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Imaging differences between coronavirus disease 2019, severe acute respiratory syndrome, and Middle East respiratory syndrome

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ABSTRACT

Since the outbreak of Coronavirus Disease-19 (COVID-19) infection in December 2019 in Wuhan, the capital Hubei province, central of China, more than 4 million people have contracted the virus worldwide. Despite the imposed precautions, coronavirus disease-19 is rapidly spreading with human-to-human transmission resulting in more than 290,000 death as of May 13, 2020 according to World Health Organization (WHO). The aim of this study was to revise the characteristic imaging features of Sever Acute Respiratory Syndrome (SARS) and Middle East Respiratory Syndrome (MERS) during their outbreak, and to compare them with that of COVID-19, to familiarize radiologists with the imaging spectrum of corona-virus syndromes. This study will help in more understanding and characterisation of COVID-19 to support the global efforts in combating its worldwide outbreak.

1. Introduction

In November 2019, a novel strain of coronavirus was isolated from the bronchoalveolar lavage of a cluster of patients having a strange lower respiratory tract febrile illness in Wuhan City, Hubei Province, China. In February 2020, World Health Organization (WHO) announced a new pulmonary syndrome as Coronavirus Disease 2019 (COVID-19). The virus rapidly spread throughout China, despite travel restrictions, and strict quarantine rules, it transmitted out of China with large number of confirmed cases reported throughout the world, causing a pandemic. The global number of confirmed cases has surpassed 4,340,058 with more than 292,816 virus-related deaths as of May 13, 2020 [1].

Coronavirus is an RNA virus, with a crown-like appearance due to the presence of glycoprotein spikes on its outer envelope [2]. There are four genera of Corona Viruses: (I) Alpha Corona Virus (α-coronavirus), (II) Beta Corona Virus (β-coronavirus) mainly found in bats and rodents, (III) Delta Corona Virus (δ-coronavirus), and (IV) Gamma Corona Virus (γ-coronavirus) this type mainly represent avian species [2–4].

This is not the first time for coronavirus to cause an epidemic with a significant global health threat; in November 2019, an outbreak of coronaviruses with Severe Acute Respiratory Syndrome (SARS) began in the China (Guangdong province) and after that, the Middle East Respiratory Syndrome MERS emerged in September 2012 [3]. The outbreak of SARS has been contained, without any report of human infection since 2003; while small outbreaks of MERS have been reported.

Imaging is a critical component of the diagnostic work-up, monitoring of disease progression, and follow-up in coronavirus-related pulmonary syndromes [5]. Imaging features in the acute and chronic phases of SARS and MERS are variable and nonspecific [6,7]. The first accounts of the imaging findings of COVID-19 have also reported nonspecific findings [8,9].

Because the etiology of COVID-19 belongs to the same corona family of SARS and MERS and the clinical features of COVID-19 are similar to those of SARS and MERS, the experience from those pulmonary syndromes can be helpful for managing the emerging COVID-19 outbreak. The aim of this study is to discuss the reported imaging features of SARS and MERS and compare them with that of COVID-19 to familiarize radiologists with the imaging spectrum of corona-virus syndromes, to support the global efforts in combating the worldwide outbreak of COVID-19 (Table 1).

1.1. Imaging features of Severe Acute Respiratory Syndrome (SARS)

The characteristic imaging feature of SARS is that it initially shows unilateral ill-defined areas of airspace opacity involving lower lung zones, with peripheral distribution. This initial involvement appears focal in about half of the patients and it appears multifocal in the

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remainder, with less than 10 % showing early diffuse involvement [10]. With the progression of the disease over a course of 6–12 days, the majority of patients will show progressive multifocal consolidation involving one or both lungs; however, in one-quarter of patients, the opacity will remain unilateral [11]. The characteristic feature of SARS on CT scan is patchy areas of ground-glass opacity and consolidation (Fig. 1). Centrilobular nodules and tree-in-bud opacities are not characteristic and likely indicate other atypical or opportunistic causes of pneumonia [6]. Most of the patients show radiologic improvement after recovery. The presence of bilateral confluent diffuse airspace opacities, as seen in acute respiratory distress syndrome, and bilateral involvement of four or more lung zones, with progressive worsening of airspace consolidation on chest imaging more than 12 days after symptom onset despite treatment are associated with unfavourable outcomes [7,11,12].

After recovery from SARS, the characteristic feature on CT scan is transient interlobular septal thickening and reticulation over a period can extend up to several months. The reticulation appears after the 2nd week and peaks around the 4th week [13]. One-third of patients with persistent respiratory symptoms will have imaging findings of fibrosis, including inter-lobular and intralobular reticulation, traction bronchiectasis, and, rarely, honeycombing [6]. Areas of air trapping, caused by damage to ciliated respiratory epithelium, have been reported in 92 % of patients who have recovered from pneumonia and are less likely to resolve completely [14].

1.2. Imaging features of Middle East Respiratory Syndrome (MERS)

The initial radiographic features in 83 % of patient with (MERS), are abnormal multifocal airspace opacities in the lower lung zones, with the progression of the disease these radiographic abnormalities will extend into the perihilar and upper lobes. CT scan will show bilateral basilar ground-glass opacities with a predilection to the peripheral lung regions; however, isolated consolidation, interlobular septal thickening, and pleural effusion are not rare in MERS and might be observed in 20–33 % of affected individuals [15] (Fig. 2). Pleural effusion, pneumothorax, and greater involvement of the lungs are associated with poorer prognosis [16]. Tree-in-bud opacities and cavitation rarely occur, and lymphadenopathy is not characteristic of this type of virus [17].

Although the majority fully recover, 33 % of patients with MERS, show evidence of lung fibrosis on follow-up imaging. These patients were commonly older, had prolonged ICU admission, and had greater lung involvement in the acute phase of the disease [18].

1.3. Imaging features of coronavirus disease 2019 (COVID-19)

Although COVID-19 is suspected on patients having symptoms of pneumonia such as fever, sore throat, dry cough, fatigue, myalgia, and dyspnoea, as well as history of contact with a known patient, chest imaging plays an important role in diagnosis, assessment and follow-up of the disease. The characteristic feature of COVID-19 on chest radiographs is patchy or diffuse asymmetric airspace opacities, similar to other causes of coronavirus pneumonias [19]. The first report of patients with COVID-19 described bilateral lung involvement on initial chest CT in 40 of 41 patients, with a consolidative pattern seen in patients in the ICU and a predominantly ground-glass pattern in patients who were not in the ICU [20]. An investigation of initial chest CT findings in 21 individuals with confirmed COVID-19 reported abnormal findings in 86 % of patients, with a majority (16/18) having bilateral lung involvement [8]. Multifocal ground-glass opacities have been reported in 57 % of patients while consolidation have been reported 29 %, with predilection to peripheral lung zones (Fig. 3).

A study done on a family cluster of seven people with confirmed COVID-19, chest imaging showed bilateral patchy ground-glass opacities with greater involvement of the lungs in the older family members [21]. Although the imaging features of COVID-19 closely resemble those of MERS and SARS, bilateral lung involvement on initial imaging is more likely to be seen with COVID-19; initial radiographic abnormalities in SARS and MERS are more commonly to be unilateral. It has been reported that pneumothorax was seen in 1 of 99 patients with confirmed COVID-19 [22], but it was not confirmed if the pneumothorax was a direct complication of the corona-virus infection.

A retrospective study done by Lomoro P et Al, among fifty-eight patients (36 men, 22 women; age range, 18–98 years) with laboratory-confirmed SARS-CoV-2 hospitalized in Valduce Hospital (Como, Italy). This study concluded that spectrum of chest imaging manifestations of COVID-19 pneumonia upon admission includes B-lines and consolidations on US, consolidations, and hazy increased opacities on CXR, and multifocal GGO with consolidations on CT [23].

El Homsi M et Al, revised the most frequently encountered imaging manifestations of COVID-19 patients with pertinent clinical findings based on the literature compiled by early investigators, and illustrative cases from a major hospital system in NYC. They found that COVID-19 has typical CT findings with GGOs and consolidation often with a peripheral and lower lung distribution. In early disease, imaging findings can be absent; therefore, CT chest cannot be used as a screening method, and RT-PCR remains the reference diagnostic test [24]. Another review study investigated the typical imaging findings in COVID-19, the differential diagnoses, and common complications. The study found that the typical CT features of COVID-19 pneumonia include multifocal bilateral GGOs, with or without patchy consolidations, prominent peripheral subpleural distribution, and posterior or lower lobe predilection [25].

It has been reported that five patients with confirmed COVID-19 had initially negative results from a swab test for coronavirus, highlighted the importance of early CT findings for diagnosis of the disease. This report showed that the presence of typical CT findings could be helpful for initial screening in individuals who are suspected to be have the virus [26]. On the other hand, a chest imaging with normal findings does not exclude the infection because it has been reported that about 15 % of individuals with confirmed COVID-19 showed normal findings in initial imaging. Preliminary unpublished data of autopsies on COVID19-positive patients in Italy have highlighted the presence of

Table 1
Comparison of radiological features of Corona Virus Disease-19,Severe Acute Respiratory Syndrome, and Middle East Respiratory Syndrome.[29]

Imaging finding	Corona Virus Disease-19	Severe Acute Respiratory Syndrome	Middle East Respiratory Syndrome
Normal Initial image	15–20% of patients	15–20% of patients	17 % of patients
Common abnormality	Peripheral multifocal ground glass opacities and consolidation on CT scan.	Peripheral multifocal ground glass opacities and consolidation on CT scan.	
Appearance on CT scan	Bilateral, multifocal, basal airspace in 15 %	Unilateral focal in 50 %, multifocal in 40 %, and diffuse in 10 %	Bilateral, multifocal, basal airspace in 80 %, isolated unilateral in 20 %
Follow up appearance on CT	Persistent or progressive opacities	Unilateral focal in 25 %, progressive unilateral multifocal or bilateral multifocal consolidation.	Extension into upper lobes in peripheral with pleural effusion in 33 % or interlobar septal thickening in 26 %.
Chronic phase	Not yet reported	Fibrosis is rare	Fibrosis in one third of patients
Indication of poor prognosis	Consolidation	Progressive involvement of bilateral lung zones after 12 days	Greater involvement of the lungs, pleural effusion, and pneumothorax.

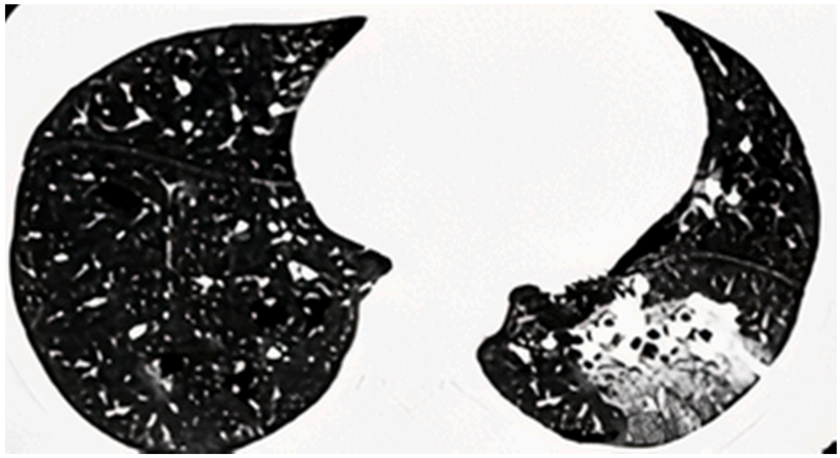

Fig. 1. Axial high-resolution CT scan of the thorax showing multifocal areas of mixed ground glass opacification and consolidation in the left lower lobe in a case of Severe Acute Respiratory Syndrome (SARS).

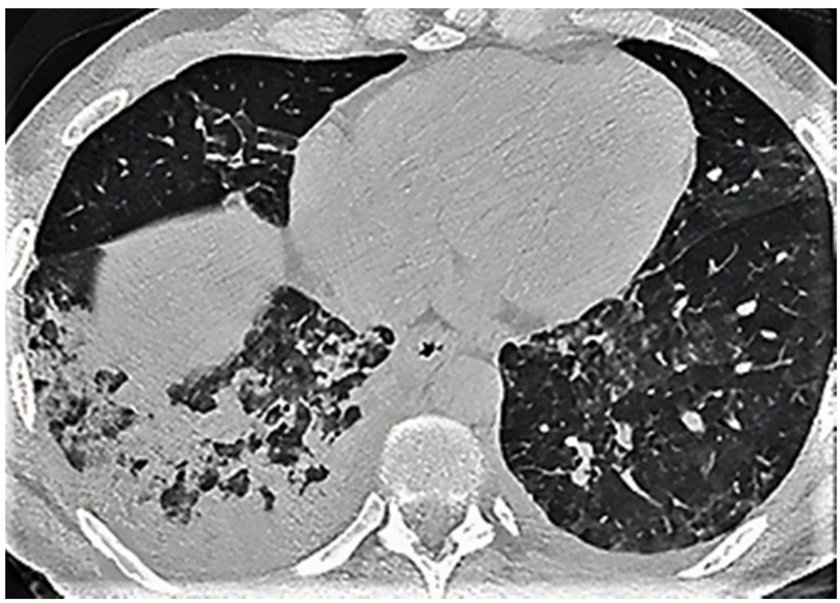

Fig. 2. Axial CT scan lower lung showing large right lower lobe and small focal left lower lobe subpleural consolidations.

thrombotic formations and of a thrombofilic vasculitis in the lung, brain, and other organs [27].

Because chest imaging is an important component of patient management in individuals with COVID-19, further investigations are required to expand understanding of the imaging findings throughout the disease course. Dealing with patients having MERS and SARS showed that follow-up imaging is mandatory for patients recovering from COVID-19 to detect features of chronic involvement of the lungs such as interlobular thickening, fibrosis, or air trapping.

Precaution is very important to prevent nosocomial human-to-human transmission, it may play a critical role in decreasing the spread of the disease. The radiology team should be aware of all precautions and strategies to minimize the risk of infection among staff and patients [28].

2. Conclusion

Although the imaging features of COVID-19 closely resemble those of MERS and SARS, bilateral lung involvement on initial imaging is more likely to be seen with COVID-19, while unilateral lung involvement is more likely to be seen in SARS and MERS. Early evidence suggests that initial chest imaging of COVID-19 will show abnormality in at least 85 % of patients, with 75 % of patients having bilateral lung involvement that most often appears as peripheral areas of consolidation and ground-glass opacity with prominent peripheral subpleural distribution, and posterior or lower lobe predilection. Older age and immunocompromised patients with progressive consolidation might suggest poorer prognosis. Despite, CT chest cannot be used as a screening method, because imaging findings can be absent in early disease, it remains the recommended imaging modality for initial diagnosis of COVID-19 beside follow-up in individuals who are recovering from it to evaluate long-term or permanent lung damage.

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Ethical statement for solid state ionics

Hereby, I / Dr Osama Abdalla Mabrouk Kheiralla, Abdulrahman Amin Tajaldeen, Adel Osman Bakheet / consciously assure that for the

Fig. 3. Axial CT scan image showing multiple patchy, peripheral, bilateral areas of ground-glass opacity.

manuscript /insert title/ the following is fulfilled:

1) This material is the authors' own original work, which has not been previously published elsewhere.

2) The paper is not currently being considered for publication elsewhere.

3) The paper reflects the authors' own research and analysis in a truthful and complete manner.

4) The paper properly credits the meaningful contributions of co-authors and co-researchers.

5) The results are appropriately placed in the context of prior and existing research.

6) All sources used are properly disclosed (correct citation). Literally copying of text must be indicated as such by using quotation marks and giving proper reference.

7) All authors have been personally and actively involved in substantial work leading to the paper and will take public responsibility for its content.

I agree with the above statements and declare that this submission follows the policies of Solid-State Ionics as outlined in the Guide for Authors and in the Ethical Statement.

CRediT authorship contribution statement

Osama Abdalla Mabrouk Kheiralla: Conceptualization, Writing - original draft, Supervision, Project administration, Writing - review & editing. **Abdulrahman Amin Tajaldeen:** Software, Validation, Visualization. **Adel Osman Bakheet:** Data curation, Formal analysis, Investigation, Methodology, Resources.

Declaration of Competing Interest

The authors whose names are listed immediately below certify that they have NO affiliations with or involvement in any organization or entity with any financial interest, or non-financial interest in the subject matter or materials discussed in this manuscript.

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