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CHEST IMAGING

ORIGINAL ARTICLE

CT findings of COVID-19 in follow-up: comparison between progression and recovery

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PURPOSE
We aimed to retrospectively analyze the imaging changes detected in the follow-up of coronavirus disease 2019 (COVID-19) patients on thin-section computed tomography (CT).

METHODS
We included 54 patients diagnosed with COVID-19. The mean interval between the initial and follow-up CT scans was 7.82±3.74 days. Patients were divided into progression and recovery groups according to their outcomes. We evaluated CT images in terms of distribution of lesions and imaging manifestations. The manifestations included ground-glass opacity (GGO), crazy-paving pattern, consolidation, irregular line, and air bronchogram sign.

RESULTS
COVID-19 lesions showed mainly subpleural distribution, which was accompanied by bronchovascular bundle distribution in nearly 30% of the patients. The lower lobes of both lungs were the most commonly involved. In the follow-up, the progression group showed more involvement of the upper lobe of the left lung than the recovery group. GGO was the most common sign. As the disease progressed, round GGO decreased and patchy GGO increased. On follow-up CT, consolidation increased in the progression group while decreasing in the recovery group. Air bronchogram sign was more commonly observed at the initial examination (90.9%) than at follow-up (30%) in the recovery group, but there was no significant change in the progression group. Pleural effusion and lymphadenopathy were absent in the initial examination, but pleural effusion was observed in three cases after follow-up.

CONCLUSION
As COVID-19 progressed, round GGOs tended to evolve into patchy GGOs, consolidation increased, and pleural effusion could be occasionally observed. As COVID-19 resolved, the crazy-paving pattern and air bronchogram significantly decreased.

An unexplained pneumonia outbreak in Wuhan, China in late 2019 was detected by Chinese authorities as having been caused by a new coronavirus. This new coronavirus was named as severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) (1), and the World Health Organization (WHO) officially termed the disease caused by SARS-CoV-2 as coronavirus disease 2019 (COVID-19) (2). COVID-19 rapidly spread from Wuhan to other cities in China and the entire world. As of April 20, 2020, a total of 2 314 621 cases have been confirmed globally, with 157 847 deaths (3). The Consensus on Guidelines for the Publication of the Seventh Trial Version of the Diagnosis and Treatment Plan of the COVID-19 in China states that infected patients may present with fever or respiratory symptoms, positive imaging findings on chest computed tomography (CT), a normal level or decrease in the total number of white blood cells, and a decrease in lymphocyte counts. A patient who meets two of the above conditions and has an epidemiological history should be considered a suspected case (4). The chest CT findings of COVID-19 may include ground-glass opacity (GGO), crazy-paving pattern, consolidation, and other findings of viral pneumonia. Chest CT can be used to evaluate the severity of lung involvement (5). One of the criteria for determining patients with severe disease is progression by more than 50% within 24–48 hours (4). The CT findings are related to the time course and show different imaging signs with progression

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(5, 6). The present study was conducted to show CT findings as the COVID-19 progresses or recovers on short-term follow-up.

Methods

Study subjects

This study was approved by the Review Committee and the Ethics Committee of our institution. Written informed consent was waived for the retrospective analyses by the Institutional Review Board. From January 10 to February 25, 2020, we collected a total of 66 patients with confirmed COVID-19. Inclusion criteria were as follows: 1) diagnosis made on the basis of either positivity for SARS-CoV-2 nucleic acid, or viral-gene sequencing with a high degree of homology to SARS-CoV-2; and 2) at least two CT scans performed at the hospital. Twelve patients were excluded for having only one CT scan; thus, a total of 54 patients were included in the final analysis.

Scanning equipment and method

We used a 16-row spiral CT scanning device (Siemens AG). The patient was instructed to lie in the supine position and hold his/her breath after inhaling. Contrast was not used. Scan coverage was from the apex of the lung to the level of the bilateral adrenals. Tube voltage was set at 130 kV with automatic tube current modulation (range 35–255 mAS). The thin-section CT was reconstructed by lung algorithm with a slice thickness of 1.5 mm. The matrix size was 512×512 for axial images.

Image evaluation

Two chest radiologists (work experience of 13 years and 16 years) evaluated the images on a picture archiving and communication system (PACS) workstation (Carestream Health); disagreements over results were negotiated and resolved. The lung window width was 1500 HU with a window level of −700 HU; the mediastinum window width was 400 HU with a window level of −40 HU. The window width and position could also be adjusted appropriately. Evaluation was performed on imaging findings on the initial CT and the follow-up CT. The patients were divided into the progression group and the recovery group according to their outcomes. The progression group included those showing an increase in size and/or density of lesions, while the recovery group included those who showed a reduction in size and/or density of lesions. The evaluation parameters included lesion distribution, GGO, crazy-paving pattern, consolidation, irregular line, air bronchogram sign, lymphadenopathy, pleural effusion, and other lesions in the lungs. Distribution of lesions was evaluated as distribution between the left and right lungs, among five lung lobes, and around the subpleural areas and bronchovascular bundles. GGO describes a fuzzy increase in density in the lungs with visible bronchial and blood vessel edges (7). Crazy-paving pattern shows the thickening of the interlobular septa and intralobular lines superimposed on the GGO. Consolidation describes an increase in parenchyma density that conceals blood vessels. Irregular line describes the linear shadow of high attenuation in the lung. Air bronchogram sign means that the bronchus containing gas is outlined by high attenuation, including consolidation or GGO (7).

Main points

- Lesions of COVID-19 pneumonia are distributed mainly in the subpleural area.
- Round ground-glass opacities are noticeable in the early stages of the disease.
- Consolidation increases during progression of the disease.
- Air bronchogram decreases during the recovery phase.

Statistical analysis

We used SPSS version 17.0 (IBM Corp.) for statistical analysis. Descriptive statistics of the data are presented as n (%) for categorical variables and mean ± standard deviation (SD) for normalized variables. The Independent sample t-test was used to analyze differences in the intervals. Categorical variables were analyzed by chi-square test or Fisher exact test. When expected value was less than 5 lattice points more than 20% in the contingency table larger than 2×2, Fisher-Freeman-Halton test was considered. $P < 0.05$ was considered statistically significant.

Table 1. CT scan intervals in progression and recovery groups

Days	Progression group	Recovery group	*P*
Days to initial CT[a]	4.79±2.29	8.45±4.08	0.016
Days to follow-up CT[a]	12.26±3.61	17.82±5.71	0.010
Days between initial and follow-up CT	7.48±3.70	9.36±3.72	0.139

[a]Days elapsed since the start of symptoms.

Results

There were 54 patients included in the analysis, 29 females and 25 males, with a mean age of 44.8±16.7 years. Forty-two patients (77.8%; 21 females and 21 males, mean age 46.2±15.7 years) were in the progression group and 11 (20.4%; 7 females and 4 males, mean age 43.18±16.92 years) in the recovery group. One patient (1.8%, 1/54; female, 4 years of age) showed no positive manifestation of COVID-19 on either the initial or the follow-up CT scan. One of the 11 cases in the recovery group was completely resolved and there was no positive manifestation on follow-up CT.

The time elapsed since the start of symptoms to initial CT and follow-up CT was significantly shorter in the progression group compared with the recovery group ($P = 0.016$ and 0.010, respectively) (Table 1). The mean interval between the initial and follow-up CT scans was 7.82±3.74 days for all patients, with no significant difference between the progression and recovery groups ($P = 0.139$) (Table 1).

Three of 54 patients (5.6%) showed no pneumonia on initial CT. Of the remaining 51 cases (94.4%) with COVID-19 pneumonia, 82.3% (42/51) involved both lungs, and the lower lobes (left 84.3%, 43/51; right 76.5%, 39/51) were more commonly involved. The proportion of right middle lobe involvement was significantly higher in the progression group than in the recovery group (62.5% vs. 27.3%; $P = 0.048$). In 36 cases (70.6%, 36/51), lesions distributed around the subpleural area (Table 2, Fig. 1).

Two of 54 (3.7%, 2/54) cases showed no pneumonia on follow-up CT. Of the other 52 cases (96.3%, 52/54) with COVID-19 pneumonia, 44 (84.6%, 44/52) showed involvement in both lungs. However, there was no significant difference between the progression (90.5%, 38/42) and recovery (60%,

Table 2. Comparison of initial CT findings between progression and recovery groups

	Progression group (%)	Recovery group (%)	Total (%)	*P*
Number	40 (100.0)	11 (100.0)	51[a] (100.0)	
Both lungs	35 (87.5)	7 (63.6)	42 (82.3)	0.122
Left lung	2 (5.0)	2 (18.2)	4 (7.8)	
Right lung	3 (7.5)	2 (18.2)	5 (9.8)	
Left upper lobe	27 (67.5)	6 (54.5)	33 (64.7)	0.488
Left lower lobe	34 (85.0)	9 (81.8)	43 (84.3)	1.000
Right upper lobe	28 (70.0)	4 (36.4)	32 (62.7)	0.075
Right middle lobe	25 (62.5)	3 (27.3)	28 (54.9)	0.048
Right lower lobe	30 (75.0)	9 (81.8)	39 (76.5)	1.000
Subpleural	28 (70.0)	8 (72.7)	36 (70.6)	1.000
Subpleural and peribronchovascular[b]	12 (30.0)	3 (27.3)	15 (29.4)	
Ground-glass opacity	40 (100.0)	11 (100.0)	51 (100.0)	
Round	25 (62.5)	6 (54.5)	31 (60.8)	0.732
Patchy	15 (37.5)	5 (45.4)	20 (39.2)	
Crazy-paving pattern	37 (92.5)	9 (81.8)	46 (90.2)	0.292
Consolidation	24 (60.0)	9 (81.8)	33 (64.7)	0.288
Irregular line	22 (55.0)	7 (63.6)	29 (56.9)	0.737
Air bronchogram	31 (77.5)	10 (90.9)	41 (80.4)	0.428

Data are presented as n (%).
[a]Three cases showed no COVID-19 pneumonia findings on CT. [b]Subpleural and peribronchovascular, subpleural accompanying peribronchovascular bundle.

Table 3. Comparison of follow-up CT findings between progression and recovery groups

	Progression group	Recovery group	Total (%)	*P*
Number	42 (100.0)	10 (100.0)	52[a] (100.0)	
Both lungs	38 (90.5)	6 (60.0)	44 (84.6)	0.055
Left lung	2 (4.8)	2 (20.0)	4 (7.7)	
Right lung	2 (4.8)	2 (20.0)	4 (7.7)	
Left upper lobe	33 (78.6)	3 (30.0)	36 (69.2)	0.006
Left lower lobe	39 (92.9)	8 (80.0)	47 (90.4)	0.242
Right upper lobe	31 (73.8)	4 (40.0)	35 (67.3)	0.062
Right middle lobe	27 (64.3)	3 (30.0)	30 (57.7)	0.075
Right lower lobe	33 (78.6)	8 (80.0)	41 (78.8)	1.000
Subpleural	29 (69.0)	8 (80.0)	37 (71.1)	0.704
Subpleural and peribronchovascular[b]	13 (30.9)	2 (20.0)	15 (28.8)	
Ground-glass opacity	42 (100.0)	8 (80.0)	50 (96.1)	0.034
Round	18 (42.9)	2 (20.0)	20 (38.5)	0.450
Patchy	24 (57.1)	6 (60.0)	30 (57.7)	
Crazy-paving pattern	40 (95.2)	6 (60.0)	46 (88.5)	0.009
Consolidation	34 (80.9)	7 (70.0)	41 (78.8)	0.424
Irregular line	30 (71.4)	7 (70.0)	37 (71.1)	1.000
Air bronchogram	33 (78.6)	3 (30.0)	36 (69.2)	0.006

Data are presented as n (%).
[a]Two cases showed no signs of COVID-19 pneumonia on CT. [b]Subpleural and peribronchovascular, subpleural accompanying peribronchovascular bundle.

6/10) groups ($P = 0.055$). Involvement of the lower lobes was more common, with 90.4% (47/52) of cases involving the left lower lobes and 78.8% (41/52) involving the right lower lobes (Fig. 1). The proportion of left upper-lobe involvement was significantly higher in the progression group than in the recovery group (78.6% vs. 30%; $P = 0.006$) (Figs. 2, 3). Subpleural distribution was the predominant finding (71.1%, 37/52), while 28.8% (15/52) of cases showed distribution both in the subpleural areas and around the bronchovascular bundle (Table 3, Fig. 3).

On the initial CT, GGO was observed in all 51 cases with COVID-19 pneumonia, and round GGO (60.8%, 31/51) was more common than patchy GGO (39.2%, 20/51). The other manifestations included crazy-paving pattern (90.2%, 46/51), air bronchogram sign (80.4%, 41/51), consolidation (64.7%, 33/51), irregular line (56.9%, 29/51), nodule (7.8%, 4/51), and localized tuberculosis (5.9%, 3/51) (Figs. 1–3). Pleural effusion and lymphadenopathy were absent on CT. There were no significant differences in imaging manifestations between the progression and recovery groups ($P = 0.288$–0.737) (Table 2).

On follow-up CT, of the 52 cases with COVID-19 pneumonia, the most common imaging manifestation was GGO (96.1%, 50/52), followed by crazy-paving pattern (88.5%, 46/52), consolidation (78.8%, 41/52), irregular lines (71.1%, 37/52), and air bronchogram sign (69.2%, 36/52). GGO was more common in the progression group than in the recovery group ($P = 0.034$); 30 cases (57.7%, 30/52) showed a patchy shadow, 20 (38.5%) had a round shadow, and 2 (3.8%) in the recovery group had the lesions completely absorbed. Crazy-paving pattern and air bronchogram were significantly higher in the progression group (95.2%, 40/42 and 78.6%, 33/42, respectively) than that in the recovery group (60%, 6/10 and 30%, 3/10, respectively; Crazy-paving pattern $P = 0.009$, air bronchogram sign $P = 0.006$) (Table 3; Figs. 4–6). Three cases showed pleural effusion, two (3.85%) of which had free pleural effusion and one (1.9%) showed localized encapsulated effusion around the lesion (Figs. 4, 7). Pulmonary nodules and localized tuberculosis did not change compared with the initial CT. Lymphadenopathy was still absent.

There was no statistically significant difference in distribution of lesions on initial

Table 4. Comparison of initial and follow-up imaging findings in recovery and progression groups

	Progression group			Recovery group		
	Initial CT	Follow-up CT	*P*	Initial CT	Follow-up CT	*P*
Number	40 (100.0)	42[a] (100.0)		11 (100.0)	10[b] (100.0)	
Bilateral lungs	35 (87.5)	38 (90.5)	0.874	7 (63.6)	6 (60.0)	1.000
Left lung	2 (5.0)	2 (4.8)		2 (18.2)	2 (20.0)	
Right lung	3 (7.5)	2 (4.8)		2 (18.2)	2 (20.0)	
Left upper lobe	27 (67.5)	33 (78.6)	0.258	6 (54.5)	3 (30.0)	0.387
Left lower lobe	34 (85.0)	39 (92.9)	0.307	9 (81.8)	8 (80.0)	1.000
Right upper lobe	28 (70.0)	31 (73.8)	0.701	4 (36.4)	4 (40.0)	1.000
Right middle lobe	25 (62.5)	27 (64.3)	0.867	3 (27.3)	3 (30.0)	1.000
Right lower lobe	30 (75.0)	33 (78.6)	0.702	9 (81.8)	8 (80.0)	1.000
Subpleural	28 (70.0)	29 (69.0)	0.925	8 (72.7)	8 (80.0)	1.000
Subpleural and peribronchovascular[c]	12 (30.0)	13 (30.9)		3 (27.3)	2 (20.0)	
Ground-glass opacity	40 (100.0)	42 (100.0)		11 (100.0)	8 (80.0)	0.214
Round	25 (62.5)	18 (42.9)	0.075	6 (54.5)	2 (20.0)	0.352
Patchy	15 (37.5)	24 (57.1)		5 (45.4)	6 (60.0)	
Crazy-paving pattern	37 (92.5)	40 (95.2)	0.672	9 (81.8)	6 (60.0)	0.361
Consolidation	24 (60.0)	34 (80.9)	0.037	9 (81.8)	7 (70.0)	0.635
Irregular line	22 (55.0)	30 (71.4)	0.123	7 (63.6)	7 (70.0)	1.000
Air bronchogram	31 (77.5)	33 (78.6)	0.907	10 (90.9)	3 (30.0)	0.008

Data are presented as n (%).
[a]COVID-19 pneumonia emerged in two cases after follow-up. [b]The lesions of COVID-19 are completely absorbed in one case after follow-up. [c]Subpleural and peribronchovascular, subpleural accompanying peribronchovascular bundle.

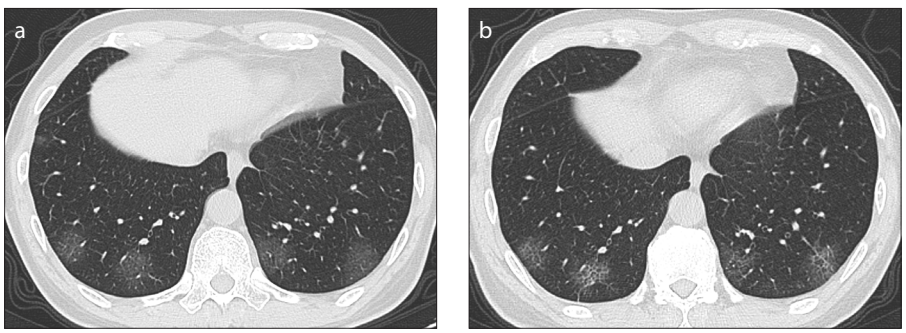

Figure 1. a, b. A 75-year-old man with COVID-19, in the progression group. Axial CT image **(a)** from the initial scan shows the round ground-glass opacities (GGOs) distributed around the subpleural area in the bilateral lower lobes. Axial image **(b)** from the follow-up CT obtained 8 days later shows crazy-paving pattern appear within the GGOs bilaterally in the lower lobes.

and follow-up CT scans in the progression and recovery groups (progression group, $P = 0.258–0.925$; recovery group, $P = 0.387–1.000$) (Table 4).

On initial CT scans, round GGO was more common than patchy GGO in both groups, but this pattern was reversed on follow-up CT (Table 4). On follow-up CT of the recovery group, crazy-paving pattern, consolidation, and air bronchogram sign were reduced, while irregular line was slightly increased. The only one of these indications with a statistically significant difference was the reduction in air bronchogram sign (90.9%, 10/11 vs. 30.0%, 3/10; $P = 0.008$) (Fig. 7, Table 4).

On follow-up CT of the progression group, crazy-paving pattern, consolidations, irregular line, and air bronchogram sign all increased. Only the increase in consolidations was statistically significant (60.0%, 24/40 vs. 80.9%, 34/42; $P = 0.037$) (Figs. 2–4) (Table 4).

Discussion

COVID-19 caused by SARS-CoV-2 infection has caused worldwide concern. Our follow-up review of CT findings of COVID-19 yielded the following observations. First, there were more cases with COVID-19 in the progression group (77.8%) than in the recovery group (20.4%). Second, both lower lobes were commonly involved, but the progression group was inclined to have involvement all of lobes. Lesions were predominantly located in the subpleural area, but still nearly 30% of these patients had simultaneous involvement of the subpleural and bronchovascular bundle area. Third, round GGO could gradually convert into patchy GGO as COVID-19 progressed. Fourth, on follow-up CT scans, consolidation significantly increased in the progression group, and air bronchogram sign significantly decreased in the recovery group. Fifth, irregular lines increased in both groups.

SARS-CoV-2 is the seventh coronavirus discovered to infect humans. Of the other six, four are less pathogenic and generally cause mild respiratory symptoms. The oth-

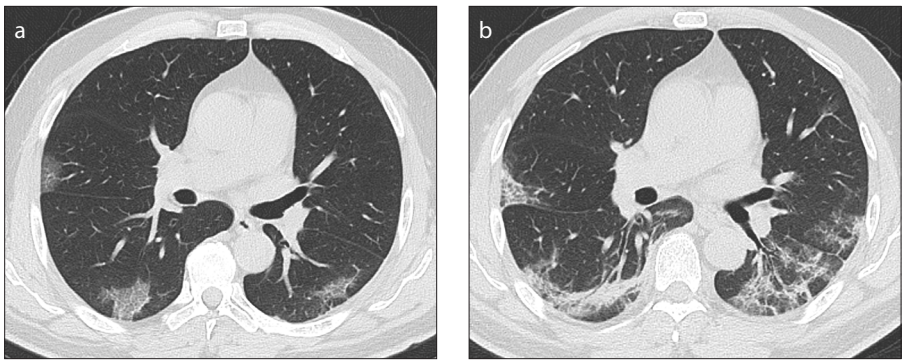

Figure 2. a, b. A 49-year-old man with COVID-19, in the progression group. Axial CT image **(a)** from the initial scan shows the round and patchy GGOs distributed around the subpleural area of right middle lobe and bilateral lower lobes. Crazy-paving patterns are present within GGOs. Axial image **(b)** from the follow-up CT obtained 13 days later shows the patchy GGOs distributed around the subpleural area of the right middle lobe, left upper lobe, and bilateral lower lobes. The GGOs, crazy-paving patterns, consolidation, and irregular lines are significantly increased.

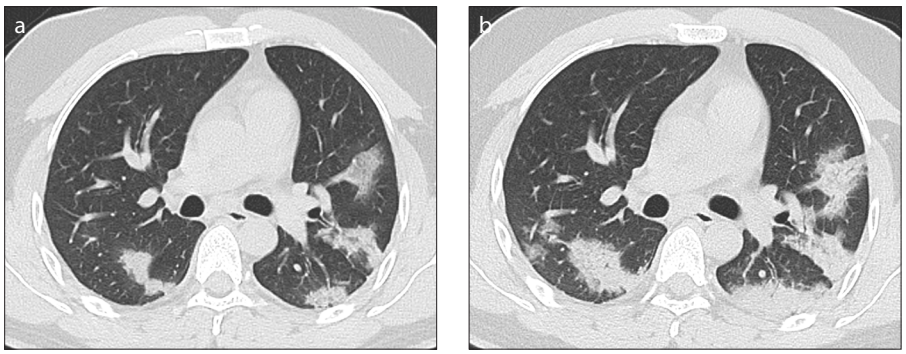

Figure 3. a, b. A 35-year-old man with COVID-19, in the progression group. Axial CT image **(a)** from the initial scan shows patchy GGOs and consolidations both around the subpleural area and around bronchovascular bundle in the bilateral upper lobes and the left lower lobe. Axial image **(b)** from the follow-up CT obtained 4 days later shows increase in the GGOs and consolidations; also, air bronchograms appear.

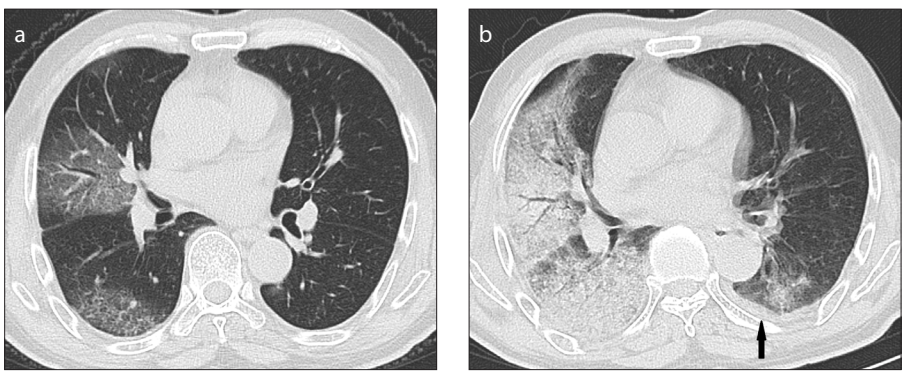

Figure 4. a, b. A 74-year-old man with COVID-19, in the progression group. Axial CT image **(a)** from the initial scan shows that the patchy GGOs are present around subpleural area and bronchovascular bundle in the right middle and bilateral lower lobes. Air bronchogram is observed within GGOs in the middle lobe. Axial image **(b)** from the follow-up CT obtained 7 days later shows patchy GGOs and apparently increased air bronchograms. Pleural effusion appears on the left *(arrow)*.

er two coronaviruses can give rise to severe acute respiratory diseases, including the severe acute respiratory syndrome (SARS) outbreak in 2003, and Middle East respiratory syndrome (MERS) in 2012 and 2015. The pathological findings of COVID-19 are similar to that of severe acute respiratory syndrome (SARS) and Middle East respiratory syndrome (MERS) according to a recent study (8). Therefore, similar CT manifestations are expected in the SARS, MERS and COVID-19 diseases caused by coronaviruses. In the early stages of SARS and MERS, distribution in the lower lobes of the lung is predominant, and both lungs are involved in the advanced stage in most patients. Distribution in the subpleural areas is greater than around the bronchovascular bundle. As SARS progresses, GGO distribution becomes diffuse, changing the diagnosis to acute respiratory-distress syndrome (ARDS) (9–13). Crazy-paving pattern and consolidation are also common, and air bronchogram sign can be observed in consolidation images (14). A few cases can be observed to have pleural effusion, whereas enlarged mediastinal lymph nodes are uncommon (12–13). MERS is more prone to result in acute renal failure (15).

In this study, COVID-19 showed similar CT results to SARS and MERS. Bilateral subpleural distribution also dominated on CT scans of COVID-19 pneumonia patients, and in nearly 30% was also accompanied by distribution around the bronchovascular bundle. Although the whole lung tended to be more commonly involved in the progression group (90.5%) than in the recovery group (60%), there was no significant difference between the two groups. The small sample size might account for absence of significant difference, and false-negative results may be avoided if the sample size is increased. GGO was the most common sign on thin-section CT commonly appearing as round on initial CT and patchy on follow-up CT. In addition, we noticed that the round GGO located in the subpleural area in the early stage could change into patchy GGO during disease progression, which had not been observed in SARS and MERS (9–14). We speculated that round GGO could be an early manifestation, and that the round shadow gradually became patchy as the disease progressed. Crazy-paving pattern was the second most common manifestation. It was more commonly observed in the progression group (92.5% and 95.2% on the initial and follow-up CTs, respectively) than in the recovery group (81.8% and 60%, respectively), which indicated that pulmonary interstitial lesions gradually increased in the progression group and gradually resolved in the recovery group. Consolidation increased in the progression group, while it gradually resolved in the recovery group. Pulmonary parenchyma became gradually more involved in the stage of progression and resolved in the stage of recovery. Air bronchogram was also a common sign, though it was significantly reduced in the recovery stage. There might be two reasons

for this reduction: first, decrease of consolidation and GGO in the recovery group; second, resolution of the interstitial lesion that pulled the bronchus. Irregular line might be a manifestation of pulmonary interstitial changes. On follow-up CT, irregular lines increased in both groups, more so in the progressive group. Whether irregular lines can be completely recovered requires long-term follow-up observation. As a result, radiologists could precisely recognize CT changes and differentiate the progression of disease, which would provide help for clinical treatment. In this study, we observed no enlarged lymph nodes or pleural effusions on the initial CT, while we saw three cases of free pleural effusion at follow-up. Attention must be paid to whether the pleural effusion is in accordance with prognosis. The time elapsed from start of symptoms to initial and follow-up CT scans was significantly longer in the recovery group than in the progression group. Therefore, it was necessary to take a longer time to observe the recovery than the progression, similar with the findings in the literature (5, 6).

This study had some limitations. First, because our study involved short-term follow-up observation, whether the imaging manifestations of COVID-19 pneumonia in the recovery stage will be completely resolved remains to be further studied in the future. Second, for emerging imaging signs of pleural effusion after follow-up, it is necessary to evaluate the significance to the prognosis of COVID-19 in further studies.

In conclusion, COVID-19 appeared as typical viral pneumonia on thin-section CT. The disease was mainly distributed around the subpleural area, predominantly in the lower lobes. GGO was the most common imaging manifestation. Round GGO was definitely noticeable in the early stage, which could convert from round to patchy during disease progression. Consolidation significantly increased during progression, while crazy-paving pattern and air bronchogram decreased during recovery. Accurate identification of CT imaging manifestations may provide precise staging of the disease for clinical diagnosis and treatment.

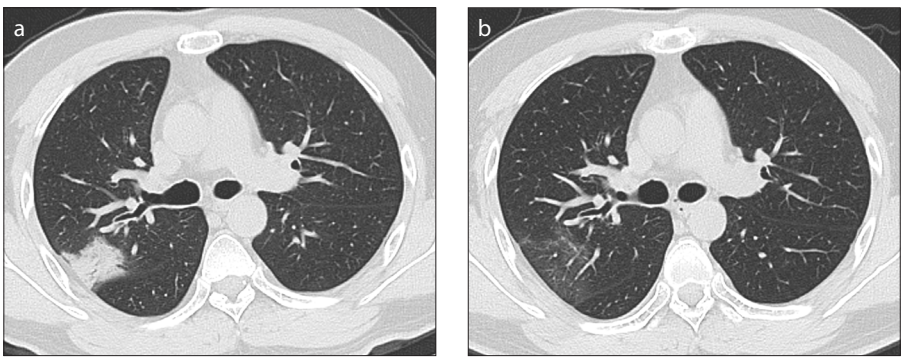

Figure 5. a, b. A 35-year-old man with COVID-19, in the recovery group. Axial CT image **(a)** from the initial scan shows patchy consolidation and air bronchogram in the right upper lobe. There are GGOs located around the consolidation. Axial image **(b)** from the follow-up CT obtained 10 days later shows that the consolidation is completely absorbed, air bronchogram is absent, and only a few GGOs remain.

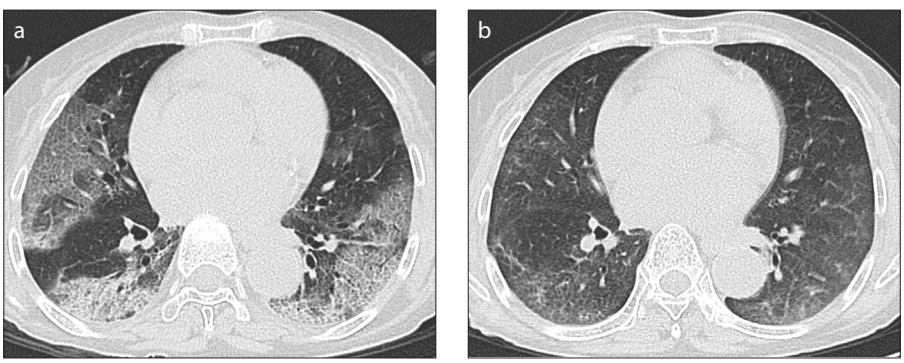

Figure 6. a, b. A 72-year-old woman with COVID-19, in the recovery group. Axial CT image **(a)** from the initial scan shows patchy GGOs located around the subpleural area in the right middle lobe, left upper lobe and bilateral lower lobes. Air bronchograms appear within the GGOs. Axial image **(b)** from the follow-up CT obtained 15 days later shows GGOs obviously reduce, the air bronchograms are absent, and only a few irregular lines are present.

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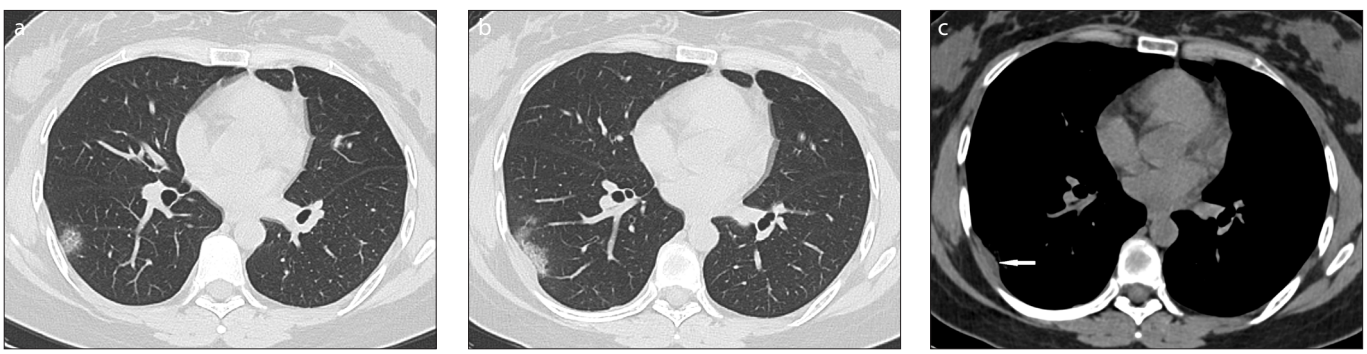

Figure 7. a–c. A 36-year-old woman with COVID-19, in the progression group. Axial CT image **(a)** from the initial scan shows a round GGO around the subpleural area in the right lower lobe. Crazy-paving pattern is present within the GGO. Follow-up axial CT images **(b, c)** were obtained 10 days later. Image **(b)** shows the round GGO gradually converting to a patchy form and extending down. An encapsulated pleural effusion (**c,** *arrow*) is present adjacent to the patchy GGO.

Conflict of interest disclosure

The authors declared no conflicts of interest.

References

1. International Committee on Taxonomy of Viruses. Available at: https://talk.ictvonline.org/. Published 11 February 2020. Accessed 11 February 2020.
2. World Health Organization. World experts and funders set priorities for COVID-19 research. Available at: https://www.who.int/news-room/detail/12-02-2020-world-experts-and-funders-set-priorities-for-covid-19-research. Published 11 February 2020. Accessed 11 February 2020.
3. World Health Organization. Coronavirus disease (COVID-19) situation reports. Available at: https://www.who.int/emergencies/diseases/novel-coronavirus-2019/situation-reports/. Published 20 April 2020. Accessed 21 April 2020.
4. National Health Commission of the People's Republic of China. Consensus on Guidelines for the Publication of the Seventh Trail Version of the Diagnosis and Treatment Plan of the Novel Coronavirus. Available at: http://www.nhc.gov.cn/yzygj/s7653p/202003/46c9294a7dfe4cef80dc7f5912eb1989.shtml. Published 4 March 2020. Accessed 4 March 2020.
5. Pan F, Ye T, Sun P, et al. Time course of lung changes on chest CT during recovery from 2019 novel coronavirus (COVID-19) pneumonia. Radiology 2020 Feb 13; 200370. [Crossref]
6. Bernheim A, Mei X, Huang M, et al. Chest CT findings in coronavirus disease-19 (COVID-19): relationship to duration of infection. Radiology 2020 Feb 20; 200463. [Crossref]
7. Hansell DM, Bankier AA, MacMahon H, McLoud TC, Müller NL, Remy J. Fleischner Society: glossary of terms for thoracic imaging. Radiology 2008; 246:697–722. [Crossref]
8. Xu Z, Shi L, Wang Y, et al. Pathological findings of COVID-19 associated with acute respiratory distress syndrome. Lancet Respir Med 2020; 8:420–422. [Crossref]
9. Peiris JS, Chu CM, Cheng VC, et al. Clinical progression and viral load in a community outbreak of coronavirus-associated SARS pneumonia: A prospective study. Lancet 2003; 361:1767–1772. [Crossref]
10. Hon KL, Leung CW, Cheng WT, et al. Clinical presentations and outcome of severe acute respiratory syndrome in children. Lancet 2003; 361:1701–1703. [Crossref]
11. Booth CM, Matukas LM, Tomlinson GA, et al. Clinical features and short-term outcomes of 144 patients with SARS in the greater Toronto area. JAMA 2003; 289:2801–2809. [Crossref]
12. Das KM, Lee EY, Enani MA, et al. CT correlation with outcomes in 15 patients with acute Middle East respiratory syndrome coronavirus. Am J Roentgenol 2015; 204:736–742. [Crossref]
13. Ajlan AM, Ahyad RA, Jamjoom LG, Alharthy A, Madani TA. Middle East respiratory syndrome coronavirus (MERS-CoV) infection: chest CT findings. Am J Roentgenol 2014; 203:782–787. [Crossref]
14. Wong KT, Antonio GE, Hui DS, et al. Thin-section CT of severe acute respiratory syndrome: evaluation of 73 patients exposed to or with the disease. Radiology 2003; 228:395–400. [Crossref]
15. 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; 13:752–761. [Crossref]