

# Radiological changes of serial CT examinations in patients recovering from coronavirus disease 2019 (COVID-19)

**Qian Xu**

Department of Radiology, Affiliated Hospital of Xuzhou Medical University

**Lin Shi**

Department of Radiology, Affiliated Hospital of Xuzhou Medical University

**Mengshuang Li**

Affiliated Hospital of Xuzhou Medical University 3 GE Healthcare, Shanghai, China

**Lina Dong**

Affiliated Hospital of Xuzhou Medical University 3 GE Healthcare, Shanghai, China

**Lulu Cai**

Affiliated Hospital of Xuzhou Medical University 3 GE Healthcare, Shanghai, China

**Shaofeng Duan**

Department of Radiology, Affiliated Hospital of Xuzhou Medical University

**Kai Xu** (✉ [xukaixz@126.com](mailto:xukaixz@126.com))

Department of Radiology, Affiliated Hospital of Xuzhou Medical University

---

## Research Article

**Keywords:** COVID-19, Infections, Coronavirus, Computed Tomography, Spiral, Pneumonia

**Posted Date:** April 21st, 2020

**DOI:** <https://doi.org/10.21203/rs.3.rs-23952/v1>

**License:** © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

---

# Abstract

**Purpose:** To find the pulmonary CT imaging characteristics in patients recovering from coronavirus disease 2019 (COVID-19).

**Method:** Twenty patients with confirmed COVID-19 were enrolled. We analyzed the changes of four pulmonary CT imaging manifestations (ground glass opacity, consolidation, crazy paving sign and cord/band sign) in patients during hospitalization. The disease course was divided into four stages: early stage (0-4 days), progressive stage (5-8 days), peak stage (9-13 days) and absorption stage ( $\geq 14$  days).

**Results:** There were 12 male and 8 female with an average age of  $45 \pm 16$  years. In the first three stages, GGO was the most common sign on CT imaging. Then, the proportion of GGO decreased in the absorption stage compared with the first three stages ( $P < 0.05$ ). The proportion of crazy paving sign peaked in the progressive stage and then declined, with statistical difference between the progressive stage and the absorption stage ( $P < 0.05$ ). Cord/band sign was increasing from the early stage to the absorption stage, and statistical differences were found between the early stage and the peak stage ( $P < 0.05$ ), as well as the absorption stage and the first three stages ( $P < 0.05$ ). No statistical differences of consolidation proportion were found among the four stages.

**Conclusions:** CT imaging showed different characteristics during the four stages. The proportion of cord/band sign significantly increased in the third stage, which might be an indicator of COVID-19 improvement.

## Introduction

In December 2019, a small number of patients with unknown etiology pneumonia were found in some medical institutions in Wuhan, Hubei Province of China, with the symptoms of fever, cough and fatigue. In a short time, patients with similar symptoms were successively found in other cities of China. The unknown etiology pneumonia was later proved to be caused by a novel coronavirus 1-3 and was officially named "coronavirus disease 2019 (COVID-19)" by the World Health Organization (WHO) on February 11, 2020 4. On the same day, International Committee on Taxonomy of Viruses (ICTV) named the novel coronavirus as "Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2)" 5. Coronaviruses were a large family of viruses, which were known to cause Middle East respiratory syndrome (MERS), severe acute respiratory syndrome (SARS) and other serious diseases. SARS-CoV-2 was a new strain of coronavirus that had never been found in humans.

As of March 6 10AM, 2020, 80711 cases of confirmed COVID-19 were reported in China, among which 3045 people died 6. Furthermore, the virus transmitted rapidly out of China, and increasing number of cases was reported in Korea, Japan, Europe and the United States. Most patients with COVID-19 could be cured and had a good prognosis. However, these patients endured varying degrees of suffering during the period of hospitalization. CT examination played an important role in the disease diagnosis, progression monitoring, treatment evaluation and follow up in COVID-19 patients 3,7-9. Some published research

mainly focused on the radiological demonstrations of the novel coronavirus pneumonia, and typical CT findings included bilateral pulmonary parenchymal ground-glass and consolidative opacities, similar to previous coronavirus infection such as SARS and MERS 8,10-13. However, the radiological imaging characteristics related to the development process and outcome of COVID-19 pneumonia remained to be clarified. The purpose of this study was to analyze the serial CT imaging during the recovery period of COVID-19 pneumonia and to summarize the imaging features representing disease regression.

## **Materials And Methods**

All protocols are carried out in accordance with guidelines and regulations of our hospital. All the methods are approved by our institutional Ethical Committee. Written informed consent was waived by the Affiliated Hospital of Xuzhou Medical University as it was a retrospective study.

### **Patients and chest CT examination protocol**

In this study, 20 patients were enrolled from 26 January 2020 to 13 February 2020. According to the “Diagnosis and Treatment Protocols of 2019 Novel Coronavirus Pneumonia” issued by the National Health Commission of the People’s Republic of China 14, the diagnostic criteria included: epidemiological history (travel/residence history in Wuhan or surrounding areas within 14 days, contacting with COVID-19 patients or fever patients with respiratory symptoms from Wuhan within 14 days, or clustering occurrence), clinical manifestations (fever and / or respiratory symptoms, imaging features of pneumonia, normal or decreased total number of leukocytes and decreased lymphocyte count in the early stage of the disease) and pathogenic evidence (detection of the novel coronavirus by real-time fluorescence RT-PCR, or detected virus highly homologous to the novel coronavirus by gene sequencing). The discharged criteria included: no fever for more than 3 days, respiratory symptoms improved significantly, CT imaging showed that the pneumonia was obviously absorbed, and the nucleic acid test of respiratory pathogens was negative for two consecutive times (at least 1 day apart).

Chest CT scans of all patients were performed using GE Discovery 690 CT scanner according to the following protocols: patients were in supine position and raised their arms above the heads. CT scans were performed during a breath-hold time after deep inhalation. The chest CT scanning range was from the tip to the bottom of the lung parenchyma with the scanning time 2-3 seconds. The slice thickness was 5 mm and the reconstruction thickness was 1.25 mm.

### **CT imaging analysis**

According to the professional consensus “Radiological Diagnosis of New Coronavirus Infected Pneumonitis: Expert Recommendation from the Chinese Society of Radiology (First edition)” and published literatures 12,13,15,16, we analyzed four imaging manifestations in our cases: the first was ground glass opacity which could be nodular, patchy or diffuse.

The second was consolidation, which could coexist with ground glass opacity or exist alone. The third was “crazy paving sign”, which caused by subpleural ecstatic vascular and thickened interlobular septa within the patchy opacities. The last was “cord/band sign”, and it was mainly distributed in the peripheral region, subpleural area and lung base. In a recently published research about the CT imaging changes during recovery from COVID-19 [17], the authors divided the disease course into four stages: early stage (0-4 days), progressive stage (5-8 days), peak stage (9-13 days) and absorption stage ( $\geq 14$  days). In our study, we adopted this staging method and two radiologists (6 and 8 years of experience in thoracic radiology, respectively) analyzed the occurrence of the four imaging manifestations in four stages. The final results were determined by consensus.

## **Statistical analysis**

Statistical analyses were performed using SPSS, version 17.0 software package (SPSS Inc., Chicago, IL). Quantitative clinical data of patients were presented as mean  $\pm$  standard deviation. The incidences of the four CT manifestations in every stage were compared using Chi-square test. P value  $< 0.05$  was defined as a statistically significant difference.

# **Results**

## **Clinical data of patients**

The clinical data of all 20 patients were listed in Table 1. The average age of the patients was  $45 \pm 16$  years, with the ratio of male to female 3:2. The main symptoms were fever (75%), cough (90%), expectoration (60%) and chest tightness (45%). Laboratory examinations showed moderately increased C-reactive protein, erythrocyte sedimentation rate (ESR) and lactate dehydrogenase (LDH). The time from the onset of symptoms to admission was  $6 \pm 3$  days, with the length of hospital stay  $14 \pm 4$  days. During hospitalization, a total of 69 chest CT scans were performed in 20 patients with the interval of  $4 \pm 1$  days.

## **Pulmonary CT imaging analysis**

Ground glass opacity (GGO), consolidation, crazy paving sign and cord/band sign were the most common imaging manifestations in the 20 patients (Figure 1). These lesions were more common in lower lobes of bilateral lungs (table 2) with a predilection of peripheral lung region or subpleura area. Hilar or mediastinal lymphadenopathy and

pleural effusion were not observed in our cases. The changes of four imaging manifestations in different stages during the disease course were shown in table 3 and figure 2. CT imaging changes in the course of the disease were shown in figure 3 and figure 4. In the early stage, the progressive stage and the peak stage, GGO (100%, 100% and 96% respectively) was the most common signs on CT imaging. With the absorption of pneumonia, GGO obviously decreased in the fourth stage (64%) and there was statistically significant difference of GGO proportion between the absorption stage and the other three stages. The proportion of crazy paving sign peaked in the progressive stage (50%) and then declined. Statistical

difference was found in the progressive stage and the absorption stage. From the early stage to the absorption stage, cord/band sign was increasing (13%, 42%, 67% and 92%, respectively), and there were statistical differences between the early stage and the peak stage, as well as the absorption stage and the other three stages. From the early stage to the peak stage, the proportion of consolidation gradually increased (50%, 67% and 75%, respectively), but decreased in the absorption stage (56%). However, there were no statistical differences of consolidation proportion among the four stages.

## Discussion

In this study, we observed series of pulmonary CT images of patients with COVID-19 during their hospitalization, summarized four most common imaging manifestations, and analyzed their changes in the occurrence, development and outcome of the novel coronavirus pneumonia. We adopted the staging method in a recently published research 17, as the complete time range of CT examinations throughout the disease course. In our cases of COVID-19, the lesions were mainly manifested as multiple patchy or diffuse asymmetric GGO and consolidation, which were distributed along the bronchovascular bundle and the subpleural region. The thickened blood vessels and interlobular septa within the lesions formed a fine reticulated pattern, presenting as a “crazy paving sign”. With the development of COVID-19, GGO, consolidation and subpleural bands coexisted in the lung parenchyma, with a predilection of peripheral areas in the lower lobes. Pulmonary cavitation, solid nodules, pleural effusion or lymphadenopathy was not found in our cases.

In our study, patients underwent multiple chest CT scans (mean  $3\pm 1$  times), which could reflect the dynamic imaging change in the course of COVID-19. GGO was the most common sign in the early stage (1-4days), the progressive stage (5-8days) and the peak stage (9-13days). Statistical difference of GGO proportion between the absorption stage ( $\geq 14$  days) and the other three stages might suggest that GGO represented the activity of pneumonia. Alveolar edema and proteinaceous exudates might explain the pathological change 18. Consolidation was the second most common sign during the progression of COVID-19. From the early stage to the peak stage, consolidation gradually increased, and then decreased in the absorption stage. However, there were no statistical differences among these stages, partly due to the small number of cases. In our cases, “crazy paving sign” was a relatively uncommon CT manifestation. It was more common in large-area lesions. The proportion of “crazy paving sign” reached the peak at the progressive stage, then declined gradually, and reached to minimum at the absorption stage. This implied that “crazy paving sign” might represent pathological progression and activity. Its pathological change might be evident proteinaceous and fibrin exudate with diffuse thickening of alveolar walls 18,19. “cord/band sign”, which was demonstrated as high density bands/cords distributed in the subpleura region and not mentioned in previous studies, could be found in the CT imaging of recovery patients, especially in the peak stage and absorption stage. The increasing proportion of “cord/band sign” from the early stage to the absorption stage might indicate a good prognosis. Possible pathological changes of pneumocyte hyperplasia and interstitial thickening indicated an ongoing reparative process 18. As in the peak stage with more pulmonary parenchyma involved than the former

stages, the occurrence of “band/cord sign” might be a good predictor for recovery and have clinical significance for the evaluation of patients’ condition during the course of COVID-19.

Our study has some limitations. Firstly, the number of our cases was relatively small. Secondly, there was no comparison group in this study. Most patients (85%) were clinically classified as common type of COVID-19, cases of severe and critical type needed to be included and confirmed our conclusion. Thirdly, we adopted the staging method of other researchers, as the first CT examinations of several patients were not performed in our hospital and we could not get the initial imaging data.

In summary, CT imaging demonstrated different radiological features during the disease course in patients recovering from COVID-19. GGO, consolidation, crazy paving sign and cord/band sign were the most common imaging manifestations in our patients with COVID-19. Obviously increased ratio of cord/band sign in the peak stage might indicate a good prognosis.

## Abbreviations

**COVID-19** Coronavirus disease 2019 WHO World Health Organization

**ICTV** International Committee on Taxonomy of Viruses SARS-CoV-2 Severe Acute Respiratory Syndrome Coronavirus 2 MERS Middle East respiratory syndrome

**SARS** Severe acute respiratory syndrome

**GGO** Ground glass opacity

## Tables

**Table 1. Clinical data of all 20 patients**

		20 patients
<b>Male/female</b>		12/8
<b>Age (years)</b>		45±16
<b>Symptoms</b>	Fever (>37.3°C)	15 (75%)
	Cough	18 (90%)
	Expectoration	12 (60%)
	Chest tightness	9 (45%)
	Sore throat	3 (15%)
	Chills	5 (25%)
	Fatigue	5 (25%)
	Decreased appetite	3 (15%)
	Nausea	3 (15%)
	Diarrhea	1 (5%)
<b>Laboratory examinations</b>	Leukocyte count (×10 <sup>9</sup> /L)	5.1±1.9
	Lymphocyte count (×10 <sup>9</sup> /L)	1.2±0.5
	Percentage of leukocytes (%)	23.9±7.8
	C-reactive protein (mg/L)	27.1±33.6
	Erythrocyte sedimentation rate (mm/H)	36.0±25.7
	Alanine aminotransferase (U/L)	27.7±14.0
	Aspartate aminotransferase (U/L)	28.7±11.2
	Creatine kinase (U/L)	96.7±72.4
	Lactate dehydrogenase (U/L)	243.5±61.0
	D-dimer (ug/ml)	0.30±0.20
<b>Time from the onset of symptoms to admission (days)</b>		6±3
<b>length of hospital stay (days)</b>		14±4
<b>Time from the onset of symptoms to discharge (days)</b>		20±5
<b>Numbers of chest CT examinations (total = 69)</b>		3±1
<b>Interval between CT examinations (days)</b>		4±1

Quantitative clinical data were presented as mean  $\pm$  standard deviation. The enumeration data was expressed in the form of counting, with the percentage in parentheses.

**Table 2. The numbers of affected lobes in four stages**

	Right lung			Left lung	
	Upper lobe	Middle lobe	Lower lobe	Upper lobe	Lower lobe
<b>Early stage (n=8)</b>	6 (75%)	3 (38%)	4 (50%)	6 (75%)	7 (88%)
<b>Progressive stage (n=12)</b>	10 (83%)	7 (58%)	11 (92%)	10 (83%)	12 (100%)
<b>Peak stage (n=24)</b>	20 (83%)	14 (58%)	23 (96%)	17 (71%)	21 (88%)
<b>Absorption stage (n=25)</b>	20 (80%)	20 (80%)	24 (96%)	20 (80%)	23 (92%)
<b>Total number=69</b>	56 (81%)	44 (64%)	62 (90%)	53 (77%)	63 (91%)

The enumeration data was expressed in the form of counting, with the percentage in parentheses.

**Table 3. The occurrence of four CT imaging manifestations in four stages**

	GGO	Consolidation	Crazy paving sign	Cord/band sign
<b>Early stage (n=8)</b>	8 (100%)	4 (50%)	1 (13%)	1 (13%)
<b>Progressive stage (n=12)</b>	12 (100%)	8 (67%)	6 (50%)	5 (42%)
<b>Peak stage (n=24)</b>	23 (96%)	18 (75%)	5 (21%)	16 (67%)
<b>Absorption stage (n=25)</b>	16 (64%)	14 (56%)	2 (8%)	23 (92%)
<b>Statistical significance</b>	II, III, IV	-	III	I, II, III, IV

I:  $P < 0.05$ , early stage vs. peak stage

II:  $P < 0.05$ , early stage vs. absorption stage

III:  $P < 0.05$ , progressive stage vs. absorption stage IV:  $P < 0.05$ , peak stage vs. absorption stage

## Figures

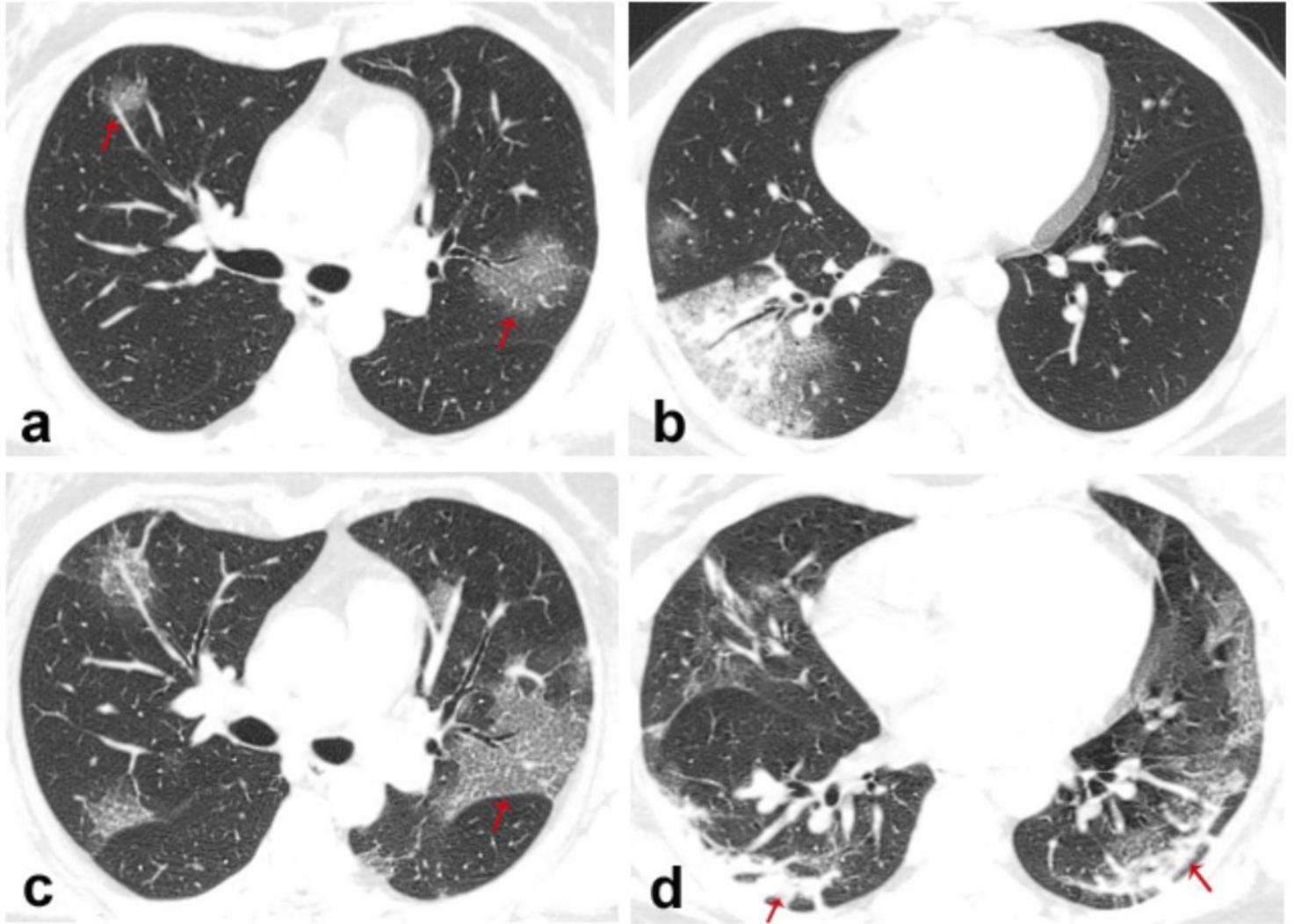
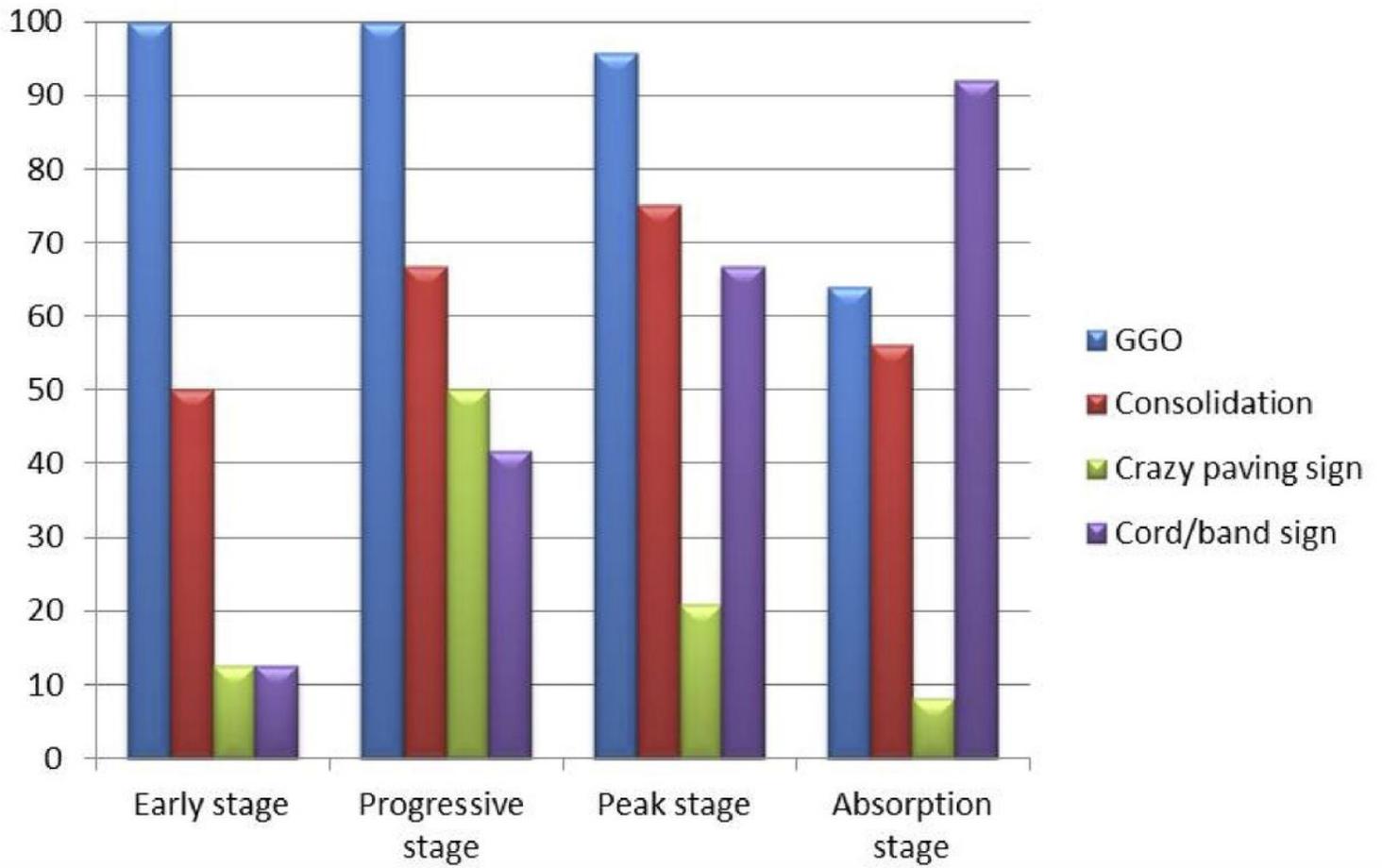


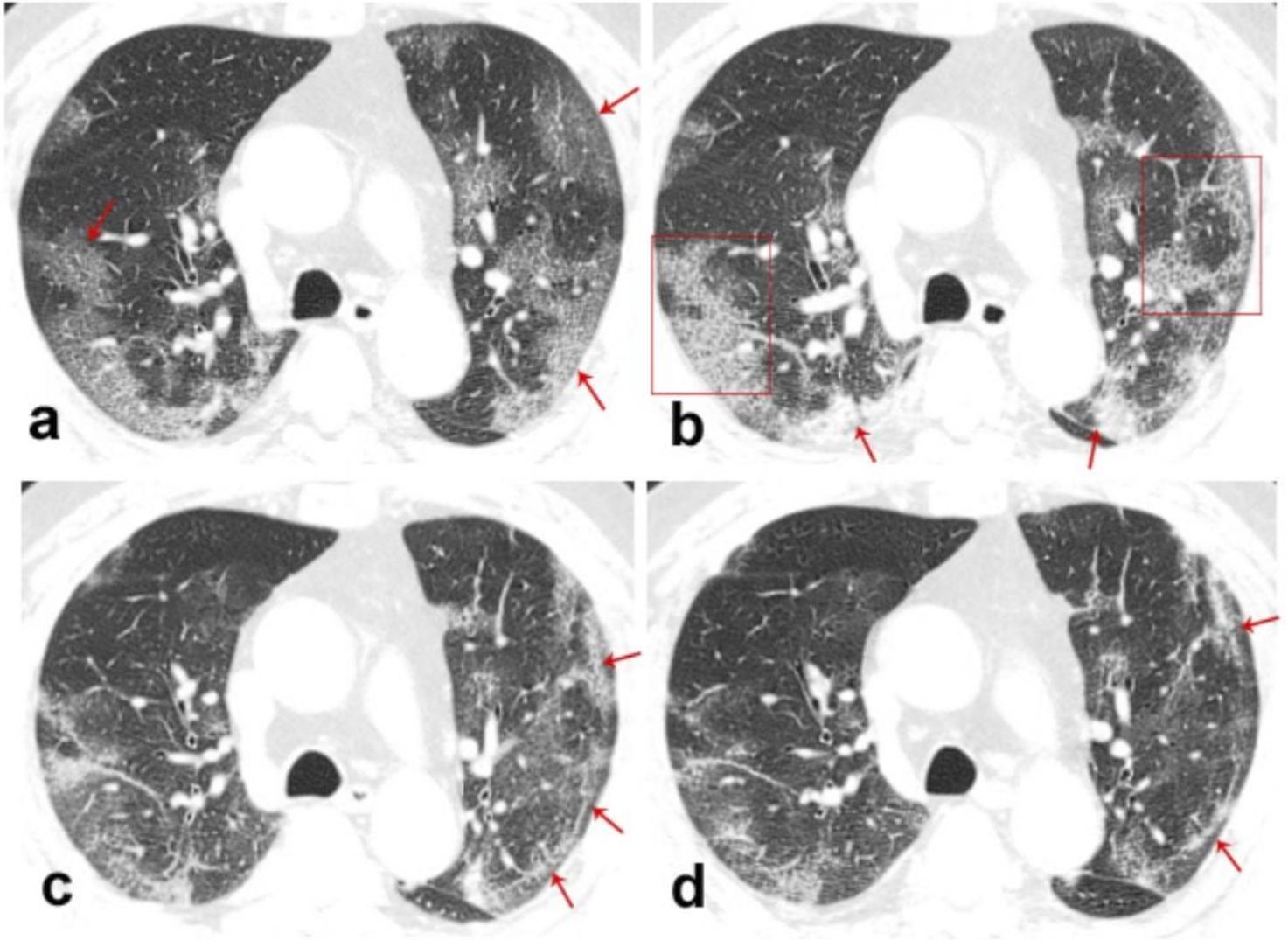
Figure 1

GGO (a), consolidation (b), crazy paving sign (c) and cord/band sign (d) were the most common manifestations of COVID-19.



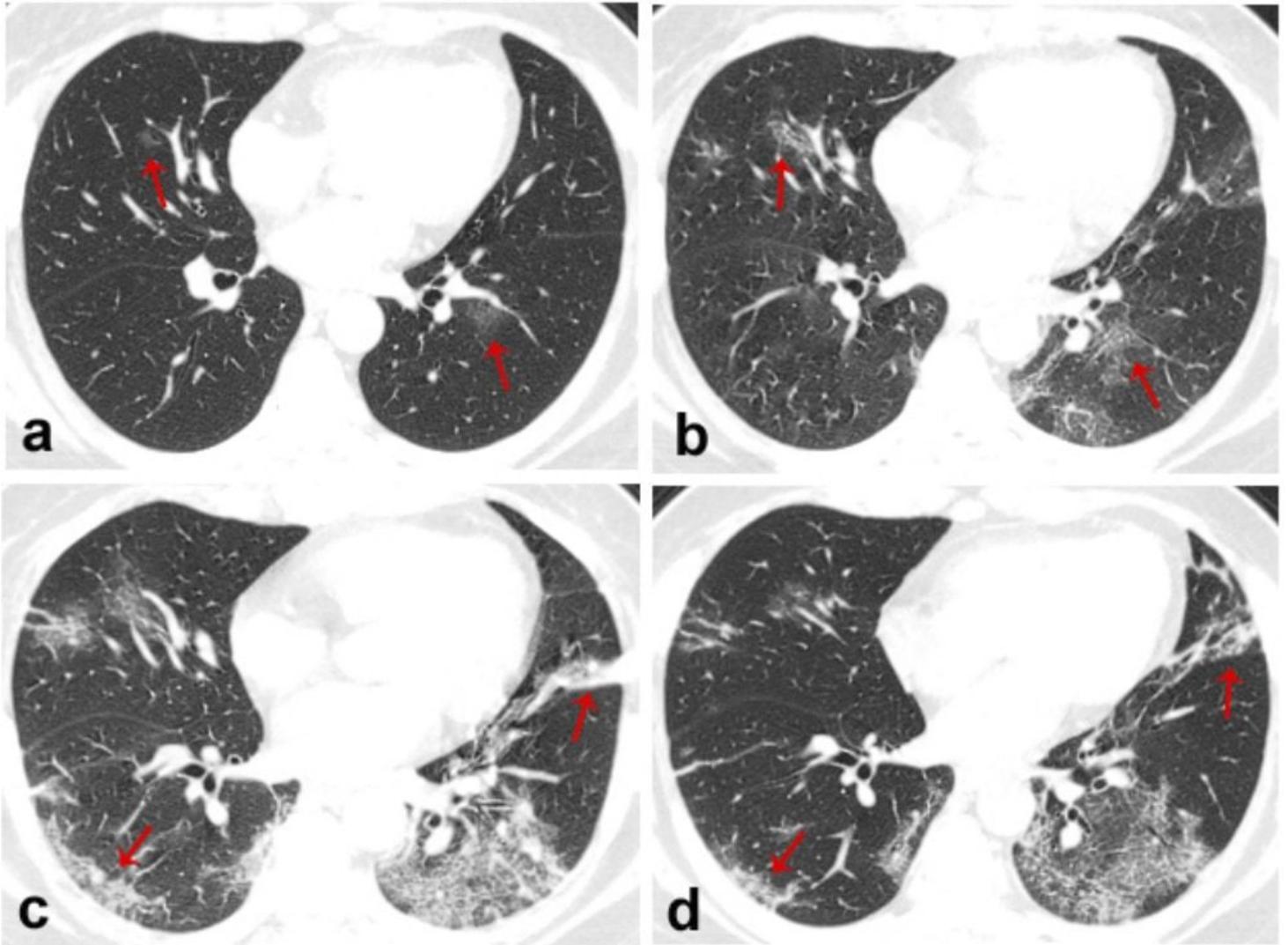
**Figure 2**

The proportion of GGO, consolidation, crazy paving sign and cord/band sign on CT imaging in four stages.



**Figure 3**

ulmonary CT imaging changes in a 56-year-old patient recovery from COVID-19. (a) After 4 days of fever, cough and expectoration, a chest CT examination found multiple patchy ground glass opacities distributed in bilateral lungs (red arrow). (b) Four days later (day 8), consolidation (red arrow) and crazy paving sign (res box) could be found in the lesions. (c) Day 12, partial GGO was absorbed, while subpleural bands/cords appeared (red arrow). (d) Day 16, subpleural high-density cords (red arrow) was still visible in the absorption stage.



**Figure 4**

A 49-year-old female complained of fever, cough and chest tightness for 3 days. (a) Chest CT revealed scattered GGO (red arrow) in bilateral pulmonary parenchymas. (b) Day 7, GGO enlarged with thickened intralobular septa within the patchy opacities. (c) Day 10, pneumonia progressed with fused and enlarged opacities, while subpleural high-density bands were observed (red arrow). (d) Day 14, partial lesions were absorbed and subpleural bands/cords (red arrow) were still seen.