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ORIGINAL ARTICLE

Dandelion and focal crazy paving signs: the lung CT based predictors for evaluation of the severity of coronavirus disease

Xi Zhan[a]*, Zhihai Chen[b]*, Huijuan Hu[c], Yibin Yang[d], Kaisong Wu[d], Zhenshun Cheng[d,e] and Bing Liu[d,e]

[a]Department of Respiratory and Critical Care Medicine, Beijing Institute of Respiratory Medicine and Beijing Chaoyang Hospital, Capital Medical University, Beijing, China; [b]Center of Infectious Diseases, Beijing Ditan Hospital, Capital Medical University, Beijing, China; [c]Radiology Department, Zhongnan Hospital of Wuhan University, Wuhan, China; [d]Department of Pulmonary and Critical Care Medicine, Zhongnan Hospital of Wuhan University, Wuhan, China; [e]Wuhan Research Center for Infectious Diseases and Cancer, Chinese Academy of Medical Sciences, Wuhan, China

ABSTRACT

Purpose: To describe the radiological features of coronavirus disease 19 (COVID-19) and to explore the significant signs that indicate severity of disease.

Materials and methods: We collected data retrospectively of 180 cases of COVID-19, from 15 January 2020 to 31 March 2020, from both the Wuhan Zhongnan and Beijing Ditan Hospitals, including 103 cases of mild and 77 cases of severe pneumonia. All patients had their first chest computed tomography scan within five days of symptom onset. The dandelion sign was defined by a focal ground glass opacity (GGO) with a central thickening of the airway wall, and the focal crazy paving sign was defined by a focal GGO with thickening of the interlobular septa.

Results: Consolidation presented in only 4.9% (5/103) of the mild pneumonia cases, which was significantly lower than that in severe pneumonia cases (70.1% 54/77), $p < .001$). Multifocal distribution and pure GGOs were observed more frequently in severe cases of pneumonia ($p < .05$). The dandelion sign was present in 86.4% (89/103) of the mild pneumonia cases, significantly more frequent than those with severe pneumonia (13.0% [10/77], $p < .001$). The focal crazy paving sign presented in 65.0% (67/103) of the mild pneumonia cases and was significantly more frequent than in severe cases (23.4% [18/77], $p < .001$). The hospital stay duration of the mild pneumonia group (13.6 ± 7.2 days) was significantly shorter than the severe pneumonia group (26.6 ± 11.7 days, $p < .001$)

Conclusions: Consolidation, pure GGO and multifocal distribution on a CT scan were associated with severe COVID-19. The dandelion and focal crazy paving signs indicate mild COVID-19.

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Introduction

Novel coronavirus disease 2019 (COVID-19) is caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV2). An outbreak in Wuhan China began in December 2019, which eventually became a pandemic. As a respiratory contagious disease, most patients (87.9%) affected were febrile at the time of onset[1]. Other symptoms included cough and dyspnea, and atypical symptoms such as alteration of the smell and taste, gastrointestinal symptoms, headache, and cutaneous manifestations were reported as well[2–7]. Diagnosis relies on a real-time reverse transcription polymerase chain reaction (RT-PCR) of the viral nucleic acid, or next-generation sequencing of a respiratory tract sample such as a nasopharyngeal swab, sputum or bronchoalveolar lavage[8], which takes hours, even days, to obtain results. A computed tomography[9] scan is sensitive to the pulmonary abnormalities that can arise due to COVID-19, although in 17.9% of confirmed cases no radiographic or CT abnormalities were found[1]. Published descriptive studies have shown that bilateral and peripheral ground-glass opacities (GGOs) and consolidation were the major forms of pulmonary involvement, and were considered a "hallmark" of COVID-19[10]. Some patients have presented with an organized pneumonia pattern[10], such as patchy consolidation with an air bronchogram and reversed halo sign[11,12]. However, the descriptions of CT findings are still non-specific and the pathological correspondence between the CT findings and COVID-19 remains rare due to the lack of autopsies, and the only full autopsy reported diffused alveolar damage[13].

Studies have shown a diverse ratio in the number of severe cases, as a result of different definitions of disease severity and because hospital wards in Wuhan were deficient in the early stage of this epidemic situation. The first three cohort studies on COVID-19, from different single centers[5,14,15], showed that 15.9–29% of patients were complicated with acute respiratory distress syndrome (ARDS), 17–23.2% of patients were on mechanical ventilators, 3% were on extracorporeal membrane oxygenation, and that

CONTACT Bing Liu bingliu@whu.edu.cn; Zhenshun Cheng chzs1990@163.com Department of Pulmonary and Critical Care Medicine, Zhongnan Hospital of Wuhan University, Wuhan, China Wuhan Research Center for Infectious Diseases and Cancer, Chinese Academy of Medical Sciences, Wuhan, China
*Both these authors have contributed equally to this manuscript.

mortality was reported to be between 4.3% and 15%. Another multicenter cohort that included 1099 cases showed that 5.0% of patients were admitted to the intensive care unit and 2.3% underwent invasive mechanical ventilation[1]. CT scans should be utilized as a helpful tool to recognize suspected cases of COVID-19 and evaluate the severity of illness. We reviewed 180 cases of COVID-19 from both the Wuhan Zhongnan and Beijing Ditan Hospitals to explore any significant signs for diagnosis and indication of disease severity.

Methods

This study was approved by the Clinical/Scientific Research Projects under the Medical Ethics Committee, Zhongnan Hospital of Wuhan University, No. 2020085 K. Consent forms from patients were waived.

Data were retrospectively collected from 180 adult COVID-19 cases, confirmed by a positive RT-PCR assay of a nasopharyngeal swab or sputum sample according to the World Health Organization (WHO) criteria[8], from 15 January 2020 to 31 March 2020, from both the Wuhan Zhongnan and Beijing Ditan Hospitals. The exclusion criteria included no abnormalities present on a CT scan and the time interval between the onset of symptoms and the first CT scan being more than five days. Data including age, gender, symptoms, laboratory tests, comorbidities and duration of hospital stay were collected from the Electronic Medical Record system. In the present study, a history of chronic obstructive pulmonary disease (COPD), coronary artery disease[9], hypertension, diabetes, chronic kidney disease (CKD) or receiving immunosuppressive medications were included in a comorbidities chart. The 180 patients with confirmed COVID-19 were divided into two groups, mild pneumonia and severe pneumonia, based on the criteria provided by the Chinese National Health Commission[16]: mild disease including non-pneumonia or mild pneumonia (mild symptoms without dyspnea; respiratory frequency $<$30/min; blood oxygen saturation [SpO_2] $>$ 93%; PaO_2/FiO_2 ratio $\geq$300 mmHg); severe pneumonia including dyspnea, respiratory frequency $\geq$30/min, $SpO_2 \leq$ 93%, PaO_2/FiO_2 ratio $<$300 mmHg and/or lung infiltrates $>$50% within 24–48 h (in our cohort, chest X-ray was never performed at admission and therefore this last criterion was not applied in our study).

CT image acquisition

All patients had their CT scans in the supine position; images were taken from the upper thoracic inlet to the inferior costophrenic level, using either a 64 row multidetector scanner (GE, USA) or a 16 row multidetector scanner (Siemens, Germany) with the following parameters: voltage of 120 kV, the milliamperage adjusted automatically to each patient, 5 mm collimation, 0.625 pitch, a sharp kernel (B80f), reconstruction matrix of 512*512, reconstruction slice thickness of 1.25 mm, and a high spatial resolution algorithm.

Image interpretation

All of the patients had more than one CT scan; however, only the first CT scans were included in our study. Two radiologists from Wuhan Zhongnan Hospital with 13 years of experience interpreted the scans. They evaluated all of the scans without knowing any of the laboratory test results or classification of pneumonia severity. The two radiologists read each scan together and a consensus was determined for all of their interpretations after a discussion. The CT scans of each patient were evaluated for the following characteristics: (1) presence of GGOs, (2) presence of consolidation, (3) the number of segments affected where either ground-glass or consolidative opacities were present, (4) airway abnormalities (including airway wall thickening and bronchiectasis), (5) presence of nodules, (6) presence of a pleural effusion, (7) presence of thoracic lymphadenopathy (defined as a lymph node size of $\geq$10 mm in the short-axis dimension).

Dandelion sign

We observed that most of the GGOs that presented in our cohort of patients always had a linear opacity, as a result of thickening of the small airway wall, and we named this focal GGO with a central linear opacity as the dandelion sign (Figures 1–3).

Focal crazy paving sign

Most of the focal GGOs in our cohort were with the thickening of the interlobular septa, and often focally (solitary or multifocal), subpleural or peripherally distributed, which we named the focal crazy paving sign (Figures 3–5).

Reversed halo sign

This sign was defined as a central opacity surrounded by a ring-shaped consolidation[17] (Figure 6).

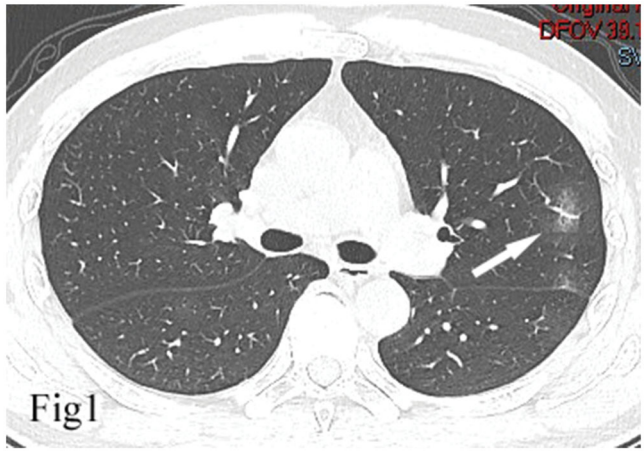

Figure 1. A 39 year old male patient diagnosed with mild COVID-19, with a chief complaint of "febrile for two days". The CT showed a focal GGO with a central thickening of airway wall (white arrow), which we named as dandelion sign.

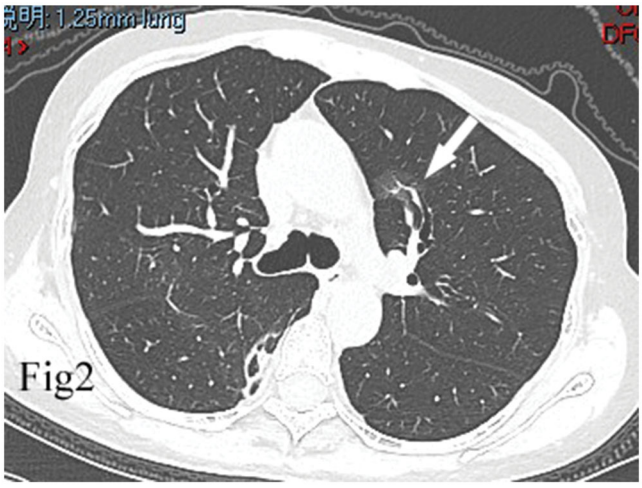

Figure 2. A 62 year old male patient diagnosed with mild COVID-19, with a chief complaint of "febrile for three days, cough for one day". The CT showed a focal GGO with a central thickening of airway wall (white arrow), which we named as dandelion sign.

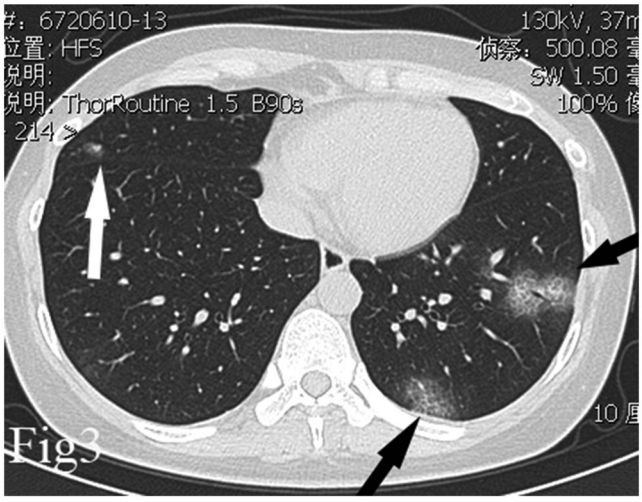

Figure 3. A 32 year old female patient diagnosed with mild COVID-19, with a chief complaint of "headache for two days". The CT showed focal GGOs with a central thickening of airway wall (white arrow) on the right middle lobe, which we named as dandelion sign, and focal GGO with thickening interlobular septa (black arrows) on the left lower lobe, which we named as focal crazy paving sign.

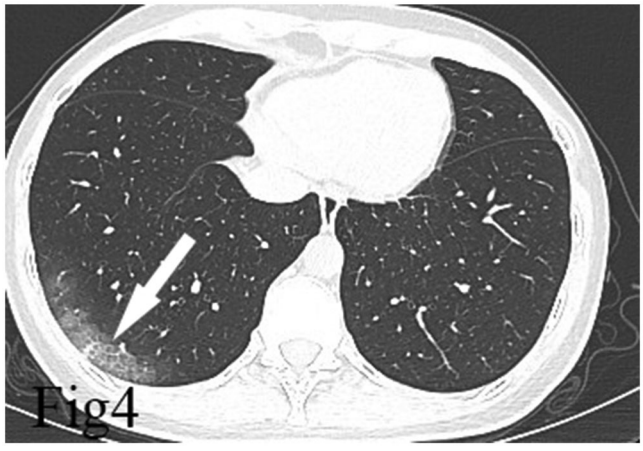

Figure 4. A 32 year old female patient diagnosed with mild COVID-19, with a chief complaint of "fever for four days and coughing for two days". The CT showed a focal GGO with interlobular septa thickening (white arrows) on the right lower lobe, which we named as focal crazy paving sign.

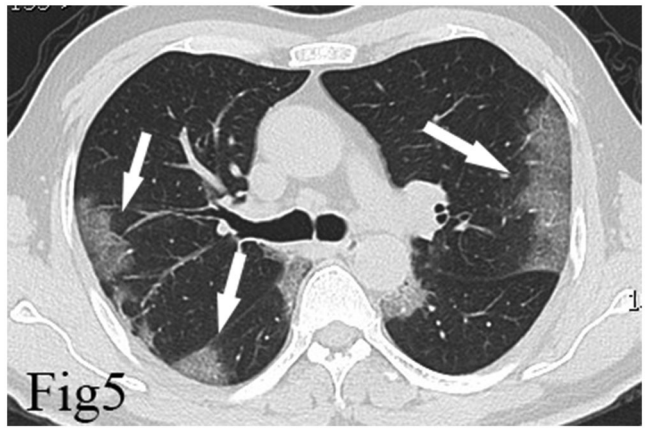

Figure 5. A 58 year old male patient diagnosed with mild COVID-19, with a chief complaint of "febrile and coughing for three days". The CT showed focal GGOs with interlobular septa thickening (white arrows) bilaterally, which we named as focal crazy paving sign.

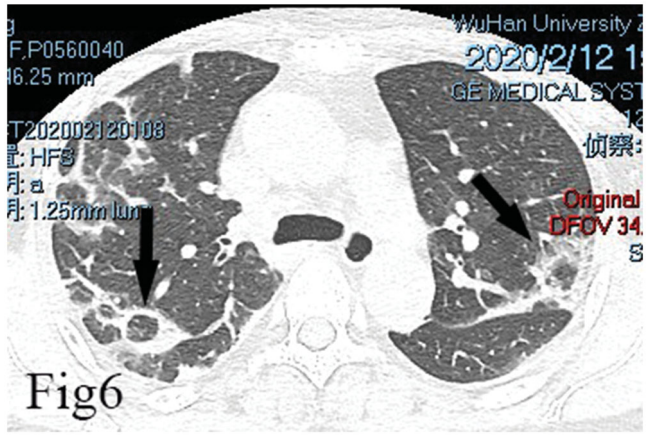

Figure 6. A 58 year old male patient diagnosed with mild COVID-19, with a chief complaint of "febrile and coughing for four days, shortness of breath for two days". The CT showed reversed halo sign (black arrows) bilaterally.

Statistical analysis

Continuous data were presented as mean ± SD and differences between groups were performed with Student's *t* test. Non-continuous data were presented as percentages and the differences between groups were performed with the χ^2 test. Statistical analyses were performed using Statistical Package for the Social Sciences (SPSS) 17.0 software (SPSS Statistics for Windows, Version 17.0. Chicago: SPSS Inc.). All probabilities were two tailed and p values $<.05$ were regarded as significant.

Results

General characteristics

One hundred and eighty patients were included in this study. The mean time between symptoms onset and the first CT result was 2.9 ± 0.8 days. Of the 180 cases, symptoms included fever (153 [85%]), cough (139 [77.2%]), shortness of breath (92 [51.1%]), diarrhea (7 [3.9%]) and headache (2 [1%]). All patients were discharged after treatment with a mean hospital duration stay of 18.6 ± 9.3 days.

The mean age in the mild pneumonia group was 45.2 ± 12.9 years, which was significantly lower than the severe pneumonia group with a mean age of 62.1 ± 14.9 years ($p < .001$). There was no significant difference in the gender distribution between the two groups ($p = .085$). The hospital stay duration of the mild pneumonia group (13.6 ± 7.2 days) was significantly shorter than the severe pneumonia group (26.6 ± 11.7 days, $p < .001$), and the incidence of comorbidities was significantly lower in the mild pneumonia group (11.7%) than that in the severe pneumonia group (37.6%, $p = .007$). One patient in the mild pneumonia group and 10 patients in the severe pneumonia group had ≥3 comorbidities. All patients in the mild pneumonia group survived, and three patients progressed to ARDS and died in the severe pneumonia group. The demographic features are shown in Table 1.

Radiological findings

GGOs and consolidation were found in 155 (86.1%) and 72 (40%) cases respectively, and were the most frequently seen CT scan abnormalities in our study. No pulmonary segments were free from being affected. The GGOs seen on the CT scans of COVID-19 patients present as focal GGOs with thickening of the airway wall, or with thickening of the interlobular septa, and we named them the dandelion sign (Figures 1–3) and focal crazy paving sign (Figures 3–5), respectively.

Dandelion sign

The dandelion sign was present in 86.4% (89/103) of the mild cases of pneumonia and in 13.0% (10/77) of the severe cases, with a significant difference of $p < .001$.

Focal crazy paving sign

The focal crazy paving sign was present in 65% (67/103) of the mild pneumonia cases and in 23.4% (18/77) of the severe cases, a significant difference of $p < .001$.

The reversed halo sign was present in three (3%) cases in the mild pneumonia group and in none of the severe pneumonia group. There was no significant difference in the frequency of the reversed halo sign between the two groups ($p = .357$).

Consolidation was present in only 4.9% (5/103) of the mild pneumonia cases, which was significantly lower than that of the severe cases (70.1% [54/77], $p < .017$). Patchy consolidation with air bronchograms was significantly more frequent in the severe pneumonia group (55.8% [43/77]) than in the mild group (17.5% [18/103], $p < .001$). The severe group had a significantly higher number of pulmonary segments involved (12.5 ± 4.1) than that of the mild group (3.9 ± 2.1, $p < .001$). The presence of pure GGOs without airway wall thickening or interlobular septa thickening was significantly less frequent in the mild pneumonia group (16.5% [17/103]) than in the severe group (37.7% [29/77], $p = .002$). A multifocal distribution (≥3 focal zones) pattern was significantly more prevalent in the severe pneumonia group (100% [77/77]) than in the mild group (23.3% [24/103], $p < .001$). Both the mild and severe pneumonia groups had a peripheral/subpleural distribution pattern. Nodules, pleural effusion and thoracic lymphadenopathy were absent in this cohort.

The radiological findings of the 180 patients participating in this study are shown in Table 2.

Table 1. The demographic features of 180 cases.

	Mild pneumonia $n = 103$	Severe pneumonia $n = 77$	p
Age	45.2 ± 12.9	62.1 ± 14.9	<.001
Gender			
Female	56 (54.4%)	31 (40.3%)	.085
Male	47 (45.6)	46 (59.7%)	
Hospital stay (days)	13.6 ± 7.2	26.6 ± 11.7	<.001
Comorbidities (%)	12 (11.7%)	29 (37.6%)	.007
COPD	3 (2.9%)	10 (13.0%)	.405
CAD	3 (2.9%)	8 (10.4%)	.010
Hypertension	6 (5.8%)	6 (7.8%)	.038
Diabetes	2 (1.9%)	7 (9.1%)	.601
CKD	0 (0%)	2 (2.6%)	.029
Under immunosuppressive therapy	0 (0%)	3 (3.9%)	.100

Abbreviations. COPD, Chronic obstructive pulmonary disease; CAD, Coronary artery disease; CKD, Chronic kidney disease.

Table 2. The radiological findings of the 180 cases.

	Mild pneumonia $n = 103$	Severe pneumonia $n = 77$	p
Dandelion sign	89 (86.4%)	10 (13.0%)	<.001
Focal crazy paving sign	67 (65.0%)	18 (23.4%)	<.001
Reversed halo sign	3 (3%)	0	.357
Crazy paving (diffused crazy paving)	0	10 (13.0%)	<.001
Pure GGO	17 (16.5%)	29 (37.7%)	.002
Consolidation	5 (4.9%)	54 (70.1%)	<.001
Patchy consolidation with bronchogram	18 (17.5%)	43 (55.8%)	<.001
Number of pulmonary segments involved	3.9 ± 2.1	12.5 ± 4.1	<.001
Multifocal distribution	24 (23.3%)	77 (100%)	<.001
Peripheral/subpleural distribution	98 (95.1%)	67 (87.0%)	.09

Abbreviation. GGO, Ground glass opacity.

Discussion

In our study of coronavirus disease, GGOs and consolidation were the most frequently seen CT scan abnormalities, similar to previous studies[11,18,19]. Consolidation, pure GGO and multifocal distribution were observed more frequently in severe cases of pneumonia, and the dandelion sign and focal crazy paving sign presented significantly more frequent in mild cases, which could be used as an evaluation tool of disease severity of COVID-19. Since the outbreak of COVID-19, CT imaging has been discussed in different cohort studies. Due to the high false negative rate of RT-PCR of respiratory tract specimens, the initial CT scan is considered very important in Chinese practice. In a cohort that included 51 patients with confirmed COVID-19, the sensitivity of the first CT scan was 98% (50/51), which was a significantly higher sensitivity than the first viral nucleic acid assays (98% vs. 71%, $p < .001$)[20]. In another cohort study, the sensitivity of chest CT scans at indicating COVID-19 was 97% (580/601) based on a positive RT-PCR result[21].

With the high sensitivity and availability of CT scans, they have been utilized for most COVID-19 patients, unless they are too weak to lay in the CT scanner. Many studies have reported GGOs and consolidation to be the major pulmonary abnormalities, with a peripheral distribution pattern in patients with COVID-19[11,19,22].GGOs and consolidation were found in 155 (86.1%) and 72 (40%) cases respectively in our cohort, and were the most frequently seen CT scan abnormalities in our study, similar to previous studies[11,18,19]. A study investigating the initial stages of infection showed that GGOs presented in 57% (12/21) of cases and consolidation in 29% (6/21) of cases, two or more lobes were involved in 71% (15/21) of cases, and there was bilateral involvement in 76% (16/21) of cases[19]. Nodules, cavities, pleural effusions and lymphadenopathy were absent in this cohort of 21 confirmed COVID-19 cases. A different cohort study involving 81 cases showed that the predominant pattern of abnormality observed in the lungs of patients with COVID-19 was GGOs (65%) which presented bilaterally (79%), peripherally (54%), ill-defined (81%) and with right lower lobe involvement (27%), and consolidation presented with a mixed pattern of GGOs in 40% of patients[23]. GGOs could be solitary or multifocal[11,24]. In the second week after the onset of symptoms, GGOs decrease and consolidation becomes the second most common pattern of abnormality[23].

The dandelion sign was named to distinguish it from pure GGOs. When reviewing the published papers on COVID-19 CT imaging, the linear opacity was actually in some cases reported as a GGO[25,26]. In our study, the dandelion sign was seen significantly more often in the patients with mild pneumonia compared to those with severe pneumonia, suggesting that this abnormality might indicate a mild disease and therefore a better prognosis.

The focal crazy paving sign was named to distinguish it from the classic crazy paving pattern. A crazy paving pattern is not a specific sign but it does present in many different pulmonary diseases such as pulmonary alveolar proteinosis (PAP), pulmonary edema, lipoid pneumonia, *Pneumocystis jiroveci* pneumonia[27] and in cytomegalovirus pneumonia[28], another type of viral infection that often affects immunocompromised individuals. It is expected that a relatively specific chest CT sign will be detected that indicates the presence of COVID-19, and in this study we used the term "focal crazy paving" sign for this indicator, which was observed more often in the patients with mild pneumonia compared to those with severe pneumonia in our cohort. Therefore, the focal crazy paving sign might indicate a mild form of the disease. More studies are needed to test the feasibility and specificity of this chest CT sign.

The presence of the reversed halo sign in COVID-19 patients has been previously reported[11,18] and similarly was also detected in our cohort. The reversed halo sign presents in different pulmonary diseases[17] including H1N1 pneumonia[29], another type of seasonal epidemic viral disease. The reversed halo sign in our cohort was only detected in the mild pneumonia cases and not in the severe cases, yet statistics showed no significant difference between the two groups.

The dynamic evolution of chest CT findings during the course of a COVID-19 infection has been studied. In a cohort of 63 cases, the initial CT findings progressed from a single GGO that increased in size and consolidated to an enlarged fibrous strip and enlarged solid nodules on a re-examination CT 14 days later, in 85.7% of the patients[30]. Different time intervals between the onset of symptoms and the initial CT scan may have influenced the pulmonary involvement patterns. The frequency of GGOs was far lower in the patients with COVID-19 if they received a CT scan within two days after symptom onset, compared with those who had a CT scan three or more days after the onset of symptoms[18]. The GGOs were gradually absorbed over approximately two weeks[19,22]. Present studies suggest that chest CT findings from those with COVID-19 change rapidly with time[30], and patients participating in other retrospective imaging studies were grouped according to the time interval between symptom onset and their first CT scan[3]. The patients who had the first CT scan performed over 2–3 weeks after symptom onset had the highest number of pulmonary segments affected[17]. In our study, all the patients that were enrolled had their first CT scan within five days of symptom onset, and only the first CT scans were used for interpretation to limit heterogeneity. Our study was retrospective, and the sample size was relatively small. However, the dandelion and focal crazy paving signs represented a distinct GGO pattern in the lungs of COVID-19 patients. The presence of these signs indicated a mild disease. More studies are needed to determine whether the dandelion and focal crazy paving signs are present in the wider population of patients with mild pneumonia related to COVID-19, and further explore the specific radiological features of this unprecedented disease.

Conclusions

The dandelion and focal crazy paving signs indicate mild COVID-19. Consolidation, pure GGO and multifocal distribution on a CT scan were associated with severe COVID-19.

Lung CT scan can be a useful tool to evaluate severity at the beginning of the coronavirus disease.

Transparency

Declaration of funding

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Declaration of financial/other relationships

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