Volume 18, No 2 | International Journal of Radiation Research, April 2020

Chest high-resolution computed tomography imaging findings of coronavirus disease 2019 (Covid-19) pneumonia

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► ***Original article***

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Revised: March 2020
Accepted: March 2020

Int. J. Radiat. Res., April 2020; 18(2): 343-349

DOI: 10.18869/acadpub.ijrr.18.2.343

ABSTRACT

Background: We aimed to investigate the chest high-resolution computed tomography (HRCT) imaging manifestations of patients with coronavirus disease 2019 (COVID-19) pneumonia. ***Materials and Methods:*** Chest HRCT images of 12 patients who were diagnosed as COVID-19 pneumonia in our institute from January 28, 2020 to February 16, 2020 were retrospectively reviewed. ***Results:*** The most typical HRCT findings were bilateral pulmonary parenchymal ground-glass opacities, with or without consolidation in the lung periphery, and sometimes also showed a rounded morphology. Three (25%) patients had typical crazy paving signs, 3 (25%) patients showed air bronchogram, 2 (16.67%) patients with bronchial wall thickening signs, and 5 (41.67%) patients had vascular perforator signs. Only one (8.33%) patient had unilateral involvement in the left upper lobe. Lung cavitation, pleural effusions and intrathoracic lymph node enlargement were not found in all patients. The severity of the lesions in the right lung, and in the lower lobe were worsen than those in the left lung and upper lobe, respectively. Lesions in the lateroposterior zone of the lung were more common than those in the apical and central areas. Notably, 9 (75%) patients with chest HRCT findings related to COVID-19 pneumonia had negative results of concurrent nucleic acid tests. ***Conclusion:*** Chest HRCT can provide an important basis for early clinical diagnosis of COVID-19 pneumonia, and help subsequent intervention for the patients to stop further transmission, especially consider that the mild clinical symptoms and the initial negative results of nucleic acid tests of these patients are common.

Keywords: *COVID-19 pneumonia, chest CT, tomography, X-ray computed.*

INTRODUCTION

In December 2019, an unexplained pneumonia outbreak was noticed in Wuhan, then was known the pathogen is a new coronavirus, which further was named as SARS-CoV-2, and the disease was named as coronavirus disease 2019 (COVID-19) [1]. COVID-19 has spread in mainland China firstly, and rapidly spread to many countries worldwide. Therefore, the World Health Organization (WHO) declared the COVID-19 outbreak as a Public Health Emergency of International Concern (PHEIC) [2]. Wu *et al.* reported that the basic reproduction number of COVID-19 was estimated to be 2.68, which means that one infected patient may lead to more than 2 new patients [3]. Similar estimated reproduction numbers were shown in severe acute respiratory syndrome (SARS) and middle east respiratory syndrome (MERS), ranged within 2 to 5 and 2.7 to 3.9, respectively [3,4]. However, the mortality of COVID-19 is lower than that of SARS and MERS [5].

According to the sixth edition of COVID-19 pneumonia diagnosis and treatment guideline

[DOI: 10.18869/acadpub.ijrr.18.2.343]

issued by China National Health Commission [6], specific onset symptoms, epidemic characteristics, clinical features, computed tomography (CT) findings, and the results of SARS-CoV-2 nucleic acid test can substantially help the diagnosis of COVID-19 pneumonia. The definitive diagnosis of SARS-CoV-2 infection is based on the results of reverse-transcription polymerase chain reaction (RT-PCR) because of the high specificity, however, the results of RT-PCR test for SARS-CoV-2 may be falsely negative due to laboratory error or insufficient viral loads in the specimen, and this test is time-consuming. False-negative RT-PCR test results may delay the diagnosis and the quarantine of the patients with COVID-19 pneumonia, and increase the risk of infection in the surrounding population. Therefore, to improve the disease control, we retrospectively analyzed the high-resolution computed tomography (HRCT) imaging findings of patients with COVID-19 pneumonia, aimed to speedy early clinical diagnosis and facilitate the processes of the quarantine and treatment as soon as possible.

MATERIALS AND METHODS

Patients

This study was approved by the Ethics of Committees of Cangzhou Central Hospital, the patients' informed consents were waived because of the retrospective design. From January 28, 2020 to February 16, 2020, totally 12 patients with COVID-19 pneumonia who attended to Cangzhou Central Hospital due to fever, fatigue, or respiratory symptoms were identified. Inclusion criteria: (1) those were diagnosed according to Diagnosis and Treatment of Novel Coronavirus Pneumonia (trial sixth edition) which is issued by China National Health Commission [6]; (2) those who had no artifacts in the chest HRCT images for the first time since the onset of the disease. All patients underwent hematological and biochemical blood tests, including white blood cell count, lymphocyte count and hypersensitive C-reactive protein. HRCT images, demographic and clinical data of the 12 patients were retrospectively reviewed and analyzed.

Imaging techniques

All patients were scanned without contrast medium using a GE BrightSpeed 16-slice spiral CT. Scanning parameters: tube voltage 120 kV, tube current 90-180 mAs, slice thickness 10 mm, slice interval 10 mm, field of view 500×500 mm, matrix size 512×512, and a 1.25-mm high-resolution algorithm to reconstruct the lung window. The scan area ranged from the thoracic portal to the base of the lung.

Image analysis and statistics

Two fellowship-trained cardio-thoracic radiologists with approximately 5 years of experience independently reviewed the HRCT images. If the opinions were discrepant, they discussed for consensus. The HRCT images were evaluated for the following characteristics [7]: (1) 4 types of the lesion distributions, including the involved region: unilateral or bilateral; the transverse distribution: central, peripheral, or no transverse predilection; the craniocaudal distribution: upper lung predominant, lower lung predominant, or no craniocaudal predilection; and the scattering distribution: 1, 2 and ≥3 lesions [8]; (2) lesion morphology: nodular, ground-glass opacities (GGO), consolidation, mixed GGO and consolidation, linear opacities, crazy paving sign, air bronchogram, bronchial wall thickening sign, or vascular perforator sign; (3) extra-pulmonary manifestations: intrathoracic lymph node enlargement and pleural effusions.

RESULTS

Demographic and clinical characteristics of patients with COVID-19 pneumonia

Table 1 listed the demographic and clinical characteristics of the patients. Among the 12 patients, 6 were male and the mean age was 47.75 ± 15.81 ranged from 22 to 74 years old. Five (41.67%) patients had underlying diseases,

[DOI: 10.18869/acadpub.ijrr.18.2.343]

including diabetes mellitus (16.67%), hypertension and coronary heart disease (8.33%), and cirrhosis (16.67%). All 12 patients had exposure history with the individuals from the major epidemic area, 5 patients contacted with their familial clusters. For the symptoms, 10 (83.33%) patients had fever (ranged from 37.5 °C to 39.3 °C), one (8.33%) patient had diarrhea, one (8.33%) patient had dry mouth, 7 (58.33%) patients had cough, 4 (33.33%) patients had expectoration, 3 (25%) patients had fatigue, and 3 (25%) patients had chest tightness. White blood cell count decreased in 2 (16.67%) patients, lymphocyte ratio decreased in 8 (66.67%) patients, and hypersensitive C-reactive protein increased in 11 (91.67%) patients. Furthermore, 9 patients (75%) had negative results of initial nucleic acid tests.

Table 1. Demographic and clinical characteristics of 12 patients.

Parameter	Value
Sex	
Men	6 (50)
Women	6 (50)
Age (year)	
Mean	47.75
Standard deviation	15.81
Range	22-74
Exposure history	
Direct or Indirect Exposure	12 (100)
Symptoms	
Fever	10 (83.33)
Dry mouth	1 (8.33)
Diarrhea	1(8.33)
Cough	7 (58.33)
Expectoration	4(33.33)
Chest tightness	3(25)
Fatigue	3 (25)
No obvious symptoms	1 (8.33)
Underlying disease	
Diabetes mellitus	2 (16.67)
Hypertension and coronary heart disease	1(8.33)
Cirrhosis	2(16.67)

Note: Except where indicated, data are numbers of patients, with percentages in parentheses.

Early and progressive HRCT manifestations

All the imaging results were summarized in table 2.

Table 2. CT findings of 12 patients with COVID-19 pneumonia.

	All Patients
CT findings	
GGO	5 (41.67)
Consolidation	0(0)
Mixed GGO and consolidation	5 (41.67)
Bronchial wall thickening	2 (16.67)
Crazy paving sign	3 (25)
Air bronchogram	3 (25)
Vascular perforator sign	5 (41.67)
Intrathoracic lymph node enlargement	0 (0)
Pleural effusions	0 (0)
Right/Left distribution	
Right lung predominant	7 (58.33)
Left lung predominant	2 (16.67)
Equivalent in both lung	3 (25)
Craniocaudal distribution	
Upper lung predominant	4 (33.33)
Lower lung predominant	7 (58.33)
No craniocaudal predilection	1(8.33)
Transverse distribution	
Central	0 (0)
Peripheral	6 (50)
No transverse predilection	6 (50)
Lung region distribution	
Unilateral	1 (8.33)
Bilateral	11 (91.67)
Scattering distribution	
1	0 (0)
2	1 (8.33)
≥3	11 (91.67)

Lesion distributions

Unilateral lung involvement was found in one (8.33%) patient, located in the upper lobe of the left lung, while bilateral lung involvement was found in 11(91.67%) patients. Peripheral distribution was observed in 6 (50%) patients, central distribution was not found in any of the 12 patients, and no transverse predilection was

[DOI: 10.18869/acadpub.ijrr.18.2.343]

found in 6 (50%) patients. Furthermore, lower lung predominant was found in 7 (58.33%) patients, upper lung predominant was found in 4 (33.33%) patients, and no craniocaudal predilection was found in one (8.33%) patient. In addition, 7 (58.33%) patients had a larger area of the lesions in the right lung, compared to those in the left lung, while in 3 (25%) patients, the areas of 2 sides were roughly equivalent. Moreover, no patient had only one lesion, one (8.33%) patient had 2 and 11(91.67%) patients had ≥3 lesions.

Lesion morphology

The lesion boundary was blurred in 9 (75%) patients and clear in 3 (25%) patients. Five (41.67%) patients had GGO in the subpleural lobular, which was rounded as rosa roxbunghii sign (figure 1), wedge-shaped, or fan-shaped, and the major diameter was approximately parallel to the pleura, and perpendicular to the bronchovascular bundles. The faint GGO in 2 patients were cloud-like and circumscribed (figure 2). A typical crazy paving sign with vascular enlargement was found in 3 patients (figure 3), with slightly higher density and more uniform. Five (41.67%) patients had mixed GGO and local consolidation opacity. One (8.33%) patient had small nodules, while one (8.33%) patient had linear opacities. Furthermore, 3 (25%) patients had air bronchograms, 2 (16.67%) patients had bronchial wall thickening signs (figure 3), and 5 (41.67%) patients had vascular perforator signs (figure 4).

Extra-pulmonary manifestations

None of the 12 COVID-19 pneumonia patients had pleural effusions or intrathoracic lymph node enlargement.

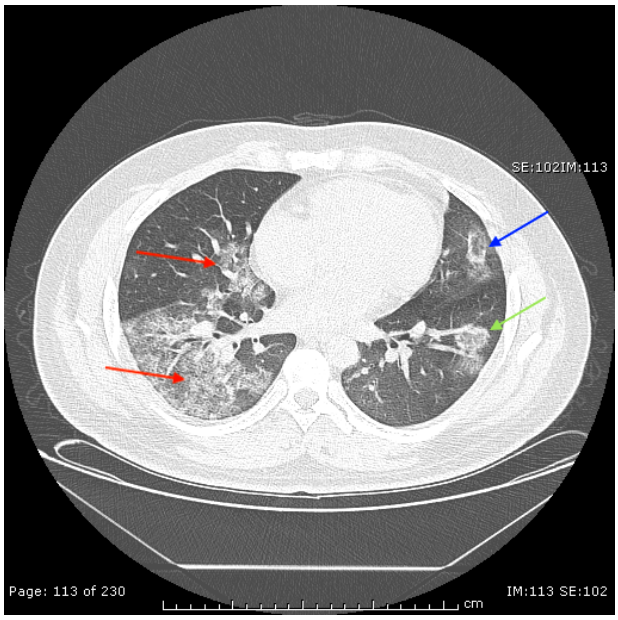

Figure 1. A 30-year-old man presented with fever, cough, expectoration and chill
Axial HRCT image shows bilateral multiple patchy ground-glass opacities and minimal consolidation with a central and peripheral distribution (red arrow), with a rounded morphology in the left lower lobe ("rosa roxbunghii" sign, green arrow), and also an area of faint ground-glass opacities in the left upper lobe with a ring of denser consolidation ("reverse halo" sign, blue arrow).

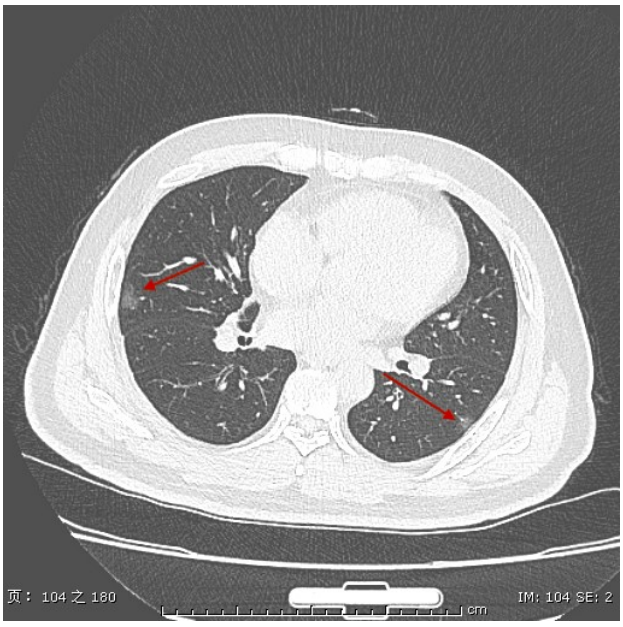

Figure 2. A 50-year-old man presented with fever and chest tightness
Axial CT image shows multiple ground-glass opacities in the lateral segment of right middle lobe and left lower lobe (arrows).

[DOI: 10.18869/acadpub.ijrr.18.2.343]

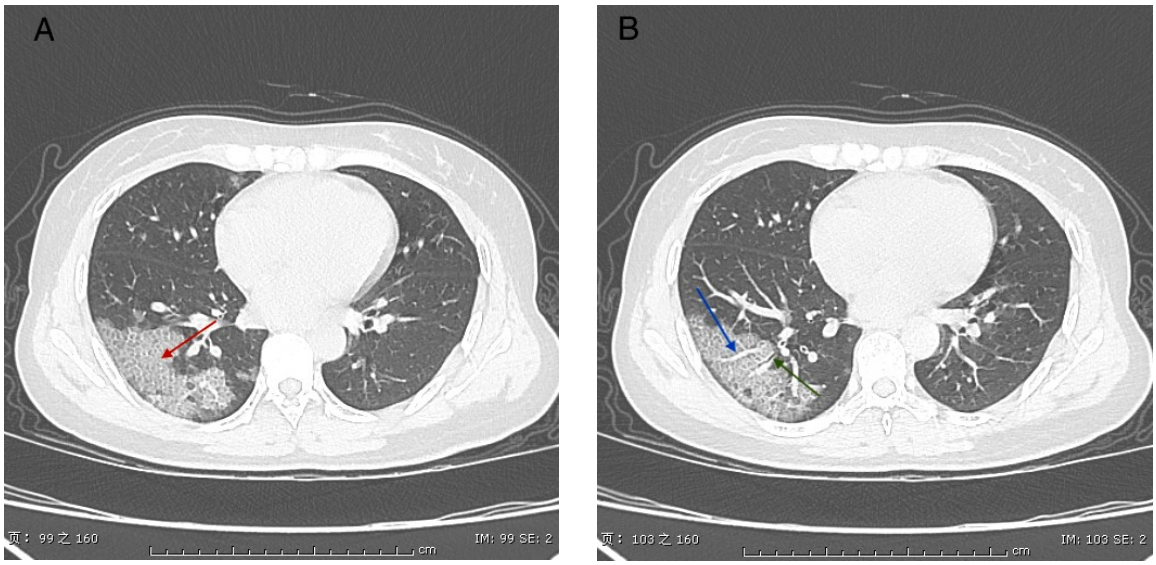

Figure 3. A 39-year-old woman who presented with fever, cough, fatigue and myalgias
Axial HRCT images show a typical crazy paving sign as manifested by right lower lobe ground. **(A)** Glass opacities is shown with interlobular septal thickening (red arrow). **(B)** Air bronchogram, bronchial wall thickening (green arrow) and vascular enlargement (blue arrow) are also found in this patient.

Figure 4. A 50-year-old man presented with fever
Sagittal HRCT image shows ground glass opacities in the posterior and inferior segment of left lower lobe with vascular enlargement (red arrow).

DISCUSSION

SARS-CoV-2 is highly infectious [9], has an incubation period and the early symptoms of this infection are not typical. Early diagnosis is conducive to timely quarantine and treatment, in order to prevent the continuous transmission of the virus to healthy people. The diagnosis of COVID-19 pneumonia mainly depends on the comprehensive approaches of the epidemiological data, clinical manifestations, medical imaging, and laboratory data. The gold standard of diagnosis is the positive result of nucleic acid tests or high homology of the alignment of viral gene sequencing data. At present, the nucleic acid tests remain the modality for the diagnosis with the highest specificity, however, the sensitivity is low, and

[DOI: 10.18869/acadpub.ijrr.18.2.343]

the waiting time for the result is long. Chest CT examination is fast, highly sensitive to lung lesions, and free from interference of extra-pulmonary structures. Therefore, it is the conventional preferred imaging method for COVID-19 pneumonia screening, diagnosis, and severity evaluation of the disease course.

The epidemic situation in Cangzhou was mainly imported. In the present study, all patients had obvious history of population aggregation, had history of the exposure with the individuals from the epidemic area and 5 patients were exposed with their familial clusters. Furthermore, the virulence of this virus in our city may be relatively weak, since the disease severity of our patients were mainly mild to moderate, and patients with severe disease were rare. Notably, 9 (75%) patients had negative results of initial nucleic acid tests. For the present symptoms, 10 (91.67%) of our patients had fever, one (8.33%) patient had diarrhea, and one (8.33%) patient had dry mouth. These suggests that fever may be the most important sign for the clinical pre-examination and triage of COVID-19 pneumonia [10]. However, it has been reported that even the portion is small, some patients with COVID-19 pneumonia may present non-respiratory symptoms [11], and these patients may be miss-diagnosed or be misdiagnosed. Therefore, under current epidemiological conditions, the physicians in the front line must be very vigilant, and arrange chest HRCT imaging and virological testing in time.

For these 12 COVID-19 pneumonia patients, most of the pulmonary lesions involved bilaterally with multiple lung lobes, with a predominant distribution in the lower and peripheral part of the lungs, but this rarely involved unilaterally. These lesions were mainly distributed in the bilateral subpleural and basilar lung regions, because these were blocked by the pleural surface, and progressed along the pleural surface. Mainly the diameter of the lesions was approximately parallel to the pleura, and perpendicular to the bronchovascular bundles. These lesions were mainly involved in the right lung and lower lung, may because the right inferior lobar bronchus is relatively thick and short and allows the virus more easily enter. Viruses in the same family share a similar pathogenesis and presentation, peripheral predominance lung involvement has also been observed in patients with SARS and MERS [10,11]. A study has revealed that H7N9 pneumonia has a predominant distribution in the right lower lung [12]. In addition, Koo *et al.* also reported that viral pneumonia tends to attach to the lower lung [13]. The lower and peripheral lung predominant distribution is very conspicuous at the first glance of the images. However, we have to acknowledge that the important features of the CT images of patients with different viral pneumonia may similar and hard to differentiate, so comprehensive consideration of the exposure history, epidemiological data with HRCT results for the establishment of the diagnosis is very important. From our finding, multifocal lesions, no pleural effusions or intrathoracic lymph node enlargement may be the specific signs of COVID-19 pneumonia in the results of HRCT imaging. These 12 COVID-19 pneumonia patients were in the early and progressive stages of the disease. The most common HRCT findings were pure GGO, GGO with interlobular septal thickening, and mixed GGO with consolidation, while no complete consolidation was found in our patients. Furthermore, we also found nodules, including solid nodules and solid nodules surrounded by a halo and linear opacities in some patients. Each patient may have two or more types of opacity lesions, but the majority of the lesions were GGO. Studies have reported that COVID-19 pneumonia is a viral interstitial pneumonia, and the early stage of pathogenesis is type II alveolar epithelial cell injury, edema, proteinaceous exudate, and focal hyperplasia of pneumocytes with only patchy inflammatory cellular infiltration, which all presented by GGO on HRCT results [12-15]. With the further thickening of the reticular and/or interlobular septa might be shown, the density of the GGO would increase, typical crazy paving signs may appear, and local vascular congestion swelling could be observed in some lesions. Also, the air bronchogram and bronchial wall thickening signs could be

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observed. The pathogenesis is considered as the virus invades the epithelial cells, causes bronchial wall inflammatory thickening and swelling, without blocking the bronchioles. None of the 12 patients had intrathoracic lymph node enlargement or pleural effusion, however, Huang *et al.* reported that pleural effusion may be an indication of severe COVID-19 pneumonia [16], further study is required for the clarification of the discrepancy.

In conclusion, the transmission of COVID-19 pneumonia mainly due to familial clustering. Clinical symptoms of our patients were relatively mild, and the most common HRCT finding was bilateral pulmonary GGO, with or without consolidation in the lung periphery but no pleural effusions or intrathoracic lymph node enlargement. Chest CT scans should be used for comprehensive evaluation, combined with the results of nucleic acid tests and the epidemiological data. In the context of typical clinical presentation and the exposure history to patients with COVID-19 pneumonia, in addition to the present of the HRCT features we reported in the present study, the patients may be strongly suspicious have SARS-CoV-2 infection, regardless of the RT-PCR results. HRCT imaging plays a vital role in the early clinical detection and diagnosis of COVID-19 pneumonia, and can be considered as a clinical diagnostic modality. Due to the short period of time, limited cases, lack of understanding, we believe that further in-depth studies and discussions are needed absolutely.

***Conflicts of interest*:** *Declared none.*

REFERENCES

1. Chen N, Zhou M, Dong X, Qu JM, Gong FY, Han Y, *et al.* (2020) Epidemiological and clinical characteristics of 99 cases of 2019 novel coronavirus pneumonia in Wuhan, China: a descriptive study. *Lancet,* ***395(10223)****:507-513*.
2. WHO (2020) https://www.who.int/news-room/detail/30-01-2020-statement-on-the-secondmeeting-of-the-international-health-regulations-(2005)-emergency-committee-regarding-the-outbreak-of-novel-coronavirus-(2019-ncov).
3. Wu JT, Leung K, Leung GM (2020) Nowcasting and forecasting the potential domestic and international spread of the 2019-nCoV outbreak originating in Wuhan, China: a modelling study. *Lancet,* ***395(10225)****: 689-697*.
4. Zhao S, Lin Q, Ran J, Musa SS, Yang G, Wang W, *et al.* (2020) Preliminary estimation of the basic reproduction number of novel coronavirus (2019-nCoV) in China, from 2019 to 2020: a data-driven analysis in the early phase of the outbreak. *Int J Infect Dis,* ***92****:214-217*.
5. Wang C, Horby PW, Hayden FG, Gao GF (2020) A novel coronavirus outbreak of global health concern. *Lancet,* ***395(10223)****:470-473*.
6. China National Health Commission (2020) Diagnosis and treatment of novel coronavirus pneumonia (Trial Sixth Edition). Beijing: China National Health Commission.
7. Chinese Society of Radiology (2020) Radiological diagnosis of new coronavirus infected pneumonitis: Expert recommendation from the Chinese society of radiology (First edition). *Chin J Radio,* ***54(00)****: E001-E001*.
8. Ajlan AM, Ahyad RA, Jamjoom LG, Alharthy A, Maddani TA (2014) Middle East respiratory syndrome coronavirus (MERS-CoV) infection: chest CT findings. *AJR Am J Roentgenol,* ***203(4)****: 782-787*.
9. Chan JF, Yuan S, Kok KH, To KK, Chu H, Yang J, *et al.* (2020) A familial cluster of pneumonia associated with the 2019 novel coronavirus indicating person-to-person transmission: a study of a family cluster. *Lancet,* ***395(10223)****: 514-523*.
10. Zhou P, Yang XL, Wang XG, Hu B, Zhang L, Zhang W, *et al.* (2020) A pneumonia outbreak associated with a new coronavirus of probable bat origin. *Nature*, ***579****: 270-273*.
11. Perlman S (2020) Another decade, another coronavirus. *N Engl J Med*, ***382(8)****: 760-762*.
12. Wang Q, Zhang ZY, Shi Y and Jiang Y (2013) Emerging H7N9 influenza A (novel reassortant avian-origin) pneumonia: radiologic findings. *Radiology,* ***268(3)****: 882-889*.
13. Koo HJ, Lim S, Choe J, Choi SH, Sung H, Do KH (2018) Radiographic and CT Features of Viral Pneumonia. *Radiographics,* ***38(3)****: 719-739*.
14. Xu Z, Shi L, Wang Y, Zhang J, Huang L, Zhang C, *et al.* (2020) Pathological findings of COVID-19 associated with acute respiratory distress syndrome. *Lancet Respir Med*, 2020 Feb 18. pii: S2213-2600(20)30076-X. doi: 10.1016/S2213-2600(20)30076-X. [Epub ahead of print].
15. Tian S, Hu W, Niu L, Liu H, Xu H, Xiao SY (2020) Pulmonary Pathology of Early Phase 2019 Novel Coronavirus (COVID-19) Pneumonia in Two Patients with Lung Cancer. *J Thorac Oncol,* 2020 Feb 28. pii: S1556-0864(20)30132-5. doi: 10.1016/j.jtho.2020.02.010. [Epub ahead of print]
16. Huang L, Han R, Yu PX, Wang SK, Xia LM (2020) A correlation study of CT and clinical features of different clinical types of 2019 novel coronavirus pneumonia. *Chin J Radiol,* ***54(00)****: E003-E0*

[DOI: 10.18869/acadpub.ijrr.18.2.343]