

The Characteristics, Manifestations and Cardiopulmonary Imaging (CT/MRI) of COVID-19 in COVID-19 Patients

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ABSTRACT

The World Health Organization (WHO) declared the transmission of SARS-CoV-2 a Public Health Emergency of International Concern. The novel coronavirus has diverse manifestations, usually similar to a common cold or influenza. The majority of patients with coronavirus disease have typical imaging features. The typical CT characteristics of patients with COVID-19 pneumonia are ground-glass opacities and consolidative lesions with a peripheral and posterior distribution. Noninvasive imaging methods are precise and rapid means of diagnosing pneumonia and cardiovascular complications caused by COVID-19 infection. Therefore, it is important for clinicians to understand the implications of this pandemic and to be familiar with the different imaging aspects of the novel coronavirus disease. This review focuses on the most commonly reported imaging findings of COVID-19 infection in different patients from different countries, the expert recommendations, and the cardiac manifestations of SARS-CoV-2 infection.

Keywords: COVID-19, cardiovascular involvement, thoracic imaging, cardiac CT, cardiac MRI

INTRODUCTION

One of the most important aspects in the evaluation and management of emerging infectious diseases is the understanding of the pathogen's biology, epidemiology, and clinical features of the infection, as well as the identification of the most appropriate diagnostic methods and effective therapies.¹

Coronaviruses are a large family of RNA viruses that can cause diseases including the common cold, severe acute respiratory syndrome (SARS), and Middle East respiratory syndrome (MERS) in humans. They have a single-layered envelope, with a spherical or pleomorphic shape and glycoprotein projections. Each subtype has many stereotypes, and its replication occurs in epithelial cells, resulting in inflammatory reactions at the site of infection and cellular lesion.²

Coronaviruses are classified into four genera: alpha coronaviruses, beta coronaviruses, gamma coronaviruses, and delta coronaviruses. They have the largest genome among the RNA viruses. Their genome is packaged inside a helical

capsid formed by nucleocapsid proteins and is surrounded by a viral envelope. The envelope has at least three structural proteins: membrane proteins, envelope proteins, and spike proteins, which help the virus enter into host cells.³

The novel coronavirus was isolated from human ciliated epithelium at the end of 2019 in Wuhan, Hubei province, by the Chinese Centre for Disease Control and Prevention and was named severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2).^{4,5} The World Health Organization (WHO) declared the transmission of SARS-CoV-2 a Public Health Emergency of International Concern.⁴ On February 12, 2020, the WHO named the disease Coronavirus Disease 2019 (COVID-19), and in March 2020, it announced that the COVID-19 outbreak is a pandemic.⁶

Both symptomatic and asymptomatic patients were found to be contagious, and the transmission capability of SARS-CoV-2 may be greater than that of SARS.⁷ Although the impact on the number of infected cases is unknown, several cases of contamination with SARS-CoV-2 have been reported during the incubation period or from asymptomatic patients. The highest contagiousness of infected patients starts in the first days of infection, and in symptomatic patients, contagiousness can persist for more than three weeks.⁸

A study that included 181 cases infected with SARS-CoV-2 showed that the incubation period was approximately 5–11 days, and 97.5% of patients showed symptoms within 11 days from the time of infection.⁹

The novel coronavirus has diverse manifestations, usually similar to a common cold or influenza. Fever, myalgia, sore throat, dry cough, and fatigue are the most common symptoms of patients infected with the virus, and the least common symptoms are diarrhea, sputum production, and hemoptysis.^{10,11} COVID-19 is leading an outbreak of atypical pneumonia. The most used methods to prevent the disease from progressing and spreading are early detection and isolation.¹² High-resolution computed tomography (CT) has an important role in the initial diagnosis of COVID-19 pneumonia and follow-up of the disease. Initial chest CT has a higher sensitivity compared with reverse transcription-polymerase chain reaction (RT-PCR).¹³ The majority of patients with coronavirus disease have typical imaging features.⁴ The typical CT characteristics of patients with COVID-19 pneumonia are ground-glass opacities and consolidative lesions with a peripheral and posterior distribution.¹⁴ According to the American College of Radiology, CT should not be performed as screening for the new coronavirus in order to decrease healthcare workers' and patients' exposure.¹⁴ The most common changes in laboratory test results are increased C-reactive protein,

lactate dehydrogenase, and erythrocyte sedimentation rate, all of which are markers of increased systemic inflammation.^{15,16}

A cohort study of 179 patients admitted to Wuhan Pulmonary Hospital with COVID-19 pneumonia conducted between December 25, 2019 and February 7, 2020 showed that mortality in these patients was 11.7%, due to respiratory and heart failure. The average age of patients who died was 70.2 years; most of them had cardiovascular and cerebrovascular comorbidities.¹⁷ The World Health Organization stated on May 27, 2020, that the number of people infected with the new coronavirus worldwide was 5,491,678, of which 349,190 have died; in Europe there were 2,061,828 confirmed cases.¹⁸

Commonly used treatments for patients infected with the new coronavirus include antiretrovirals, anti-inflammatory drugs, antibiotics such as azithromycin and doxycycline, and antiparasitics such as chloroquine and hydroxychloroquine. The replication of the virus in infected cells can also be stopped by Zn²⁺ inside the infected cell. So far, no antiviral vaccine has been officially approved.^{19,20}

Noninvasive imaging methods are precise and rapid means of diagnosing pneumonia and cardiovascular complications caused by COVID-19 infection. Therefore, it is important for clinicians to understand the implications of this pandemic and to be familiar with the different imaging aspects that are important in the evaluation and management of this emerging infectious disease. This review focuses on the most commonly reported imaging findings of COVID-19 infection in different patients from different countries, the expert recommendations, and the cardiac manifestations of SARS-CoV-2 infection.

IMAGING FINDINGS OF COVID-19 PNEUMONIA

The disease most commonly affects all five lung lobes, and the lesions are predominantly peripheral and subpleural, with a few along the bronchovascular bundles, as shown by initial thoracic CT in patients with COVID-19.¹³ Ground-glass opacities and consolidation in singular or multiple areas are the most frequent signs of COVID-19 lesions on CT images.^{21–23}

A study on 42 Chinese patients infected with the new coronavirus, which aimed to show the association between CT appearance and clinical parameters, showed that at the initial CT, most patients had more than one lobe affected, had consolidation and interstitial thickening, and the lesions were located predominantly in the lower lung lobes – the most frequently affected being the left lower lobe. At subsequent clinical evaluations by CT, multiple

ground-glass infiltrates were found, and most patients had pulmonary consolidation or interstitial thickening and fibrous bands.¹⁵

Pneumonia caused by COVID-19 has four clinical stages: (1) the mild stage, in which there are no signs of pneumonia on imaging tests and no clinical symptoms; (2) the common stage, in which imaging examinations detect signs specific to pneumonia; (3) the severe stage, characterized by respiratory distress or an oxygen partial pressure to fraction of inspired oxygen ratio ($\text{PaO}_2/\text{FiO}_2$) of less than 300; and (4) the critical stage, which requires orotracheal intubation and mechanical ventilation.²⁴

On CT examination, pneumonia from infection with the new coronavirus differs from other pneumonias through its particular aspects such as alveolar edema, interstitial changes with predominantly peripheral distribution and air bronchograms, with gradually increasing parenchymal density and ground-glass opacities.²⁴ Streptococcal pneumonia has no ground-glass opacities on the CT examination, but it presents with lobar and lobular consolidation. Aspiration pneumonia and pneumonia caused by *Mycoplasma pneumoniae* also do not have ground-glass opacities and distribution along the bronchovascular bundle on the CT examination.²⁴

Pre- and post-treatment transverse thin-slice CT scans of a 46-year-old patient confirmed with COVID-19 pneumonia showed multiple ground-glass opacities in both lungs, in the superior segments of the lower lobes, on the first day of admission. On the seventh and thirteenth day of admission, after receiving treatment, the ground-glass opacities completely regressed in the superior segment of the right lower lobe and partly in the superior segment of the left lower lobe.⁷

A chest CT without changes characteristic of the new coronavirus infection cannot rule out the diagnosis of COVID-19 infection.²⁵ However, it is important to note that CT can be used in the long term to assess lung damage in patients cured of the new coronavirus infection.²⁴

POSSIBLE PATHOPHYSIOLOGICAL MECHANISMS OF CARDIAC DAMAGE CAUSED BY COVID-19

Cardiac involvement in COVID-19 infection occurs due to viral binding via its S-spike to ACE-2 receptors in the cardiac myocytes, which triggers an inflammatory reaction. Severe immune system reactivity can lead to acute coronary syndromes by destabilizing atherosclerotic plaques. Also, patients can present fulminant myocarditis by myocardial infiltration of macrophages and T-lymphocytes,

activated by proinflammatory cytokines as an immune response to the COVID-19 infection.²⁶

Viral infection triggers a strong immune response that leads to the production of large amounts of cytokines. The cytokines cause injury to the pulmonary and myocardial tissues, leading to high levels of troponin and abnormal imaging examinations.²⁷ Acute myocardial injury, myocarditis, severe arrhythmia, heart failure, and cardiac arrest are the main heart conditions caused by the new coronavirus.^{26,28}

CARDIAC IMAGING IN THE COVID-19 PANDEMIC

Cardiac imaging during the coronavirus pandemic should take into consideration safety measures to prevent infection of the personnel such as wearing protective equipment, face masks, gloves, headcovers, goggles, and disinfection of medical equipment that has been in contact with the patient.²⁹ During the imaging acquisition, the patient is advised to wear a face mask if the risk of infection is low; in the case of moderate risk of infection and in patients confirmed with the novel coronavirus, wearing a face mask is mandatory.³⁰

The European Association of Cardiovascular Imaging recommends that unnecessary imaging examinations should be avoided in patients confirmed with the new coronavirus, and routine imaging tests should be postponed.²⁶ Lengthy cardiac imaging tests, namely CT or cardiac magnetic resonance imaging (MRI), will increase the risk of contamination. As a result, every cardiac imaging test should be performed appropriately in order to minimize the risk of disease dissemination.²⁹

Coronavirus-infected patients who are suspected to have myocarditis or pericarditis, intermediate pretest probability of coronary artery disease, myocardial dysfunction, elevated troponin levels, severe arrhythmias, lung embolism, or suspected heart failure in whom cardiac imaging is the only clear diagnostic method, have an indication for thoracic computed tomography, cardiac magnetic resonance (CMR), or cardiac computed tomography angiography only if imaging is very important for treatment and the patient is hemodynamically stable.³⁰ It is important to note that a small fraction of patients who tested positive for the novel coronavirus can have normal chest imaging findings.³¹

ACUTE MYOPERICARDITIS AND CARDIAC IMAGING IN COVID-19 PATIENTS

In Italy, the case of a 53-year-old patient without comorbidities was reported, whose main condition following

infection with COVID-19 was acute myopericarditis with systolic dysfunction, confirmed by MRI. The patient had demonstrated cardiac involvement of the new coronavirus without signs and symptoms of pneumonia.³² In this case report, MRI evidenced the following changes suggestive for acute myopericarditis: thickening of the cardiac walls with diffuse biventricular hypokinesia and severe left ventricular failure, biventricular myocardial interstitial edema showed in T2-mapping sequences, diffuse late gadolinium enhancement in the entire biventricular wall, and circumferential pericardial effusion.³³

MYOCARDIAL INJURY AND CARDIAC IMAGING IN COVID-19 PATIENTS

Cardiac imaging is frequently used in patients infected with the new coronavirus who have myocardial injury. Imaging plays a crucial role in the diagnosis of the aforementioned injury by monitoring myocardial function. CMR can differentiate between myocardial infarction, myocarditis, and stress cardiomyopathy.³⁰

A study that included 416 patients with COVID-19, hospitalized at Renmin Hospital at Wuhan University between January and February 2020 showed that the proportion of patients with heart injury was 19%; these patients had high levels of inflammatory markers such as C-reactive protein and procalcitonin. The proportion of patients with cardiac injury and pneumonia was 74.8%; most of them had bilateral pneumonia. Of these patients, 16.3% had ground-glass opacities on CT, which was linked with longer duration of hospitalization and higher risk of in-hospital mortality.³³

CONCLUSIONS

The pandemic caused by the new coronavirus has led to the application of new safety measures worldwide such as rigorous hygiene, social distancing, and isolation of infected persons in order to prevent the spread of the virus. Knowing the characteristics, manifestations, and cardiopulmonary imaging of COVID-19 patients is very useful in the early diagnosis of COVID-19 pneumonia, in the clinical follow-up of infected patients, and also in the diagnosis, patient management, and treatment of cardiovascular complications such as acute myocardial injury, myocarditis, severe arrhythmia, heart failure, and cardiac arrest caused by the new coronavirus.

CONFLICT OF INTEREST

Nothing to disclose.

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