was 50.2 years old (SD, 15.2). The most common complaints were fever (88.7%), cough (64.2%) and fatigue (34%). The common coexisting disorder is hypertension (17%). The median time from onset to admission was 5.0 days (IQR, 4.0–7.0). 76.7% of patients in Wuhan group were non-severe, and 91.3% of patients in nonWuhan group were non-severe. There was no significant difference between Wuhan group and nonWuhan group in the demographic and clinical characteristics.

Table 1. Clinical characteristics of patients with COVID-19 at admission

	All patients (n=53)	[^] Wuhan (n=30)	[^] nonWuhan (n=23)	p value
Age, Mean (SD), years	50.2 (15.2)	52.2 (15.1)	47.6 (15.3)	0.279 [‡]
Sex, Female - No., (%)	31/53 (58.5%)	16/30 (53.3%)	15/23 (65.2%)	0.384
Signs and symptoms- No., (%)				
Fever	47/53 (88.7%)	27/30 (90%)	20/23 (87%)	1.000
< 37.5	4/53 (7.5%)	2/30 (6.7%)	2/23 (8.7%)	1.000
37.5 - 38.5	30/53 (56.6%)	17/30 (56.6%)	13/23 (56.5%)	0.992
> 38.5	13/53 (24.5%)	8/30 (26.7%)	5/23 (21.7%)	0.679
Cough and sputum production	34/53 (64.2%)	21/30 (70.0%)	13/23 (56.5%)	0.311
Myalgia or arthralgia	10/53 (18.9%)	5/30 (16.7%)	5/23 (21.7%)	0.640
Chill	7/53 (13.2%)	6/30 (20.0%)	1/23 (4.3%)	0.208
Shortness of breath	9/53 (17.0%)	5/30 (16.7%)	4/23 (17.4%)	1.000
Fatigue	18/53 (34.0%)	10/30 (33.3%)	8/23 (34.8%)	0.912
Nasal congestion	6/53 (11.3%)	3/30 (10.0%)	3/23 (13.0%)	1.000
Headache	8/53 (15.1%)	6/30 (20.0%)	2/23 (8.7%)	0.452
Throat discomfort	9/53 (17.0%)	7/30 (23.3%)	2/23 (8.7%)	0.299
Nausea or vomiting	7/53 (13.2%)	4/30 (13.3%)	3/23 (13.0%)	1.000
Diarrhea	1/53 (1.9%)	1/30 (3.3%)	0/23	1.000
Coexisting disorders- No., (%)				
Diabetes	4/53 (7.5%)	2/30 (6.7%)	2/23 (8.7%)	1.000
Hypertension	9/53 (17.0%)	4/30 (13.3%)	5/23 (21.8%)	0.661
Cardiovascular disease	3/53 (5.7%)	2/30 (6.7%)	1/23 (4.3%)	1.000
Hyperlipidemia	1/53 (1.9%)	0/30	1/23 (4.3%)	0.434
Hepatitis B infection	3/53 (5.7%)	3/30 (10.0%)	0/23	0.249
Cancer	3/53 (5.7%)	2/30 (6.7%)	1/23 (4.3%)	1.000
Time from onset to admission, Median (IQR)	5.0 (4.0-7.0)	4.5 (3.8-6.3)	5.0 (4.0-7.0)	0.364 [#]
[^]Disease severity- No., (%)				
Non-severe	44/53 (83.0%)	23/30 (76.7%)	21/23 (91.3%)	0.299
Severe	9/53 (17.0%)	7/30 (23.3%)	2/23 (8.7%)	

Note:

IQR: interquartile range.

[^] Wuhan: patients who lived in/or travelled to Wuhan recently.

[^] nonWuhan: patients who contacted with confirmed case or unknown exposure.

[^] Disease severity: based on the Guidelines for the Diagnosis and Treatment of COVID-19 patients by National Health Commission of the People's Republic of China [7].

^{||} The differences between rates were tested by χ^2 or Fisher exact tests, if appropriate.

[#] Independent sample Student *t*-test.

^{##} Mann-Whitney U test.

Significant level *p*<0.05.

CT and laboratory findings at admission

Data of CT and laboratory findings at admission were listed in Table 2. Ground-glass opacity (86.8%) and patchy shadowing (50.9%) were the main findings, and subpleural was the most common location (88.7%) (Figure 2). The median CT score of lung involvement was 4 (IQR, 3.0–6.0). Most patients presented elevated levels of CRP (13.7, IQR 4.1–30.0), decreased LYM (1.13, SD 0.49), ALB (36.7, SD 3.7)

and A/G ratio (1.02, SD 0.20). Compared to nonWuhan group, although the CRP and CT score of lung involvement in Wuhan group had a tendency to increase, and the lymphocytes, albumin, and A/G had a tendency to decrease, the difference was not statistically significant.

Table 2. CT and laboratory characteristics of patients with COVID-19 at admission

	All patients (n=53)	[^] Wuhan (n=30)	[^] nonWuhan (n=23)	p value
Chest CT- No., (%)				
Ground-glass opacity	46/53 (86.8%)	28/30 (93.3%)	18/23 (78.3%)	0.231
Patchy shadowing	27/53 (50.9%)	14/30 (46.7%)	13/23 (56.5%)	0.477
Consolidation	7/53 (13.2%)	3/30 (10%)	4/23 (17.4%)	0.705
Subpleural	47/53 (88.7%)	26/30 (86.7%)	21/23 (91.3%)	0.928
CT score of lung involvement				
Median (IQR)	4.0 (3.0-6.0)	4.0 (3.8-6.0)	3.00 (2.0-5.0)	0.322 ^{‡‡}
Laboratory findings				
Mean (SD) or Median (IQR)				
White blood cell, NR: $3.5\text{-}9.5 \times 10^9/\text{L}$	4.01 (3.46-4.76)	3.98 (3.17-5.05)	4.02 (3.54-4.65)	0.753 ^{‡‡}
Lymphocyte, NR: $1.1\text{-}3.2 \times 10^9/\text{L}$	1.13 (0.49)	1.08 (0.48)	1.19 (0.51)	0.418 [‡]
Lymphocyte percent, NR: 20-50%	28.4 (12.3)	27.9 (12.2)	29.1 (12.7)	0.731 [‡]
Neutrophil, NR: $1.8\text{-}6.3 \times 10^9/\text{L}$	2.30 (1.79-2.98)	2.15 (1.75-2.93)	2.42 (2.02-3.11)	0.490 ^{‡‡}
Neutrophil percent, NR: 40-75%	60.5 (13.1)	60.5 (13.1)	60.5 (13.5)	0.991 [‡]
C-reactive protein, NR < 3 mg/L	13.7 (4.1-30.0)	15.0 (8.4-24.8)	13.7 (2.0-51.1)	0.809 ^{‡‡}
Procalcitonin, NR < 0.1 ng/mL	0.11 (0.10-0.12)	0.11 (0.10-0.12)	0.11 (0.10-0.12)	0.372 ^{‡‡}
Alanine aminotransferase, NR: 9-50 U/L	28.0 (20.0-49.0)	28.5 (19.8-45.5)	28.0 (23.0-51.0)	0.548 ^{‡‡}
Aspartate aminotransferase, NR: 15-40 U/L	28.0 (22.0-39.0)	28.0 (22.0-35.0)	29.0 (19.0-42.0)	0.986 ^{‡‡}
Albumin, NR: 40-55g/L	36.7 (3.7)	36.2 (3.2)	37.3 (4.3)	0.304 [‡]
Globulin, NR: 20-40g/L	36.4 (33.0-40.0)	36.3 (33.0-41.4)	36.5 (33.0-38.3)	0.554 ^{‡‡}
Albumin / globulin ratio, NR: 1.2-2.4	1.02 (0.20)	0.99 (0.19)	1.06 (0.21)	0.226 [‡]
Glomerular filtration rate, NR >90 ml/min/1.73m ²	104.3 (93.7-112.9)	100.1 (92.5-109.0)	108.6 (93.6-117.1)	0.170 ^{‡‡}
Creatine kinase, NR: 50-310 U/L	61.0 (42.0-116.0)	59.0 (39.0-99.5)	70.0 (45.0-134.0)	0.206 ^{‡‡}

Note:

NR: normal range.

[^] Wuhan: patients who lived in/or travelled to Wuhan recently.

[^] nonWuhan: patients who contacted with confirmed case or unknown exposure.

^{||} The differences between rates were tested by χ^2 or Fisher exact tests, if appropriate.

[‡] Independent sample Student *t*-test.

^{‡‡} Mann-Whitney U test.

Significant level $p < 0.05$.

Changes in CT manifestation and laboratory parameters during hospitalization

It was noticeable that the disease improvement or progression ratio of Wuhan and nonWuhan groups were different, based on the extent and density change of lung opacities on chest CT images. In total 66.7% of patients (20/30) in Wuhan group and 47.8% of patients (11/23) in nonWuhan group showed progression at the first follow-up of 4 days (Table 3, Figure 2). The improvement ratio of nonWuhan group (100%, 20/20) was higher than that of Wuhan group (69.2%, 18/26) on the CT follow-up of 8 days ($p = 0.006$) (Table 3, Figure 2).

Table 3. Follow-ups during hospitalization and after discharge of patients with COVID-19

	All patients	[^] Wuhan	[^] nonWuhan	<i>p</i> value
[^]Follow-ups during hospitalization- No., (%)				
Follow up 1 (4 days after admission)				
Progression	31/53 (58.5%)	20/30 (66.7%)	11/23 (47.8%)	0.168
Improvement	22/53 (41.5%)	10/30 (33.3%)	12/23 (52.2%)	
Follow up 2 (8 days after admission)				
Progression	8/46 (17.4%)	8/26 (30.8%)	0/20	0.006 ^U
Improvement	38/46 (82.6%)	18/26 (69.2%)	20/20 (100%)	
Mean length of stay hospital, Mean (SD)	13.9 (4.1)	14.5 (4.7)	13.2 (3.2)	0.213 [‡]
Median interval between symptom onset and discharge, Median (IQR)	19.0 (16.0- 23.0)	20.0 (15.8- 23.3)	18.0 (16.0- 20.0)	0.171 ^{‡‡}
[^]Follow-ups after discharge- No., (%)				
Follow up 1 (2 weeks after discharge)				
Partly absorption of lesions	41/45 (91.1%)	25/25 (100%)	16/20 (80%)	0.033 ^U
Complete absorption of lesions	4/45 (8.9%)	0/25	4/20 (20%)	
Follow up 2 (4 weeks after discharge)				
Partly absorption of lesions	4/18 (22.2%)	3/12 (25%)	1/6 (16.7%)	1.000
Complete absorption of lesions	14/18 (77.8%)	9/12 (75%)	5/6 (83.3%)	

Note:

IQR: interquartile range.

[^] Wuhan: patients who lived in/or travelled to Wuhan recently.

[^] nonWuhan: patients who contacted with confirmed case or unknown exposure.

[^] Follow-ups: based on the extent and density change of lung opacities of chest CT images.

^{||} The differences between rates were tested by χ^2 or Fisher exact tests, if appropriate.

[‡] Independent sample Student *t*-test.

^{‡‡} Mann-Whitney U test.

* Significant level $p < 0.05$.

To further evaluate the dynamic changes in CT characteristics during the disease process, we analyzed the imaging findings from 46 patients (26 Wuhan cases and 20 nonWuhan cases), who had undergone all chest CT examinations, including admission, follow-up of days 4, and second follow-up of days 8. The within-group comparison showed that the CT scores of lung involvement in Wuhan group increased at the first follow-up ($p = 0.015$) compared to the examination at admission (Figure 3, Table S1), which suggested disease progression in the short-term follow-up. The comparison between Wuhan and

nonWuhan groups exhibited that the CT scores of nonWuhan group were significantly lower than that of the Wuhan group at the second follow-up ($p = 0.006$) (Figure 3, Table S2).

As the same as CT features, we also analyzed the laboratory indicators of 42 patients (25 Wuhan cases and 17 nonWuhan cases), who had undergone all examinations at admission, follow-up of days 4, and second follow-up of days 8. The level of ALB and A/G of Wuhan group significantly decreased at the first follow-up ($p < 0.001$, $p < 0.001$), and similar results were observed in nonWuhan group ($p = 0.014$, $p < 0.001$) (Figure 4, Table S3). Compared to the first follow-up, the LYM significantly increased ($p = 0.043$), the CRP significantly decreased in Wuhan group ($p = 0.005$) at the second follow-up. For nonWuhan group, the LYM and A/G significantly increased ($p = 0.019$ and 0.035), and the CRP significantly decreased ($p = 0.015$) (Figure 4, Table S3). Changes in the above indicators at the second follow-up show an improvement in the clinical condition. There was no significant difference in laboratory indicators between Wuhan and nonWuhan groups at the initial examination, follow-up of days 4 and 8.

Correlation analysis between lung involvement CT scores and laboratory findings during hospitalization

In initial examination, the CT scores of lung involvement were negatively correlated with LYM ($r = -0.318$, $p = 0.020$), ALB ($r = -0.556$, $p < 0.001$), A/G ($r = -0.656$, $p < 0.001$), and positively correlated with CRP ($r = 0.616$, $p < 0.001$), respectively (Figure 5). Spearman correlation was performed between the CT score and laboratory finding of all 53 cases.

At the first follow-up of days 4, the CT scores of lung involvement were negatively correlated with LYM ($r = -0.428$, $p = 0.002$), ALB ($r = -0.553$, $p < 0.001$), A/G ($r = -0.583$, $p < 0.001$), and positively correlated with CRP ($r = 0.615$, $p < 0.001$), respectively (Figure 5). A total of 53 cases underwent the first CT follow-up, but 1 case was dropped due to the absence of laboratory tests at the time point of the first CT follow-up. Therefore, the spearman correlation was performed with the indicators of 52 patients.

The CT scores of lung involvement were negatively correlated with ALB ($r = -0.596$, $p < 0.001$), A/G ($r = -0.590$, $p < 0.001$), and positively correlated with CRP ($r = 0.347$ and 0.025) at the second follow-up (8 days later), respectively (Figure 5). A total of 46 cases underwent the second CT follow-up, 4 cases were dropped due to the absence of laboratory tests. Therefore, the spearman correlation test was performed between the CT scores and laboratory indices of 42 patients.

Follow-ups after discharge

In this study, the average length of hospital stay was 13.9 days (SD, 4.1), and the median interval between symptom onset and discharge was 19.0 days (IQR, 16.0–23.0). Compared with the nonWuhan group, the average length of hospital stay and interval between symptom onset and discharge in Wuhan group had a tendency of longer but the difference was not statistically significant.

Forty-five patients (25 Wuhan cases and 20 nonWuhan cases) were first followed up of 2 weeks after discharge. The CT images show partly absorption with decreased size and density of the lesions in all Wuhan cases (100%, 25/25) and 80% nonWuhan cases (80%, 16/20) (Figure 2). Moreover, the complete absorption of lesions in 4 nonWuhan cases (20%, 4/20) was shown (Table 3). Subsequently, 10 of 45 patients (7 Wuhan cases and 3 nonWuhan cases) were followed up of 4 weeks after discharge. Complete absorption of lesions was shown on the CT imaging of 4 Wuhan patient and 2 nonWuhan patients (Figure 2), and CT images of the other 3 Wuhan patients and 1 nonWuhan patient still exhibited small-scale lesions. Eight patients (5 Wuhan cases and 3 nonWuhan cases) were followed up only 4 weeks after discharge, and the complete absorption of lesions was found. As the same as CT images, laboratory indicators of all patients such as CRP, lymphocyte, albumin and A/G ratio returned to normal between 2 to 4 weeks after discharge, and the RT-PCR assay results of all patients after discharge were negative.

Discussion

Consistent with former studies and reports, the clinical symptoms of COVID-19 patients in our research were atypical and similar to the common cold or influenza. The onset of symptoms mainly included fever (88.7%), cough (64.2%) and fatigue (34%), and some patients with COVID-19 had lymphopenia[2, 14–16, 18, 19]. In this study, the decrease not only in LYM but also in ALB and A/G were observed, and the CRP level was elevated at the same time.

Moreover, LYM, ALB and A/G were significantly negatively correlated with CT scores of lung involvement, the CRP level was positively correlated with the CT scores of lung involvement at the initial examination and the follow-ups. Recent research also demonstrated that severe patients had more prominent laboratory abnormalities (i.e., lymphopenia, elevated CRP levels) than non-severe patients[15]. The results indicated that the levels of LYM, ALB, A/G, and CRP were significantly correlated with the severity of the COVID-19. These indicators combined with CT features are expected to benefit the early diagnosis and prognosis of COVID-19. Furthermore, LYM, ALB, A/G and CRP could also be used to assess the progression and predict prognosis.

Ground-glass opacity (86.8%) and patchy shadowing (50.9%) under the pleura are most common during the initial CT scan. One of our findings was that the CT images of most patients (especially in Wuhan group) showed an increase in lesion density and size at the short-term follow-up (4 days after admission), suggesting disease progression, although all patients received regular treatments. Changes in laboratory indicators (increased CRP, decreased LYM, ALB, A/G) also suggested progression. Recent studies from Wuhan also found that most patients exhibited progression in the early stage follow-up[12, 18]. The possible explanation is that the coronaviruses interact with and modify the host intracellular environment during infection for rapid replication. Despite careful treatment, time is necessary for COVID-19 patients to build the immune response and produce antibodies to inhibit viral replication. As a result, it is important to control the progression in the early stages of the disease with the utmost effort.

According to the treatment guidelines of COVID-19, RT-PCR assay is the gold standard for the diagnosis of COVID-19 for all patients[7]. Nasopharyngeal swab had been adopted in clinical practice most widely due to its convenience. But recently it was clinically found that some suspected patients' throat swabs were SARS-CoV-2 negative after repeated RT-PCR tests, while the clinical symptoms and CT manifestation of them were consistent with the performance of COVID-19. At last, the RT-PCR showed SARS-CoV-2 positive after repeated assays or test with deep sputum. The false-negative results in the RT-PCR assay of respiratory secretions may be caused by the low viral load of SARS-CoV-2 in testing samples[20–24]. Both the upper and lower respiratory tract specimens should be analyzed to increase the sensitivity of the test. However, sampling from the lower respiratory tract is not easy to obtain.

Due to the limitations of respiratory tract specimens, too depending on the result of RT-PCR assay will lead to the delay in diagnosis and treatment in a certain extent, and will affect the control of COVID-19 pandemic eventually. It was particularly important to combine epidemiological history, clinical symptoms, laboratory indicators, and CT findings. A detailed history of exposure is critical for the diagnosis. In the correct clinical and laboratory setting, such as fever, cough, progressive lymphopenia and hypoalbuminemia, negative for the other common respiratory pathogens, patients with ground-glass opacities or consolidation on chest CT images, a possible diagnosis of COVID-19 should be considered.

Age, viral load, lung injury score, and albumin, CRP, LDH, LYM (%), LYM, and NEU (%), may be predictors of disease severity[25], and lymphopenia is linked to the increased severity, mortality and dysregulated immunological response[26, 27]. In our study, there was no significant difference in age, gender and duration from onset to admission between Wuhan group and nonWuhan group. However, patients in Wuhan group had a higher tendency of lung involvement CT scores and a lower tendency of LYM, ALB, and A/G at the initial examination and the follow-ups during hospitalization. It was worth noting that, the proportion of severe patients in Wuhan group was 23.3%, and most of them showed progression (66.7%) by increasing involvement range and density of lung opacities on CT imaging at the first follow-up of 4 days, and 69.2% of the patients showed improvement at the second follow-up of 8 days. For patients in nonWuhan group, the proportion of severe patients was 8.7%, and about half of the patients' CT imaging (47.8%) showed progression at first follow-up, but the improvement account for 100% at the second follow-up.

A single-center study from Zhongnan Hospital of Wuhan University reported a higher proportion of severe patients (26%)[14]. Xu et al reported that compared with COVID-19 patients initially infected in Wuhan, the symptoms of patients in other regions are relatively mild[16]. One possible reason is the limited medical resources. Wuhan is a high-endemic area, and the number of confirmed cases has dramatically increased. The medical resources may be relatively insufficient. The other possible explanation is that the virulence of SARS-CoV-2 may diminish during transmission. Like the severe acute respiratory syndrome coronavirus (SARS-CoV) and the middle east respiratory syndrome coronavirus (MERS-CoV), due to error-prone RNA-dependent RNA polymerase (RdRP) of coronaviruses, SARS-CoV-2 are also prone to mutation and recombination[28, 29]. We speculate that the adaptive evolution of SARS-CoV-2 was occurred in the transmission, resulting in the change of capacity to cause disease. The viral virulence in patients with

COVID-19 from Wuhan may be different from that of infected patients who have not been to Wuhan. The viral load in serum or other body liquids might be a useful marker related to disease severity of SARS-CoV-2 infection. Further researches are needed to confirm this speculation.

According to the follow-up laboratory indicators and CT manifestations, though most patients presented progression 4 days after admission, most of them exhibited improvement 8 days after admission, indicating that the disease can be controlled by timely treatment. To date, there are no effective drugs for COVID-19 approved[30, 31]. Treatment is individualized according to the severity of the condition and individual heterogeneity. Treatment measures mainly include symptomatic supportive care, antiviral therapy (lopinavir/ritonavir), oxygen support, respiratory support, antibacterial drugs, and appropriate dose of corticosteroid therapy. It is recommended Traditional Chinese Medicine (TCM) for symptomatic treatment.

Patients can be discharged if they meet the following conditions: body temperature returned to normal at least for 3 days, significant improvement in respiratory symptoms, chest CT performance improved significantly, and respiratory specimens (sputum and nasopharyngeal) nucleic acid tests were negative for consecutive twice (sampling interval at least 1 day). The average length of hospitalization was 13.9 days and the median interval between symptom onset and discharge was 19 days. According to the diagnosis and treatment guidelines[7], self-isolation for 2 weeks after discharge, and follow-up visits to the hospital are recommended 2 and 4 weeks after discharge. The prognosis of patients with COVID-19 at our institution is satisfying. We found that the lung lesions of most patients were partially absorbed within 2 weeks after discharge. Complete absorption of the lesions was observed 2 weeks after discharge in a few non-Wuhan patients and after 4 weeks for most patients. Moreover, it may take longer to complete absorption of pneumonia for a couple of severer patients. A study on the prognosis of SARS revealed that pulmonary fibrosis in 62% of patients (15/24) was found at about 5 weeks after discharge[32]. Although the fibrotic change was not found in this study, we have to be cautious about COVID-19, due to the infectivity of some patients with negative results of RT-PCR assay and lung lesions which were not fully absorbed[33]. Therefore, at least 4 weeks are necessary for self-quarantine after discharge as much as possible, which may be helpful in reducing human-to-human infection.

Our study has several limitations. First, the study subjects were limited to discharged patients who had at least twice CT scans during hospitalization and at least 1 CT scan after discharge to ensure more information on clinical and CT features. Thus, the sample size was relatively small and there might be selection biases, further research with larger cohorts is needed to verify our results. Second, our results should be interpreted with caution, because 4 elderly critically ill patients (median age 72.5 years old) still being treated in the respiratory intensive care unit (RICU) and 4 infected children with normal chest CT were not included. Third, the CT score of lung involvement is only related to the range of affected areas, and the changes in the density of the lesion cannot be quantified and need to be improved in future research. Fourth, the viral load and other laboratory indicators, as the potential markers related to the disease severity of COVID-19, should be assessed. Moreover, the role of adaptive evolution in reducing pathogenicity of SARS-CoV-2 also needs to be considered.

In conclusion, CT is an intuitive method with great value in early diagnosis and monitoring of changes in COVID-19. Lymphocytes, C-reactive protein, albumin, and albumin/globulin ratio are sensitive indicators of disease progression and prognosis. Viral pathogenicity may differ between non-endemic areas and core infected areas. Though it is satisfactory that the pneumonia could be completely absorbed in most patients one month after discharge, it is necessary to continue to self-isolation for one month at least after discharge as much as possible.

Abbreviations

Severe acute respiratory syndrome-related coronavirus 2: SARS-CoV-2; corona virus disease: COVID-19; reverse transcription-polymerase chain reaction: RT-PCR; white blood cell: WBC; lymphocytes: LYM; percentage of LYM: %LYM; neutrophil: NEUT; percentage of NEUT: %NEUT; C-reactive proteins: CRP; procalcitonin: PCT; alanine aminotransferase: ALT; aspartate aminotransferase: AST; albumin: ALB; globulin: GLOB; albumin/globulin ratio: A/G; glomerular filtration rate: eGFR; creatine kinase: CK.

Declarations

Ethics approval and consent to participate

This research was approved by the ethics committee of Beijing Youan Hospital, Capital Medical University.

Consent for publication

This was a retrospective study, which involved no risk for subjects. The written informed consent was waived.

Availability of data and materials

The material supporting the conclusion of this study has been included in the manuscript.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

R.L. and G.L. prepared this paper; R.L., G.L., X.H., C.J., Z.X., W.S., X.L., X.W. and H.L. participated in the data collection, clinical analysis and the data analysis; R.L. and G.L. and H.L. designed this study.

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References

1. Zhou P, Yang X, Wang X, Hu B, Zhang L, Zhang W, Si H, Zhu Y, Li B, Huang C *et al*: A pneumonia outbreak associated with a new coronavirus of probable bat origin. *Nature*. Published online 03 Februar 2020. <https://doi.org/10.1038/s41586-020-2012-7>.
2. Huang C, Wang Y, Li X, Ren L, Zhao J, Hu Y, Zhang L, Fan G, Xu J, Gu X *et al*: Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. *Lancet* 2020, 395(10223):497-506. [https://doi.org/10.1016/S0140-6736\(20\)30183-5](https://doi.org/10.1016/S0140-6736(20)30183-5).
3. Lu H, Stratton CW, Tang YW: Outbreak of pneumonia of unknown etiology in Wuhan, China: The mystery and the miracle. *J Med Virol* 2020, 92(4):401-402. <https://doi.org/10.1002/jmv.25678>.
4. NHC. Daily briefing on novel coronavirus cases in China. Beijing, China. [Accessed 10 March 2020]. Available from: http://en.nhc.gov.cn/2020-03/10/c_77552.htm.
5. Zhou F, Yu T, Du R, Fan G, Liu Y, Liu Z, Xiang J, Wang Y, Song B, Gu X *et al*: Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: a retrospective cohort study. *Lancet*. Published online 09 March 2020. [https://doi.org/10.1016/S0140-6736\(20\)30566-3](https://doi.org/10.1016/S0140-6736(20)30566-3).
6. WHO. Novel Coronavirus(2019-nCoV) Situation Report-49. Geneva, Switzerland.2020 [Accessed 09 March 2020]. Available from: <https://www.who.int/emergencies/diseases/novel-coronavirus-2019/situation-reports/>.
7. NHC. Guidelines for the Diagnosis and Treatment of Novel Coronavirus (2019-nCoV) Infection (Trial Version 7). Beijing, China. [Published online 03 March 2020]. Available from: <http://www.nhc.gov.cn/xcs/zhengcwyj/202003/46c9294a7dfe4cef80dc7f5912eb1989.shtml>.
8. Bernheim A, Mei X, Huang M, Yang Y, Fayad ZA, Zhang N, Diao K, Lin B, Zhu X, Li K *et al*: Chest CT Findings in Coronavirus Disease-19 (COVID-19): Relationship to Duration of Infection. *Radiology*. Published online 20 February 2020. <https://doi.org/10.1148/radiol.2020200463>.
9. Chung M, Bernheim A, Mei X, Zhang N, Huang M, Zeng X, Cui J, Xu W, Yang Y, Fayad ZA *et al*: CT Imaging Features of 2019 Novel Coronavirus (2019-nCoV). *Radiology*. Published online 04 February 2020. <https://doi.org/10.1148/radiol.2020200230>.
10. Pan F, Ye T, Sun P, Gui S, Liang B, Li L, Zheng D, Wang J, Hesketh RL, Yang L *et al*: Time Course of Lung Changes On Chest CT During Recovery From 2019 Novel Coronavirus (COVID-19) Pneumonia. *Radiology*. Published online 13 February 2020. <https://doi.org/10.1148/radiol.2020200370>.

11. Song F, Shi N, Shan F, Zhang Z, Shen J, Lu H, Ling Y, Jiang Y, Shi Y: Emerging Coronavirus 2019-nCoV Pneumonia. *Radiology*. Published online 06 February 2020. <https://doi.org/10.1148/radiol.2020200274>.
12. Pan Y, Guan H, Zhou S, Wang Y, Li Q, Zhu T, Hu Q, Xia L: Initial CT findings and temporal changes in patients with the novel coronavirus pneumonia (2019-nCoV): a study of 63 patients in Wuhan, China. *Eur Radiol*. Published online 13 February 2020. <https://doi.org/10.1007/s00330-020-06731-x>.
13. Chang D, Lin M, Wei L, Xie L, Zhu G, Dela Cruz CS, Sharma L: Epidemiologic and Clinical Characteristics of Novel Coronavirus Infections Involving 13 Patients Outside Wuhan, China. *JAMA*. Published online 07 February 2020. <https://doi.org/10.1001/jama.2020.1623>.
14. Wang D, Hu B, Hu C, Zhu F, Liu X, Zhang J, Wang B, Xiang H, Cheng Z, Xiong Y et al: Clinical Characteristics of 138 Hospitalized Patients With 2019 Novel Coronavirus-Infected Pneumonia in Wuhan, China. *JAMA*. Published online 07 February 2020. <https://doi.org/10.1001/jama.2020.1585>.
15. Guan WJ, Ni ZY, Hu Y, Liang WH, Ou CQ, He JX, Liu L, Shan H, Lei CL, Hui DSC et al: Clinical Characteristics of Coronavirus Disease 2019 in China. *N Engl J Med*. Published online 28 February 2020. <https://doi.org/10.1056/NEJMoa2002032>.
16. Xu X, Wu X, Jiang X, Xu K, Ying L, Ma C, Li S, Wang H, Zhang S, Gao H et al: Clinical findings in a group of patients infected with the 2019 novel coronavirus (SARS-CoV-2) outside of Wuhan, China: retrospective case series. *BMJ*. 2020, 368:m606. <https://doi.org/10.1136/bmj.m606>.
17. Tao Z, Yang Y, Shi W, Xue M, Yang W, Song Z, Yao C, Yin J, Shi D, Zhang Y et al: Complementary and alternative medicine is expected to make greater contribution in controlling the prevalence of influenza. *Biosci Trends*. 2013, 7(5):253-256. <https://doi.org/10.5582/bst.2013.v7.5.253>.
18. Xiong Y, Sun D, Liu Y, Fan Y, Zhao L, Li X, Zhu W: Clinical and High-Resolution CT Features of the COVID-19 Infection: Comparison of the Initial and Follow-up Changes. *Invest Radiol*. Published online 03 March 2020. <https://doi.org/10.1097/RLI.0000000000000674>.
19. Chen N, Zhou M, Dong X, Qu J, Gong F, Han Y, Qiu Y, Wang J, Liu Y, Wei Y 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. [https://doi.org/10.1016/S0140-6736\(20\)30211-7](https://doi.org/10.1016/S0140-6736(20)30211-7).
20. Ai T, Yang Z, Hou H, Zhan C, Chen C, Lv W, Tao Q, Sun Z, Xia L: Correlation of Chest CT and RT-PCR Testing in Coronavirus Disease 2019 (COVID-19) in China: A Report of 1014 Cases. *Radiology*. Published online 26 February 2020. <https://doi.org/10.1148/radiol.2020200642>.
21. Fang Y, Zhang H, Xie J, Lin M, Ying L, Pang P, Ji W: Sensitivity of Chest CT for COVID-19: Comparison to RT-PCR. *Radiology*. Published online 19 February 2020. <https://doi.org/10.1148/radiol.2020200432>.
22. Xie X, Zhong Z, Zhao W, Zheng C, Wang F, Liu J: Chest CT for Typical 2019-nCoV Pneumonia: Relationship to Negative RT-PCR Testing. *Radiology*. Published online 12 February 2020. <https://doi.org/10.1148/radiol.2020200343>.

23. Yang W, Yan F: Patients with RT-PCR Confirmed COVID-19 and Normal Chest CT. *Radiology*. Published online 06 March 2020. <https://doi.org/10.1148/radiol.2020200702>.
24. Zou L, Ruan F, Huang M, Liang L, Huang H, Hong Z, Yu J, Kang M, Song Y, Xia J *et al*: SARS-CoV-2 Viral Load in Upper Respiratory Specimens of Infected Patients. *N Engl J Med*. Published online 19 February 2020. <https://doi.org/10.1056/NEJMc2001737>.
25. Liu Y, Yang Y, Zhang C, Huang F, Wang F, Yuan J, Wang Z, Li J, Li J, Feng C *et al*: Clinical and biochemical indexes from 2019-nCoV infected patients linked to viral loads and lung injury. *Sci China Life Sci*. 2020, 63(3):364-374. <https://doi.org/10.1007/s11427-020-1643-8>.
26. Bermejo-Martin JF, Almansa R, Menendez R, Mendez R, Kelvin DJ, Torres A: Lymphopenic community acquired pneumonia as signature of severe COVID-19 infection: Lymphopenia in severe COVID-19 infection. *J Infect*. Published online 04 Mar 2020. <https://doi.org/10.1016/j.jinf.2020.02.029>.
27. Mendez R, Menendez R, Amara-Elori I, Feced L, Piro A, Ramirez P, Sempere A, Ortega A, Bermejo-Martin JF, Torres A: Lymphopenic community-acquired pneumonia is associated with a dysregulated immune response and increased severity and mortality. *J Infect*. 2019, 78(6):423-431. <https://doi.org/10.1016/j.jinf.2019.04.006>.
28. de Wit E, van Doremalen N, Falzarano D, Munster VJ: SARS and MERS: recent insights into emerging coronaviruses. *Nature Reviews Microbiology*. 2016, 14(8):523-534. <https://doi.org/10.1038/nrmicro.2016.81>.
29. Chen J: Pathogenicity and transmissibility of 2019-nCoV-A quick overview and comparison with other emerging viruses. *Microbes Infect*. Published online 04 February 2020. <https://doi.org/10.1016/j.micinf.2020.01.004>.
30. Morse JS, Lalonde T, Xu S, Liu WR: Learning from the Past: Possible Urgent Prevention and Treatment Options for Severe Acute Respiratory Infections Caused by 2019-nCoV. *Chembiochem*. 2020, 21(5):730-738. <https://doi.org/10.1002/cbic.202000047>.
31. Lu H: Drug treatment options for the 2019-new coronavirus (2019-nCoV). *Biosci Trends*. Published online 28 January 2020. <https://doi.org/10.5582/bst.2020.01020>.
32. Antonio GE, Wong KT, Hui DS, Wu A, Lee N, Yuen EH, Leung CB, Rainer TH, Cameron P, Chung SS *et al*: Thin-section CT in patients with severe acute respiratory syndrome following hospital discharge: preliminary experience. *Radiology*. 2003, 228(3):810-815. <https://doi.org/10.1148/radiol.2283030726>.
33. Lin C, Ding Y, Xie B, Sun Z, Li X, Chen Z, Niu M: Asymptomatic novel coronavirus pneumonia patient outside Wuhan: The value of CT images in the course of the disease. *Clin Imaging*. 2020, 63:7-9. <https://doi.org/10.1016/j.clinimag.2020.02.008>.

Figures

125 suspected patients from Jan 21 to Mar 10, 2020
with epidemiological history, chest CT and clinical features of COVID-19

excluded 30
negative results on PCR assay of
SARS-CoV-2

95 patients with confirmed COVID-19 were admitted after Jan 21, 2020

excluded 8
4 not discharged as of Mar 10
4 children (up to 7 years old)

87 patients with confirmed COVID-19

excluded 34
34 without CT follow-ups after
discharge as of Mar 10

53 patients with confirmed COVID-19 were included in this study

Figure 1

Flow diagram of this study COVID-19=Corona Virus Disease, SARS-CoV-2=severe acute respiratory syndrome-related coronavirus.

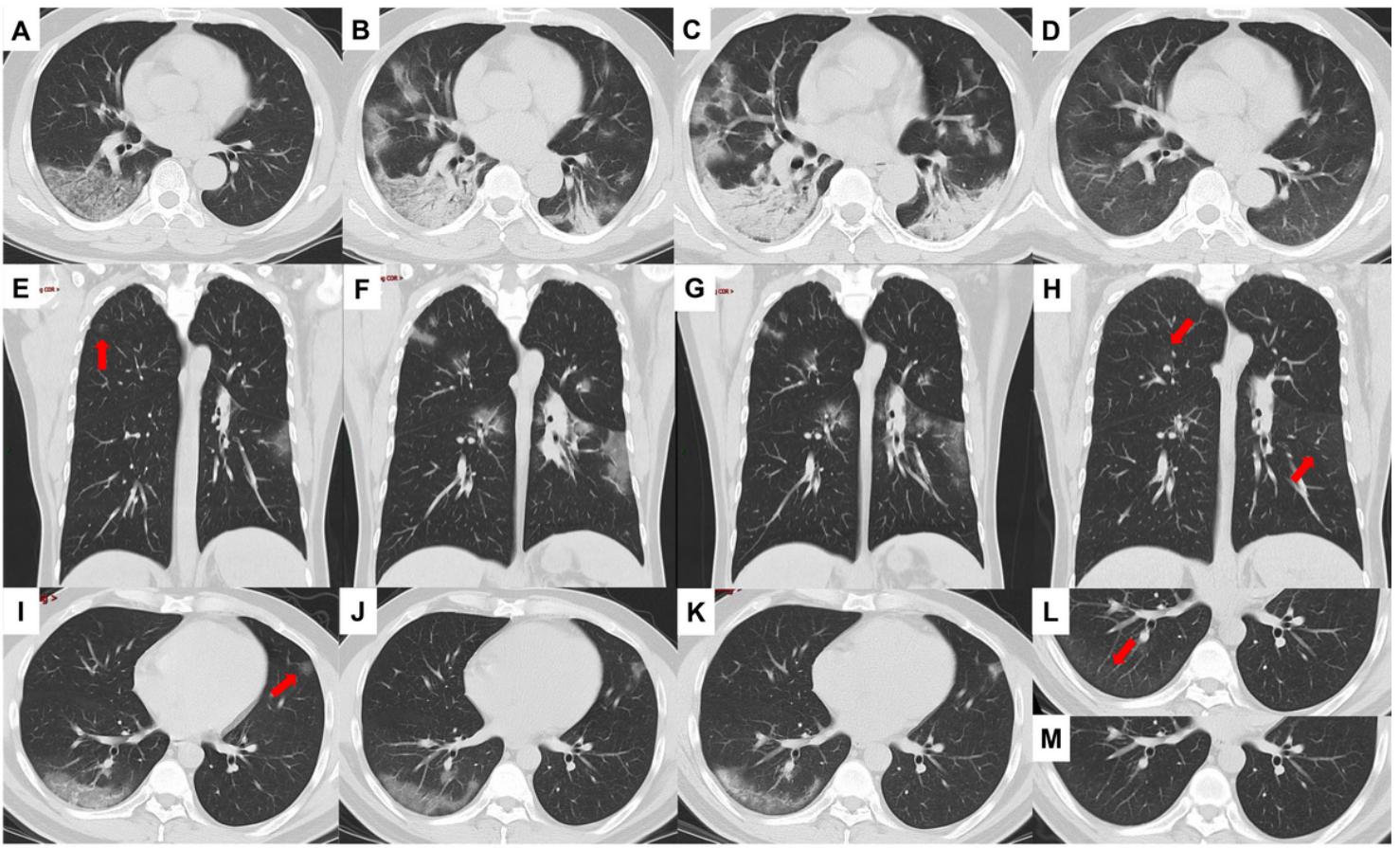


Figure 2

CT images of COVID-19 patients with different exposure history Axial CT images of a patient living in Wuhan, Hubei, but arrived in Beijing, 9 days before admission (A-D). The initial CT image showed ground-glass opacity and patchy shadowing, with air bronchial signs, in the right lower lobe (day 6 after symptom onset) (A). Image obtained 4 days after admission showed the increased size, number and density of the lesions in both lungs (day 10 after symptom onset) (B). Follow-up CT image 8 days after admission showed progressive consolidation (day 14 after symptom onset) (C). Follow-up CT image 18 days after discharge showed obvious absorption with ground-glass opacity (day 45 after symptom onset) (D). Coronal CT images of a patient with a short travel history to Wuhan, Hubei, 4 days before admission (E-H). The initial CT image exhibited ground-glass opacity in the left lower lobe and right upper lobe (red arrow) (day 3 after symptom onset) (E). CT images 4 days after admission exhibited that the size, number and density of the lesions increased (day 7 after symptom onset) (F). CT images 8 days after admission exhibited that the density of the lesions decreased (day 11 after symptom onset) (G). CT images 24 days after discharge exhibited almost complete absorption with only light ground-glass opacity in the left lower lobe and right upper lobe (red arrows) (day 36 after symptom onset) (H). Axial CT

images of a patient, who hadn't been to Wuhan, but was contacted with a confirmed patient from Wuhan, 10 days before admission (I-M). CT image at admission presented as ground-glass opacity with strip-shaped consolidation in the right lower lobe and ground-glass opacity in the tongue segment of the left superior lobe (red arrow) (day 6 after symptom onset) (I). Follow-up CT image 4 days after admission showed decreased lesion density (day 10 after symptom onset) (J). CT image on 8 days after admission presented as slight absorption with strip shadowing (day 14 after symptom onset) (K). Follow-up CT image 16 days after discharge showed almost complete absorption with only light ground-glass opacity (red arrow) (day 31 after symptom onset) (L). Follow-up CT image 30 days after discharge showed complete absorption (day 45 after symptom onset) (M).

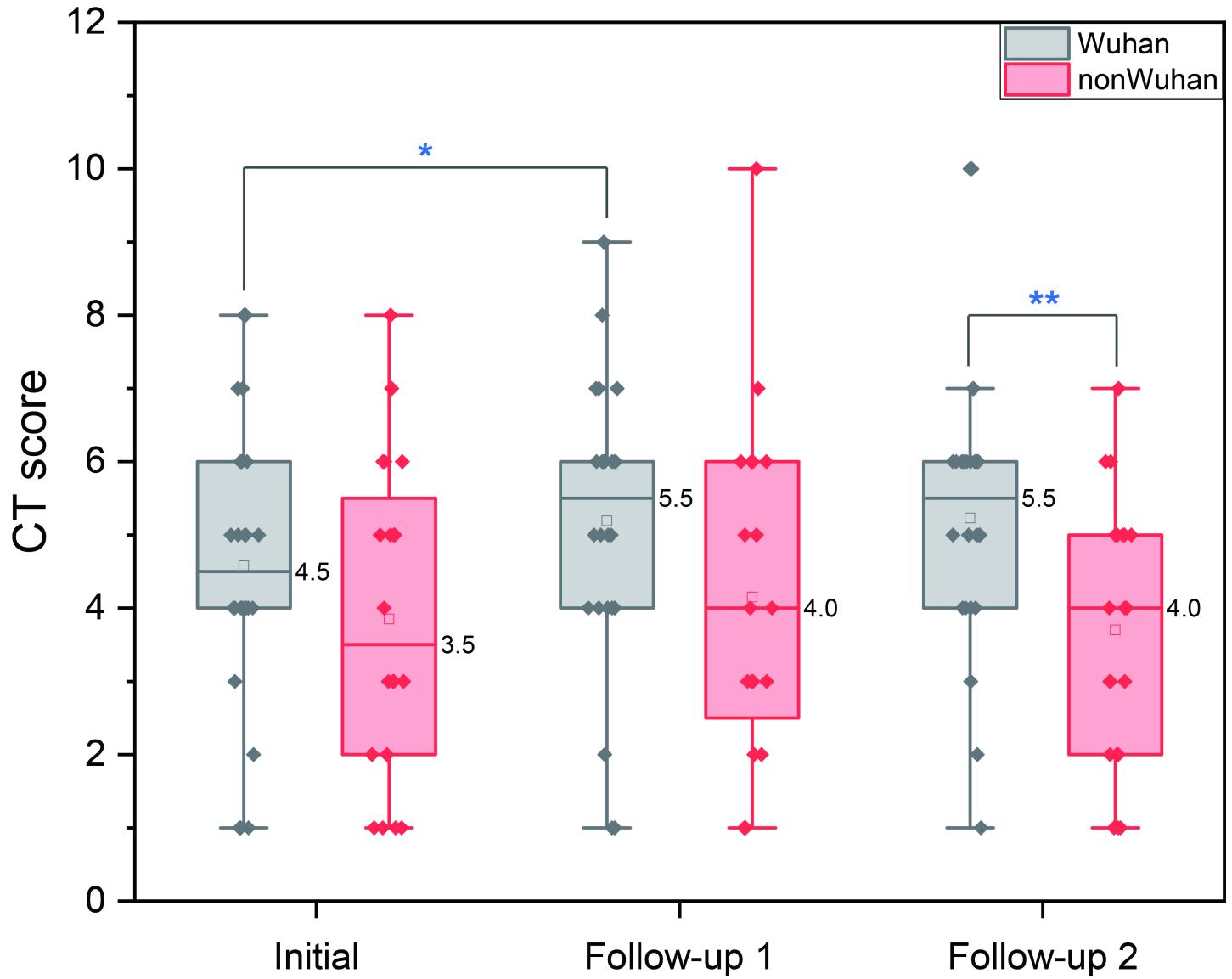


Figure 3

Dynamic changes in lung involvement CT scores in 46 COVID-19 patients during hospitalization A total of 46 patients (26 Wuhan, 20 nonWuhan) had completed CT scans at admission, first follow-up of days 4, and second follow-up of days 8. The CT scores were compared between and within groups during clinical process. Statistics in Box Plot was presented as median. *, P < 0.05; **, P < 0.01. Group "Wuhan" stands

for the patients who lived in/or traveled to Wuhan recently. Group "nonWuhan" stands for the patients who contacted with confirmed case or unknown exposure.

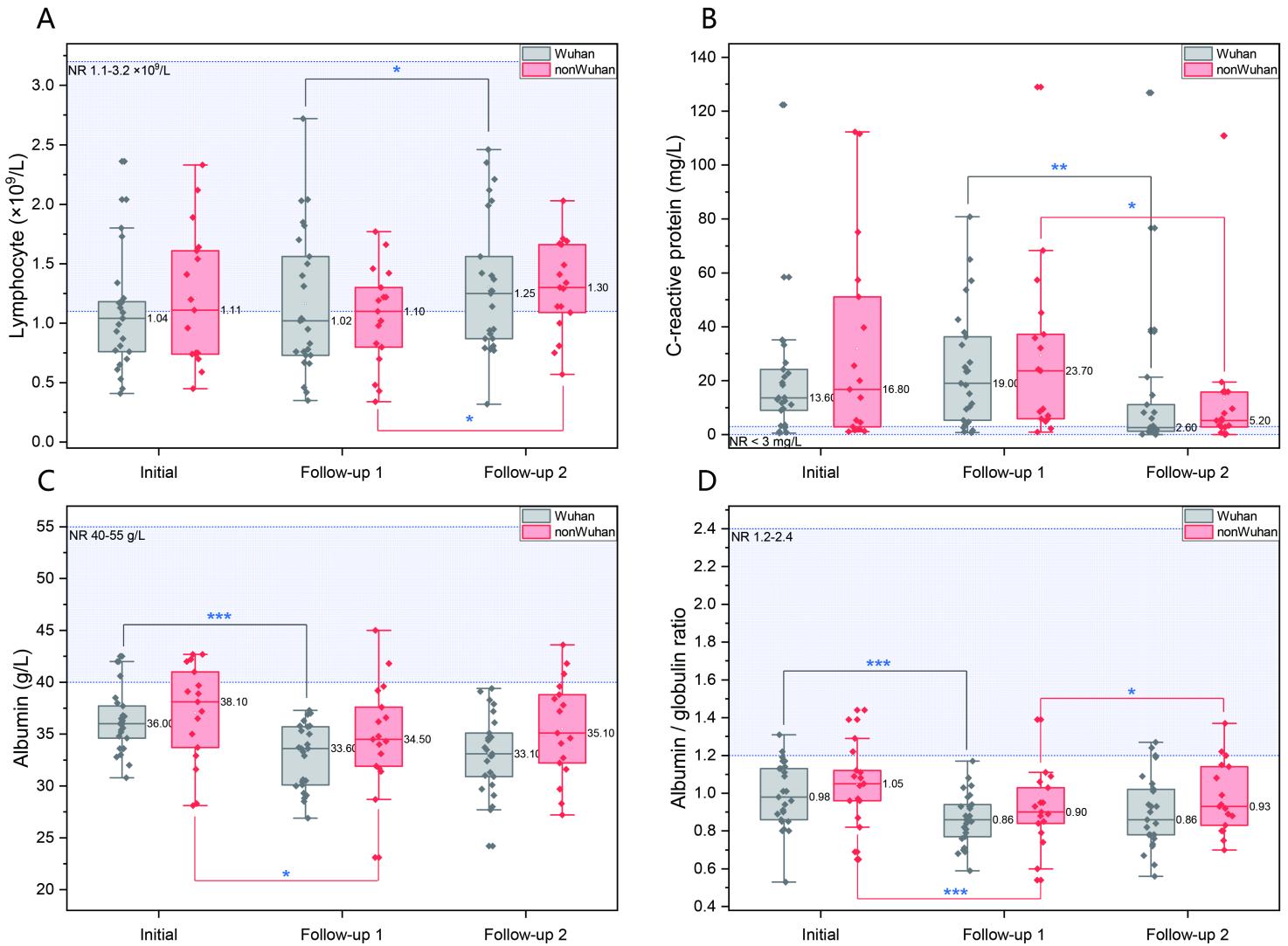


Figure 4

Dynamic changes in laboratory parameters in 42 COVID-19 patients during hospitalization. A total of 42 patients (25 Wuhan, 17 nonWuhan) had completed examinations at admission, first follow-up of days 4, and second follow-up of days 8. The laboratory indicators were analyzed between and within groups during clinical process. Statistics in Box Plot was presented as median. The dotted lines indicate the upper and lower normal limits for each parameter. *, P < 0.05; **, P < 0.01; ***, P < 0.001. NR, normal range. Group "Wuhan" stands for the patients who lived in/or traveled to Wuhan recently. Group "nonWuhan" stands for the patients who contacted with confirmed case or unknown exposure.

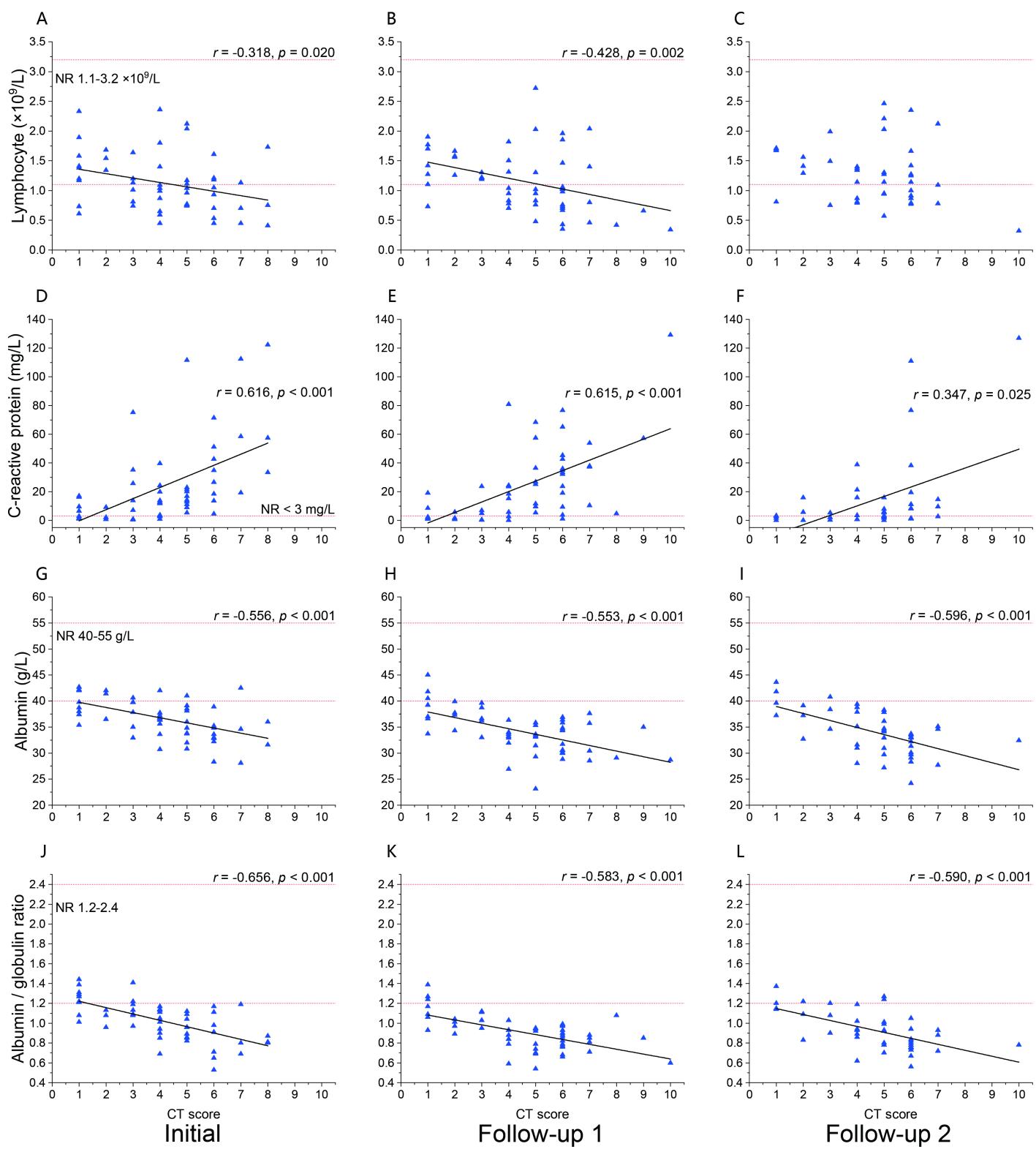


Figure 5

Correlation of lung involvement CT scores and laboratory findings during hospitalization. The CT scores of lung involvement were negatively correlated with lymphocyte, albumin, albumin / globulin ratio, and positively correlated with C-reactive protein at initial examination and follow-ups. Abbreviations: NR, normal range.

Supplementary Files

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