Review Article

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Quick Response Code:

Website: www.eurasianjpulmonol.com

DOI: 10.4103/ejop.ejop_41_20

Radiological findings of COVID-19 pneumonia

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Abstract:

Although real-time polymerase chain reaction (RT-PCR) remains the standard reference for a definitive diagnosis of coronavirus disease 2019 (COVID-19) infection, the false-negative rate and the lack of availability of RT-PCR assays in the early stages of the outbreak restricted the prompt diagnosis of infected patients. Since most COVID-19 infected patients were diagnosed with pneumonia based on characteristic imaging patterns, radiological examinations have become vital for early diagnosis and the assessment of disease course. Although chest radiography is not sufficiently sensitive for the detection of small ground-glass opacity (GGO) and may produce normal findings in the early stage of infection, it can be used as an initial imaging method, especially in young patients. Thin-slice chest computed tomography (CT) plays a vital role in early detection, observation, and disease evaluation. Typical CT findings of COVID-19 include peripherally distributed multifocal GGOs with patchy consolidations and predilection for the posterior part or lower lobe involvement. The increasing numbers, extent, and density of GGOs on CT indicate disease progression. Lung involvement progresses to consolidation up to 2 weeks after disease onset. Clear and frequent communication among health-care providers, including radiologists, is vital for the improvement of patient care during this pandemic.

Keywords:

Computed tomography, coronavirus disease 2019, radiological findings, radiology

Introduction

The most important organ of involvement in coronavirus disease 2019 (COVID-19) is the lung.[1] As such, it is vital to assess lung involvement radiologically. The optimum approach to the diagnosis of the disease is a real-time polymerase chain reaction (RT-PCR test), although radiological imaging has been used extensively in the absence of RT-PCR assays in some centers and the possible false negativity in the early stage of the disease.[2,3] Nevertheless, it should be kept in mind that radiologic methods are not a screening test and so should be used only as an auxiliary method in the diagnosis and follow-up of patients. Chest radiography, computed tomography (CT) of the thorax, and in some centers, thoracic ultrasonography has been used for imaging.

Chest X-ray

Chest X-ray is the first-line imaging method for the identification of COVID-19 pneumonia. This should be preferred especially in young patients and in the pediatric age group, since patients are exposed to a lesser dose of radiation than with CT. It offers some advantages, among these, given that the risk of disease transmission requires the device to be cleaned, this task is easier with chest X-ray equipment, and also bedside imaging is possible with this method for the follow-up

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Received: 20-04-2020
Accepted: 18-05-2020
Published: 26-08-2020

How to cite this article: Ceylan N, Savas R. Radiological findings of COVID-19 pneumonia. Eurasian J Pulmonol 2020;22:S19-24.

of patients. Nevertheless, it should be kept in mind that a chest radiography may not show the limited ground-glass type involvement of the lung, especially in the early period of the disease. Sensitivity of chest radiography in demonstrating disease involvement has been reported to be 30%–60%.[4]

Bilateral increased density and consolidation with irregular borders, located especially in the middle and lower zones, and predominant in the periphery, is seen in the chest radiography [Figure 1a and b]. It can also be used in cases where there is a suspicion of pneumothorax or pleural effusion. One should remember that a normal chest radiography does not rule out this disease, and cases with a compatible clinical picture should be evaluated with CT.

Computed Tomography

Thorax CT plays an important role in the diagnosis of COVID-19, in the follow-up of the treatment results, and in the evaluation of possible complications. CT is important for rapid diagnosis of patients, since this helps rapid isolation due to the high risk of transmission, and is also helpful in the planning of treatment. As such, various factors such as possible negativity of the RT-PCR test in the early period in the diagnosis of the disease, some difficulties in the availability of this test, and easier imaging of the CT have resulted in the overuse of CT worldwide.[5] CT was used as a screening tool at the beginning of the epidemic in China, but the approach was later changed. The sensitivity of the RT-PCR test and thorax CT in the early period of the disease were reported to be 71% and 98%, respectively, in a study.[2,3] It should be kept in mind, however, that a thorax CT may be normal in the early period of the disease. Thorax CT is recommended primarily for use in symptomatic cases with suspicious chest radiography and when there is a suspected presence of complications. The need to clean the CT room after each imaging to protect the CT technicians and to prevent the possibility of surface contamination of the device is another challenge that has arisen during this outbreak.

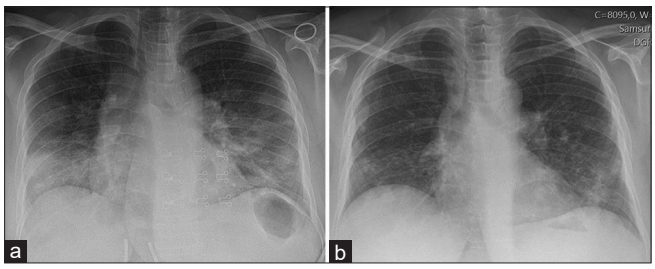

Figure 1: A 53-year-old female coronavirus disease 2019 patient presenting with fever and dry cough for 4 days. (a) Initial chest radiography reveals bilateral extensive peripheral consolidation in the middle and lower zones. (b) 2-week later, partial regression was noted in a follow-up chest radiography

A high-resolution thin-slice (1–1.5 mm) noncontrast-enhanced CT protocol should be used. Normal dose or low-dose imaging is recommended, depending on the age and clinical picture of the patient, and follow-up examinations are recommended to be low dose. The test should be performed using a contrast-enhanced thorax CT-angiography protocol in cases with suspicious complications such as pulmonary embolus.

Typical Findings of Computed Tomography in Coronavirus Disease 2019 Pneumonia

- Ground-glass image: This is the most common finding in COVID-19 pneumonia. It is generally seen bilateral, but can also be single sided, although this is rare. It most frequently involves the periphery and posterior sides of the lower lobes [Figure 2]. It is seen frequently with consolidation. The development of these infiltrations is frequently suggested to be associated with organized pneumonia, alveolar damage, and edema [Figure 3].[6,7] Involvement in the nodular type can occasionally be seen
- Crazy-paving appearance: This image, developing due to the thickening of the interlobular septa and accompanying a ground-glass appearance, points to alveolar edema and interstitial inflammation [Figure 4]. Its conjunction with consolidation is considered to be the peak point of the disease or progression[8]
- Consolidation: It is seen as multifocal foci with irregular contours, generally located peripherally in the lower lobe. It can be seen less frequently within the bronchovascular bundle. It is seen in the advanced stages of the disease or in cases with progression [Figure 5]. Its incidence is reported to be around 30%–50% in literature[9]

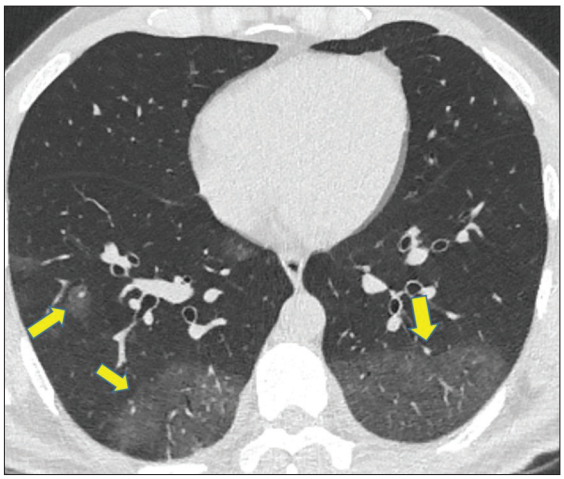

Figure 2: A 37-year-old male coronavirus disease 2019 patient presenting with fever and dry cough for 2 days. The computed tomography scan shows bilateral peripheral ground-glass opacities in the lower lobes

Figure 3: A 53-year-old female coronavirus disease 2019 patient presenting with fever and dry cough for 4 days. A computed tomography scan showed a ground-glass opacity with consolidation in the right upper lobe. A paravertebral focal consolidation was also noted in the right lower lobe

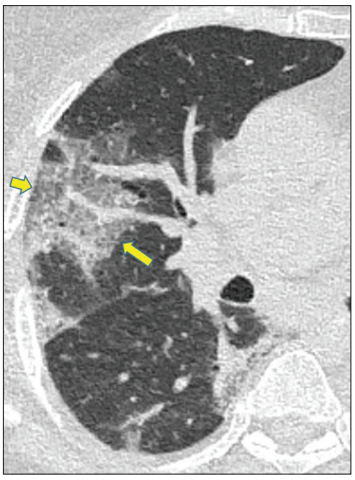

Figure 4: A 77-year-old female coronavirus disease 2019 patient presenting with fever and with cough for 7 days. A computed tomography scan revealed a reticular pattern superimposed on the background of the ground-glass opacity, resembling cobblestones in the right middle lobe (yellow arrows)

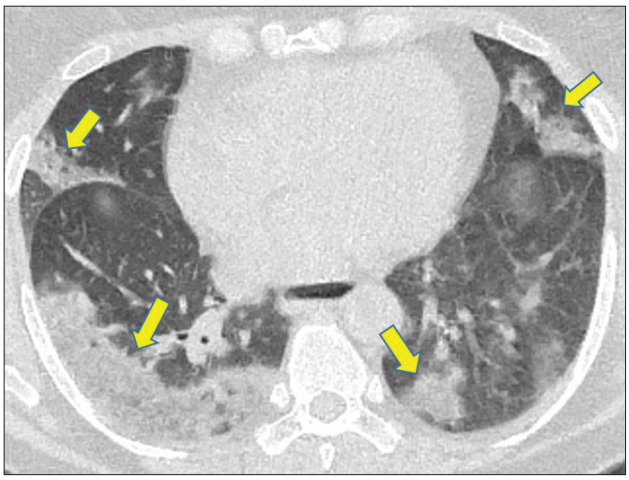

Figure 5: A 55-year-old female coronavirus disease 2019 patient. A computed tomography scan revealed bilateral multifocal consolidations (yellow arrows)

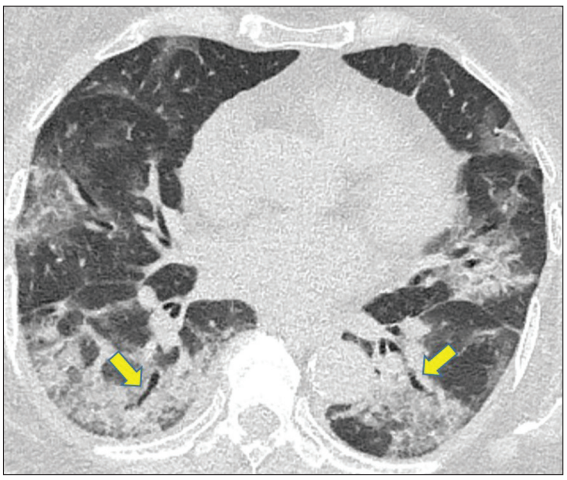

Figure 6: A 77-year-old female coronavirus disease 2019 patient presenting with fever and with cough for 7 days. A computed tomography scan revealed a bilateral air bronchogram in the lower lobe (yellow arrows)

- Air bronchogram: This is the finding seen secondary to the presence of air in the bronchus in the areas where soft tissue displaces the air due to infiltration; its incidence is reported to be up to 80% [Figure 6][10]
- Vascular enlargement: Increased vascular diameter in the parenchymal area of the lesion is a frequently reported finding and is reported to be positive in 70% of cases. Although the cause is not completely known, it is thought to be secondary to vascular involvement due to the inflammation in this region [Figure 7]
- Bronchial dilation: Involvement in the form of bronchial dilation or bronchiectasis, secondary to the inflammatory involvement of the bronchial wall and fibrous tissue proliferation, is reported in 10%–20% of cases. This involvement is considered to reflect a rather progressive course [Figure 8]
- Halo sign: This is the name of the consolidation or ground-glass appearance around the nodule. It is observed especially in fungal pneumonia, or more rarely in conditions such as hemorrhagic metastasis, but can also be seen in COVID-19 pneumonia [Figure 9][11]
- Reverse halo sign: This is the name given to the mainly circular infiltration in which the ground-glass appearance is seen in the central part and consolidation in the periphery; it is a frequent sign, especially in organized pneumonia. It can develop secondary to the progression of the ground-glass appearance to consolidation, or the regression of consolidation in COVID-19 pneumonia [Figure 10]
- Nodules: Nodules with irregular borders and a ground-glass appearance in the periphery are reported in approximately 10% of cases
- Air bubble sign: This is the appearance of a focal air bubble observed in the consolidation and should not

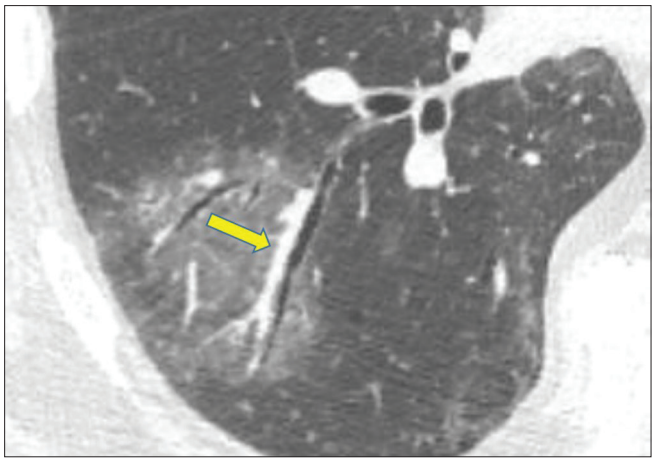

Figure 7: A 65-year-old male coronavirus disease 2019 patient presenting with fever and cough for 10 days. A computed tomography scan shows a ground-glass opacity in the right lower lobe with vascular enlargement (yellow arrow)

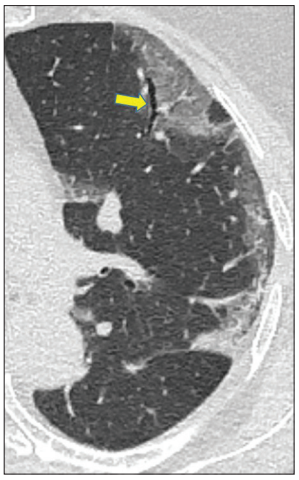

Figure 8: A 70-year-old male coronavirus disease 2019 patient. A computed tomography scan shows ground-glass opacity in the left upper lobe with bronchial dilatation (yellow arrow)

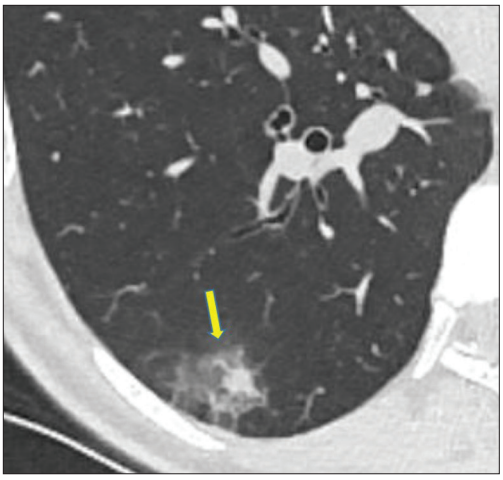

Figure 9: A 46-year-old male coronavirus disease 2019 patient presenting with fever with dry cough for 8 days. A computed tomography scan shows a solid nodule surrounded by a ground-glass halo in the right lower lobe (yellow arrow)

Figure 10: A 27-year-old male confirmed with coronavirus disease 2019 presenting with fever and myalgia for 7 days. A computed tomography scan shows a reversed halo sign (yellow arrow) in the posterior basal segment of the left lower lobe

be misdiagnosed as a cyst or cavity [Figure 11]
- Subpleural and parenchymal bands: These are the primarily linear lines observed mostly during the recovery period [Figure 12]. They are considered to be sequela foci, developing primarily secondary to fibrosis
- Pleural changes: Pleural effusion and thickening is reported in rare cases.

The change in time of CT findings in patients with a mild clinical picture can be divided into four periods:

- Early period (first 4 days after the onset of symptoms): Foci of ground-glass appearance observed as single or multiple and mainly in the lower lobes
- Progressive period (5–8 days): The ground-glass appearances increase, and infiltrations of a crazy-paving appearance and consolidations accompany the findings [Figure 13]
- Peak period (9–14 days): Infiltrations reach a peak point in this period, and consolidations become dominant. Parenchymal bands may accompany the picture in addition to the ground-glass and crazy-paving appearances and consolidations.
- Regression period (post day 14): Findings start to regress and are expected to have completely resolved by day 26. Residual fibrotic bands may develop in the parenchymal infiltration areas.[12]

The progression of consolidation over time, enlargement into the upper lobes, the development of pleural or pericardial fluid, the development of lymphadenopathy, the presence of bronchiectasis and halo sign, and the development of cavitation and pneumothorax are considered poor prognostic signs [Figure 14].[13,14] As causes of mortality, complications such as Acute respiratory distress syndrome (ARDS), secondary

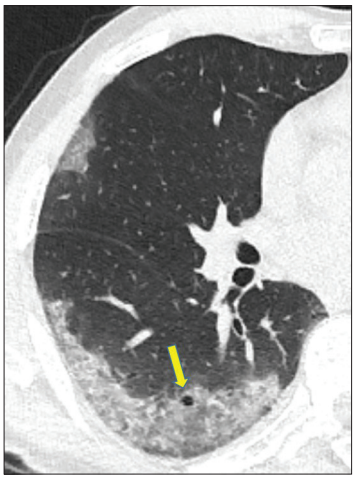

Figure 11: A 58-year-old male coronavirus disease 2019 patient presenting with fever and dry cough for 10 days. A computed tomography scan shows consolidation with an air bubble sign (yellow arrow) in the right lower lobe

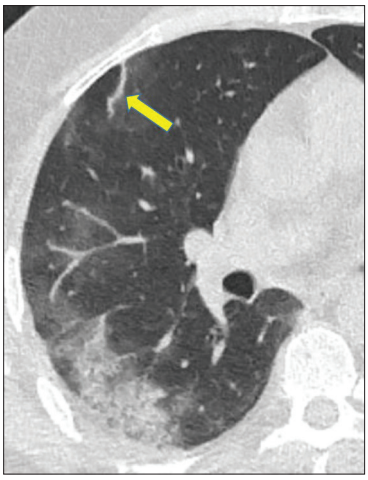

Figure 12: A 43-year-old female coronavirus disease 2019 patient presenting with fever and chills for 12 days. A computed tomography scan reveals a subpleural line (yellow arrow) in the right upper lobe

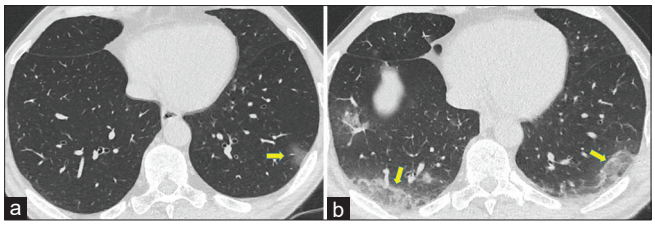

Figure 13: A 55-year-old male coronavirus disease 2019 patient presenting with fever and dry cough for 3 days. (a) At presentation, a small subpleural nodular ground-glass opacity was seen in the left lower lobe (yellow arrow). (b) 1-week later, there was an enlarged region of ground-glass opacity with superimposed consolidations in both lower lobes (yellow arrows)

infections, sepsis, cardiac failure, and multiorgan failure can develop as the disease progresses.

The above-defined signs are nonspecific for COVID-19 pneumonia and may be seen in many other diseases. Viral pneumonia such as influenza and cytomegalovirus, diseases with interstitial involvement (such as organized pneumonia, usual interstitial pneumonia, nonspecific interstitial pneumonia, acute and chronic eosinophilic pneumonia, and hypersensitivity pneumonia), lung edema, drug toxicity, and atypical pneumonia should be considered in a differential diagnosis. For reporting, it is recommended to report the CT findings as "findings are compatible with viral pneumonia and support primarily COVID-19 pneumonia" in cases with findings in CT with a high suspicion of COVID-19 pneumonia and to report "findings suspicious for viral pneumonia and it is recommended that the diagnosis should be verified with clinical and laboratory findings" in suspicious cases with atypical findings. In addition, it can be reported as "incompatible with COVID-19 pneumonia" when the findings are completely incompatible. That said, CT results should always be evaluated alongside clinical findings.

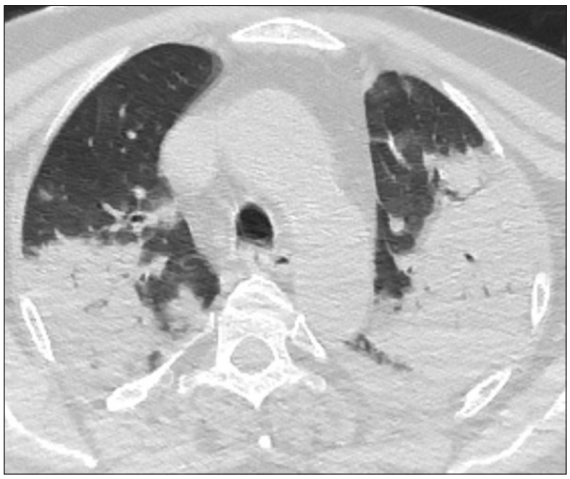

Figure 14: A 74-year-old male COVID-19 patient presenting with fever, chills and cough for 7 day. A CT scan shows bilateral extensive consolidations. The patient died 10 days later

Thoracic Ultrasonography

This can be used in a limited number of centers, and especially in intensive care units, for certain conditions, such as the follow-up of pneumonic infiltrations, and the detection of a possible development of pleural fluid, and for guidance in its drainage. It has the advantage of being performed at the bedside, however its availability in only a limited number of centers and requirement of an experienced operator are the main factors limiting its extensive use.

Fleischner Recommendations

The Fleischner Society, in a multinational consensus report, recommended direct radiography and CT for the diagnosis and follow-up of the disease.[15] Further recommendations included:

- Imaging methods should not be used routinely for the screening of asymptomatic cases of COVID-19
- Imaging methods should not be used in the presence of mild clinical findings compatible with COVID-19 when there is no risk of disease progression
- Imaging methods are recommended in the presence of intermediate or severe clinical findings compatible with COVID-19, independent of the test results
- Imaging is recommended in cases of COVID-19 when respiratory symptoms worsen
- Direct radiography may be preferred as an imaging method in cases of COVID-19 when resources are limited, and when access to CT is also limited, and when a worsening of respiratory symptoms does not require obtaining a CT
- Daily routine chest X-rays are not recommended in stable intubated cases with COVID-19
- CT is recommended in cases with COVID-19 if functional deterioration and/or hypoxemia develop following recovery
- Testing is recommended when imaging findings supporting the presence of COVID-19 are detected by CT incidentally.

Conclusion

Chest radiography should be the first-line imaging method in a radiologic diagnosis of COVID-19, although low densities, such as the ground-glass appearance, may be difficult to see. A bilateral ground-glass appearance and accompanying consolidation are the most common findings seen on CT. The findings may vary over time and should not be accepted as progression unless no clinical deterioration is noted. Evaluations of clinical and other laboratory findings should be made in collaboration through a multidisciplinary approach for an accurate diagnosis.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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