Discoveries Journals
publishing the future

DISCOVERIES REPORTS 2021, 4: e20
DOI: 10.15190/drep.2021.5

REVIEW Article

Role of Chest Imaging in Diagnosis and Management of COVID-19

Madeeha Subhan Waleed[1,], Kinal Paresh Bhatt[2], Farwah N. Fatima[3], Anoopa Mathew[4], Paz Ines M. Domingo[5], Mehrie H. Patel[6], Bishnu M. Singh[7]*

[1]Ayub Medical College, 22040, Abbottabad, Pakistan
[2]Larkin Health System, 33143, South Miami, FL, USA
[3]Lahore Medical and Dental College,53400, Lahore, Pakistan
[4]K.S. Hegde Medical Academy, 575018, Mangaluru, Karnataka, India
[5]University of the East Ramon Magsaysay Memorial Medical Center, 1113, Quezon City, Philippines
[6]Pramukhswami Medical College, 388325, Gujarat, India
[7]Hetauda City Hospital, 44107, Hetauda, Nepal

* *Corresponding authors*: *Madeeha Subhan Waleed MBBS,* Ayub Medical College, 22040, Abbottabad, Pakistan; Email: madeehas99@gmail.com; Phone:00923335634888.

Submitted: Mar. 31, 2021; *Revised*: May 08, 2021; *Accepted:* May 08, 2021; *Published:* June 30, 2021;
Citation: Waleed MS, Bhatt KP, Fatima FN, Mathew A, Domingo PIM, Patel MH, Singh BM. Role of Chest Imaging in Diagnosis and Management of COVID-19. *Discoveries Reports,* 2021; 4: e20. DOI: 10.15190/drep.2021.5

ABSTRACT

The COVID-19 pandemic is a serious global health threat. The standard gold test for detecting COVID - 19 is a real-time reverse transcription-polymerase chain reaction (RT-PCR) of viral nucleic acid. There are different specific and nonspecific diagnostic tests available for COVID-19. The use of imaging in COVID-19 is considered a specific diagnostic test and is stratified based on the severity of the disease. Chest radiographs of COVID-19 patients are usually insensitive to detecting COVID-19 in the early stage. They may have some utility, with the potential to serve as a screening tool on the frontlines in medical settings with limited resources. CT (computerized tomography) scans have greater sensitivity and are used in disease staging. They are a good indicator of the infection in patients with negative viral testing or chest X-ray results, when clinical findings are still serious concerns for COVID-19. However, meticulous equipment decontamination is required to reduce any chance of viral contamination and spread across patients and facility staff. It is salient to utilize the advantages of different imaging modalities in the wrestle against COVID-19. The mounting prevalence of COVID-19 in the community demands for an accurate and sensitive test for COVID-19. This review article sheds light on the limited role of different imaging modalities in diagnosing and managing COVID-19.

SUMMARY

Keywords
Coronavirus, COVID-19, SARS-CoV-2, imaging, chest computerized tomography, chest X-ray.

Abbreviations
Severe acute respiratory syndrome (SARS); Middle East respiratory syndrome (MERS); Enzyme immunoassay (EIA); Enzyme-Linked Immunosorbent Assay (ELISA); Emergency department (ED); British Society of Thoracic Imaging (BSTI); American Society of Thoracic Radiology (STR).

1. Introduction

Coronaviruses, which are RNA viruses, have been known to cause respiratory infections in humans. Previous outbreaks of severe acute respiratory syndrome (SARS) in 2002 in China and the Middle East respiratory syndrome (MERS) in 2012 in Middle East countries were highly pathogenic strains of coronavirus, which were associated with increased infectivity[1]. COVID-19 first emerged in December 2019 when a cluster of patients in Wuhan, China, were diagnosed with pneumonia of an unknown etiology. The outbreak was determined to be caused by a novel coronavirus, which was later named SARS-CoV-2. COVID-19 was declared a pandemic by WHO on March 11, 2020.

The mode of transmission of the virus is via direct contact or respiratory droplets. Respiratory droplets usually spread when a person sneezes, coughs, talks, or even sings. Indirect transmission of the virus through contaminated or infected surfaces (fomites) also plays a role in the community spread of the disease[2]. The mean incubation period for COVID-19 is 5.2 days, with a range of 2-14 days. An infected person's potential to transmit the virus to another person is measured by R_0. It is the average number of people who will get the disease from one person with that disease. R_0 is 2.2 for SARS-CoV-2 meaning each existing infection causes more than one new infection [3]. COVID-19 is mostly associated with fever, cough, and fatigue at the onset of the disease. Headache, lymphopenia, or shortness of breath are other commonly associated symptoms[4]. Intestinal symptoms like diarrhea are less commonly associated with SARS-COV-2 when compared to SARS-CoV and MERS-CoV. Most patients have mild to moderate illness. Severe manifestations of the disease include severe pneumonia (respiratory distress, tachypnea, and hypoxia), acute respiratory distress syndrome (ARDS), sepsis, and other systemic complications[5]. People with at least one underlying condition, especially those aged 70 years or older, are more likely to have severe COVID-19 symptoms requiring hospital admission[6]. The spread of the virus from asymptomatic individuals or those within the incubation period has also been reported[7].

The identification of the disease is made through both clinical and laboratory parameters. Molecular testing using RT-PCR is done for upper respiratory specimens collected from oropharyngeal or nasopharyngeal samples and lower respiratory samples collected through sputum, broncho-alveolar lavage, or endotracheal aspirate. Despite the limited sensitivity and specificity, serology tests like rapid antigen and antibody tests are also used because of the quick turn-around time. Radiological imaging like chest X-ray, chest CT, and lung ultrasound is also used to assist with the disease's clinical diagnosis. High-resolution chest CT (HRCT) detects the early stage of the disease. The most common radiological findings include multifocal ground-glass appearance along with areas of consolidation[5].

2. Diagnostic tests of COVID-19

There are different specific and nonspecific diagnostic tests available for COVID-19.

2.1. Specific diagnostic tests

- RT-PCR: The gold standard diagnostic test of COVID-19 demonstrates SARS-CoV-2 RNA in respiratory samples[8]. RT-PCR is the specific diagnostic test that is used to confirm the presence of SARS-CoV-2 RNA in nasopharyngeal and oropharyngeal secretions. In the RT-PCR system, the RNA extracted from upper respiratory samples undergoes a reverse transcription step where RNA is converted into complementary DNA (cDNA). These cDNA will undergo amplification, and finally, fluorescent probes will recognize and hybridize segments of amplification products[9].
- Enzyme immunoassay (EIA) or Enzyme-Linked Immunosorbent Assay (ELISA): These tests are fast, simple, and safe assays used in infected patients. These tests detect IgM and IgG antibodies against SARS-CoV-2 nucleoprotein Rp3[10]. Different commercially available ELISA tests are Wantai SARS-CoV-2 total antibody ELISA, Euroimmun IgA ELISA, Euroimmun IgG ELISA. These tests are not used for diagnosing the acute phase of disease but for retrospective assessment of illness,

diagnosing asymptomatic patients, and close contacts of confirmed cases[11,12].

- Immunochromatographic tests (rapid tests): These are quick tests utilizing a patient sample like whole blood, serum, or plasma and specific buffer on an immunochromatographic stick[13]. Colloidal-Gold-Immunochromatographic Assay (GICA) and Lateral Flow immunoassays (LFA) are immunochromatographic tests[14,15]. These tests are useful for diagnosing large samples, identifying suspicious cases, and also useful for screening, monitoring COVID-19 in populations[13].
- Protein Microarray: This technique detects proteins in the specimen by antibodies immobilized on a surface. Whenever antibodies recognize proteins, there is an emission of a fluorescent signal that is captured and analyzed by equipment[16,17]. Microarray techniques are used to map antibodies, monitor immune response, develop diagnostic tests, vaccines, and identify new targets for the treatment of COVID-19[18].
- Chest CT: Typical imaging findings in most patients with COVID-19 are ground-glass opacities, mixed ground-glass opacity and consolidation, vascular enlargement in the lesion, and traction bronchiectasis[19].
- Chest X-ray: The most common chest X-ray finding in COVID-19 patients was peripheral ground -opacities seen in the lower lobes[20].

2.2 Nonspecific diagnostic tests

There are various nonspecific diagnostic findings of COVID-19. One can find leukopenia and lymphopenia in 80 % of CBC cases (complete blood count) along with decreased CD4, CD8 lymphocytes, and platelets[18].In severe COVID-19 disease, there have been observed changes in neutrophil-to-lymphocyte ratio and lymphocyte-to-C reactive protein ratio [21.] The following inflammatory markers are raised in patients with COVID-19: lactate dehydrogenase (LDH), erythrocyte sedimentation rate (ESR), C-reactive protein (CRP), aspartate aminotransferase (ASAT), troponin, ferritin, creatine kinase (CK) and D-dimer, and extended prothrombin time[18]. Cytokines like IL2, IL4, IL6, IL7, IL10, and tumor necrosis factor (TNF) are elevated in severely ill COVID-19 patients[18]. If sick, severely COVID-19 patients develop the severe acute respiratory syndrome, additional cytokines like CCL2, CCL3, CCL5, and CXCL10 are also released[18].

3. Indications for the chest X-ray or CT scan

COVID-19 associated lung involvement could vary from severe pneumonia to ARDS[22, 23]. The standard gold test for detecting COVID-19 is a real-time RT-PCR of viral nucleic acid[22]. The nucleic acids are detected in throat swabs, lower respiratory tract secretions, and blood. It has low efficiency due to the low viremia and unsuitable clinical sampling. False negatives from viral nucleic acid testing can occur due to instrument error, sampling error, and disease characteristics (asymptomatic patients). The RT-PCR role is limited. It can lead to several false negatives, thus urging the need for radiological evaluation of patients, especially in the emergency department (ED) for urgent lung involvement evaluation.

COVID-19 is very contagious, so early diagnosis carries supreme importance as the diseased individual's isolation is critical in controlling the global health emergency. Some patients may have negative results of initial RT-PCR but have suggestive imaging features of COVID-19 on chest imaging. Also, patients who had an initial negative test for COVID-19 can have positive later on a repeat swab. Thus, evidence of viral pneumonia on chest imagining may precede negative RT-PCR test results and serve as a warning signal. A combination of repeated swab tests and imaging can help in the early detection of COVID-19 with negative RT-PCR results[24,25].

A chest radiograph detects pneumonia, its location, and extension can also detect pleural effusions. In comparison, a CT has high sensitivity and detects conditions not detectable with a chest radiograph. The most common X-ray findings are interstitial and alveolar opacities having a multifocal peripheral pattern predominantly in the lower lung. However, variation can be there. These opacities can become confluent, and in extreme cases, the lung appears as "whited out"[26]. In more advanced cases, pleural effusions may form[27]. The more the disease progresses, the more opacities and consolidation are formed on chest radiographs[28].

Chest radiographs of COVID-19 are usually insensitive to detecting COVID-19 in the early stage. They may have some utility, with the potential to serve as a screening tool on the frontlines in medical settings with limited resources.

The radiological literature relating to COVID-19 signifies the superiority of CT over chest X-ray. CT scan has been found to have a higher sensitivity in diagnosing COVID-19 and is recommended as an essential tool in diagnosing and monitoring disease progression and follow up by the National Health Commission of China. Though RT-PCR is recognized as the gold standard in COVID-19 diagnosis, false negatives may ensue hence the alternative of CT Scan which has a higher sensitivity, however specificity is not assured. Timely application of CT Scan in patients with initially negative RT-PCR is of utmost importance, as CT findings may help guide the staging and evolution of COVID-19[29,30].

The National Health Commission of China's diagnosis and treatment protocol priorities CT scan as an essential imaging modality for diagnosing and monitoring progression and therapeutic efficacy[31]. Most Italian hospitals had employed chest X-ray as a primary method for diagnosing COVID-19, especially during the crisis when the number of critically ill patients was at large, and their mobility was restricted. Their physical condition did not allow for transport to the CT scanner[32-34].

Typical CT findings in COVID-19 patients are a bilateral distribution of ground-glass opacities (GGOs) with or without consolidation[35-37]. A CT scan has a higher spatial and contrast resolution when compared to a conventional chest X-ray. Miao et al. emphasized that these ground-glass opacities could assist in diagnosing SARS-CoV-2-related pneumonia, alerting the physicians to treat it in time and repeat the RT-PCR test until the end of the incubation[38]. Zhao and his colleagues also highlighted that ground-glass opacities are a hallmark of SARS-CoV-2-related pneumonia[39]. Fang et al. claims that chest CT's sensitivity was statistically more significant than RT-PCR (98% vs. 71%)[40]. However, the use of CT is tricky, especially in the Emergency Department, since it requires adequate decontamination. Therefore, in some low-risk regions and countries, the positive predictive value of CT alone or adding CT to RT-PCR should be adjusted.

4. International approach and practice

The British Society of Thoracic Imaging (BSTI) suggested that CT imaging is insignificant in the diagnosis of COVID-19 unless the patient is seriously ill (NEWS score >3) or the PCR cannot be done. The American Society of Thoracic Radiology (STR) says, "routine screening CT for the identification of COVID-19 pneumonia is currently not recommended by most radiology societies". The Fleischner Society has a similar approach. In China, computed tomography has been preferred over chest radiography. In the US and UK, diagnosis majorly relies on PCR. However, patients usually present to the hospital later in the course of the disease, and the chance of detecting COVID-19 changes on chest radiography is likely to be higher. In low resource settings where PCR is not readily available, chest X-ray is more available than CT.

5. Percentage of people having normal versus abnormal imaging

Sun et al. published a meta-analysis of 55 studies where positive COVID-19 chest imaging was reviewed[41]. Chest CT scan is not recommended as the first line of diagnosis in COVID-19 patients. It cannot detect pneumonia caused by any other etiology compared to that of COVID-19 ($p > 0.05$). As many as 26 of 55 (47.3%) studies reported a normal CT scan in positive COVID-19 patients. Positive COVID-19 chest imaging findings were as follow: 1) peripheral (65.35%, 95% CI: 25.93–100%) and peripheral plus central (31.12%, 95% CI: 1.96–74.07%) distribution were more likely than central distribution (3.57%, 95% CI: 0.99–9.80%); 2) ground-glass opacities (GGO) (58.05%, 95% CI: 16.67–100%) were most common findings; followed by consolidation (44.18%, 95% CI: 1.61–71.46%) and GGO plus consolidation (52.99%, 95% CI: 19.05–76.79%) amongst 52 of 55 (94.5%) of the studies. Less common findings reported were air bronchograms, linear opacities, crazy-paving pattern, and interlobular septal thickening.

Rodriguez-Morales et al. completed a systematic review of 19 studies published between January 1, 2020, and February 21, 2020, of studies published in China and Australia[42]. The study included 2874 patients, ranging from a case series of 9 patients to a cross-sectional study with 1,590 patients. The chest X-rays of positive COVID-19 patients presented predominantly bilateral pneumonia with GGO in 68.5% (95% CI 51.8-85.2) of the patients. A total of 39 case report articles were analyzed separately, summarizing 126 positive COVID-19 cases. Once again, GGO with bilateral compromise was the dominant finding in at least 46% of the patients. Salehi et al. also completed a systematic review of

30 studies (19 case series and 11 case reports) with a total of 919 patients[43]. All except one case report was from Korea, and the rest of the studies were from China. Chest CT was the imaging modality used in all selected studies. Bilateral GGO (88%), mostly peripheral (76%), and multilobar (more than one lobe, 78.8%) were the most common findings.

Borges do Nascimento et al. provided a scoping review of 60 studies, including case reports, case series and, epidemiological reports of 59,254 patients from 11 countries[44]. A total of 51 of 60 studies were included to analyze chest imaging findings. However, not all patients in these studies had received chest CT or X-Ray. Among the COVID-19 patients who received chest imaging, GGO was the most prevalent findings (n=1204), while only eight patients had normal chest CT.

6. Benefits of imaging in COVID-19 patients

The benefits of imaging in COVID-19 are dependent upon possible clinical results, therefore guiding management plans in diagnosis, triage, or therapeutics. The decision to use imaging in assessment for COVID-19 patients should be weighed against possible costs such as COVID-19 transmission to health care workers, risk of radiation exposure, PPE consumption, and maintenance of radiology rooms, especially in settings with constrained resources[45].

The use of imaging in COVID-19 is stratified based on the severity of the disease. Imaging is indicated in patients assessed to have moderate to severe clinical features of COVID-19 and worsening respiratory status. A patient with a mild clinical presentation is not advised to undergo imaging unless at risk for progression of COVID-19.

Among the different imaging modalities, a chest CT scan is the most sensitive in the initial diagnosis and management of suspected and confirmed COVID-19 patients. A benefit of a chest CT scan is the short examination duration due to high reproducibility and ease of use, which allows for reliable estimates of disease severity. With a chest CT scan, an initial diagnosis of COVID-19 is possible due to lung lesions' early characterization. Disease progression is also demonstrated by tracking the improvement of lung lesions via a chest CT scan while undergoing treatment. This was seen in patients recovering from COVID-19 pneumonia, as abnormalities in their chest, CT scans slowly decreased two weeks after being symptomatic[46].

Aljnodi and Alghamdi reported a study on CT imaging involving 1014 patients in Wuhan, China, which revealed 97% sensitivity, 25% specificity, 68% diagnostic accuracy, 65% positive predictive value, and 83% negative predictive value for identifying positive COVID-19 infection based on RT-PCR results as reference standards. There were significant lung abnormalities in some patients with initially negative RT-PCR results and abnormal chest CT scan findings in all patients with positive laboratory-confirmed COVID-19 infection. Li and Xia evaluated chest CT scan findings in COVID-19 patients confirmed by nucleic acid test and found a low 3.9% misdiagnosis rate of COVID-19 viral pneumonia[46]. These studies further confirm chest CT scan as the best imaging modality in the initial diagnosis of COVID-19, especially in areas with a short supply of RT-PCR testing kits. The use of chest CT scans and clinical and laboratory tests are helpful in early infection control and prompt initial management of suspected and confirmed COVID-19 patients.

Chest X-ray is the most commonly used imaging modality in diagnosing COVID-19 despite its low sensitivity in the early stages of infection. With RT-PCR results used as a gold standard, baseline chest X-rays were found to be at 69% in the accurate diagnosis of mild to moderate COVID-19 cases[46]. The chest X-rays usually have normal lung appearance and often have no significant abnormalities in patients in the early stages of COVID-19. Aljnodi and Alghamdi cited a report by Wong et al. that revealed that significant chest x-ray findings appeared 10-12 days after the onset of symptoms in COVID-19 patients. Though not the first-line option, the use of portable chest X-rays is encouraged for the diagnosis and management of patients highly suspicious for COVID-19 due to cost-effectiveness and easy accessibility[46]. Mobile chest X-ray units are advised as they hamper the spread of infection in radiology rooms.

The diagnostic value of imaging is emphasized when varying issues are encountered in the clinical setting, and virus detection becomes difficult. These issues include but are not limited to irregular sampling, short supply of RT-PCR test kits, laboratory error, insufficient material in the viral specimen, improper extraction of nucleic acid from clinical materials, contamination of sample, false-negative results, and other technical issues[47]. Given such unforeseen circumstances may occur, imaging's benefits further strengthen its diagnostic value as an essential tool for suspected and confirmed COVID-19 patients.

7. Distinguishing between COVID-19 and other respiratory infections

Currently, the definitive diagnosis of COVID-19 infection requires RT-PCR testing, laboratory analysis of blood, nose and throat samples, specialist equipment, and usually takes at least 24 hours to produce a result (though some laboratories may process a stat request and release a RT-PCR result in 6-12 hours). Albeit being the standard test, RT-PCR is not entirely accurate, and a second RT-PCR or another diagnostic test may be required to confirm the diagnosis. COVID-19 respiratory infection causes a set of symptoms including fever, cough, and in severe cases, dyspnea. Such severe cases may lead to an impending acute respiratory distress syndrome-like presentation which necessitates clinicians to use other diagnostic modalities like chest imaging for early diagnosis and management of COVID-19 disease while awaiting RT-PCR test results. Chest imaging is widely used for aiding in the diagnosis of COVID-19, which includes chest X-ray, chest CT scan, and thoracic ultrasonography[48]. In contrast, the latter lacks statistically significant data to support its effectiveness.

In a systematic review and meta-analysis, Altmayer S.et al included observational studies and case series with more than ten immunocompetent patients who were ≥ 16 years of age; among these 1911 patients, 934 were RT-PCR positive for COVID-19 and 977 were non-COVID patients that tested positive for other viral respiratory infections including, influenza A, adenovirus, rhinovirus, respiratory syncytial virus or parainfluenza. All these patients underwent a chest CT scan to differentiate between the clinical findings of COVID-19 and that of other respiratory viral illnesses, however imaging in COVID-19 cannot be reliant on a specific diagnostic tool alone due to the lack of a clear delineation between COVID-19, and non-COVID-19 diseases. There is still the present inability of various imaging modalities to differentiate COVID-19 apart from other non-COVID-19 respiratory infections.

Frequent CT features for both COVID-19 and non-COVID viral pneumonia were a mixed pattern of consolidation and ground-glass opacity (GGO) or predominantly GGO pattern with bilateral distribution and more involvement of lower lobes. COVID-19 pneumonia presented a higher prevalence of peripheral, with the involvement of upper and middle lobes[49]. Hence, the clinical picture of COVID-19 and non-COVID respiratory illnesses, including viral pneumonia, does not differ based on Chest CT imaging and only shows a certain predilection towards peripheral distribution and involvement of upper and middle lobes of the lung in patients with COVID-19.

It should therefore be recommended that imaging methods are used with other diagnostic modalities, such as RT-PCR. Though RT-PCR is the current gold standard in diagnosing COVID-19, it should not be the sole criterion for diagnosis, treatment and management of patients. In diagnosing a suspected COVID-19 patient, the combination of RT-PCR, clinical features, and medical imaging evaluation (i.e. chest radiography, chest CT-Scan) will increase the likelihood of an accurate facilitation of proper patient management.

The reliability of chest radiography comes into question due to multiple factors, one of which is limited to performing the test during the disease. Wong. HYF et al. completed a retrospective case series in Hong Kong on 64 COVID-19 positive hospitalized patients and found that 31% (20 patients) had normal chest radiographs on admission. Of these patients, 35% (n=7) developed radiographical changes on follow-up radiography[50-52]. Four patients did not develop any abnormality on a chest X-ray but one of them had ground-glass opacities on chest CT [50,51]. This study not only suggested that the radiological severity on chest radiography is seen at days 10-12 of onset of symptoms[51] but also, on the basis of this study, it was stated by the multinational consensus statement from the Fleischer Society for thoracic radiology that during mild or early COVID-19 infection, chest radiography can be insensitive[50-52]. Hence thoracic radiological imaging may be normal in up to 63% of people with COVID-19 pneumonia, particularly in the early stages[51,53-56].

Among the Thoracic imaging clinical finds of COVID-19, the most common early presentation is ground-glass appearance and may precede the appearance of consolidation [50,51,57]. However,

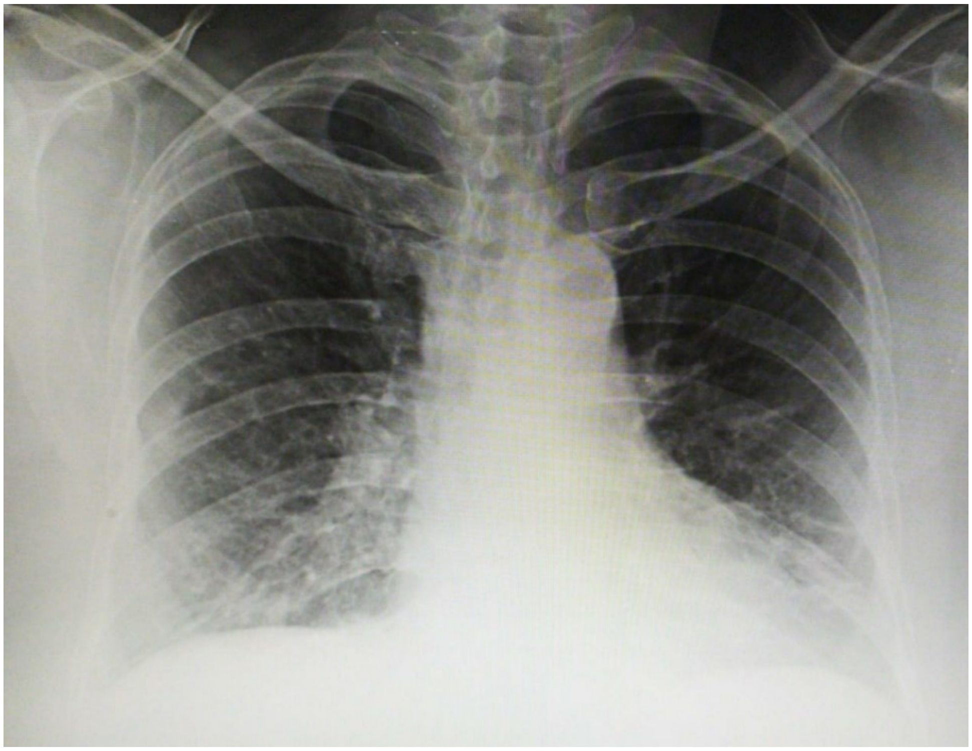

Figure 1. **Chest X-ray of a COVID-19 patient**
Prominent bronchovascular markings with patch ground-glass soft tissue opacities are seen at bilateral mid-lower zones. Reproduced with permission from reference[61].

Changes include ground-glass opacities (68.5%)[42,50], coarse horizontal linear opacities, and consolidation[50,57] that are commonly seen pathological findings in COVID-19 are very nonspecific, if not coupled with RT-PCR positive COVID-19 status and not correlated with the clinical signs symptoms exhibited by the patient-relevant to COVID-19. As these radiological findings are individually nonspecific, they cannot help distinguish between COVID-19 or any other respiratory illness, warranting the clinician to rule out other differential diagnosis pertinent to the appearance of these findings such as atypical pneumonia, invasive aspergillosis, pulmonary edema, pulmonary aspiration, inflammatory lung diseases (such as pulmonary eosinophilia), vasculitides (e.g., granulomatosis with polyangiitis), bleeding and lung cancer[50]. Consequently, chest imaging alone does not suffice as a single diagnostic modality for patients infected with COVID-19.

8. Hazards of using hospital equipment on COVID-19 patients

Imaging machines require decontamination continually after each patient as given the mode of transmission of the novel coronavirus, COVID-19. During the SARS outbreak in 2003 originating from southern China, the radiology departments globally had turned to widely available disinfectants like bleach and formaldehyde to disinfect imaging equipment surfaces[58]. The emergence of the COVID-19 pandemic has led to lots of discomfort amongst patients and healthcare workers in managing fever versus non-fever patients, as the patients with fever are primarily under investigation for COVID-19[59]. The pandemic has created immense practical and ergonomic problems within hospitals amongst hospital staff and patients[59]. Due to the high virus transmission rate, there comes a desperate demand to protect the healthcare workers,

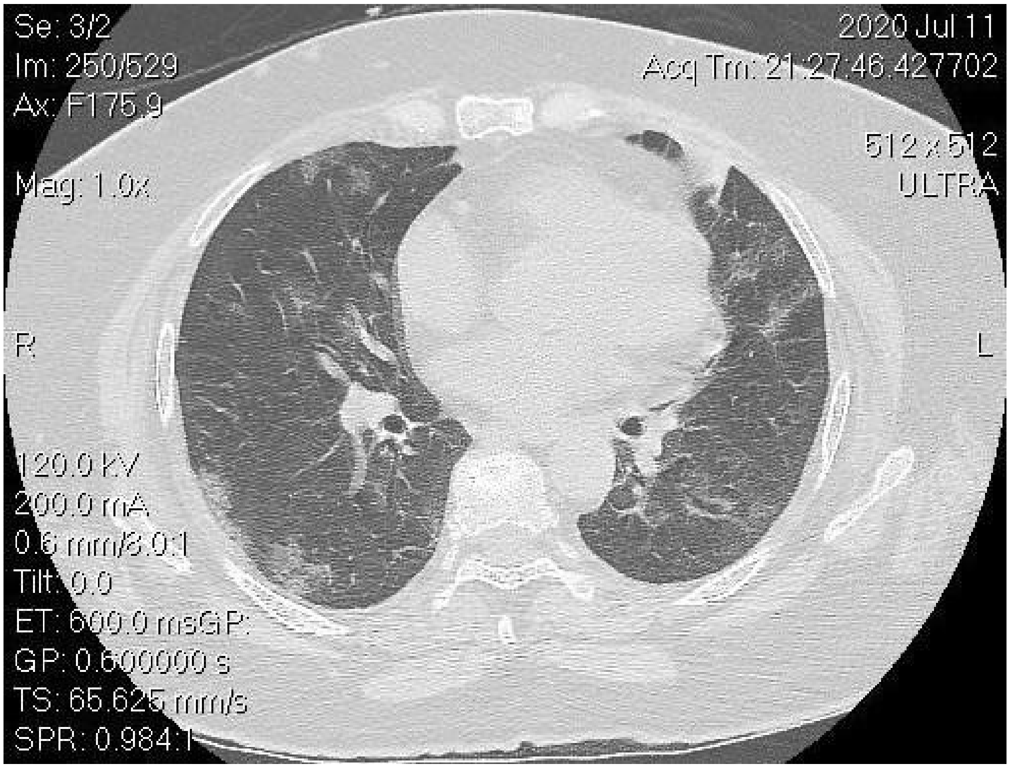

Figure 2. A high-resolution chest CT of a COVID-19 patient
Viral pneumonitis, with bilateral asymmetrical patchy peripheral pleural based ground-glass opacities with early inter and intralobular wall thickening are seen involving all lobes of both lungs, predominantly involving bilateral lower lobes. Reprinted with permission from reference[61].

in-patients and out-patients, and other visitors at the hospitals in the wake of the COVID-19 pandemic.

COVID-19 primarily targets the respiratory system and pneumonia is one of the main manifestations of this disease, an imaging test is necessary to keep track of disease progression and check for severity in COVID-19 infection[58]. However, COVID-19 infection being highly contagious, cross-infection is highly possible amongst patients and hospital staff who undergo scans and manage radiology machines, respectively[60]. Zhao Y. et al. mentions in their paper that their hospital has set up a separate CT scanner for infected individuals[60]. This is an excellent move as this helps keep the non-COVID-19 individuals and protects the COVID-19 infected individuals. They further mention that they also changed the layout of their Radiology department and changed it to three areas[60]. This is indeed a brilliant move as these three areas included a) contaminated area, b) potentially toxic area and c) clean area[60]. The Radiologic department staff uses the clean area first to put on their personal protective equipment, then go through two buffer rooms, eventually to the potentially contaminated site, and end with the scanning of the infected patients in the CT control room (a contaminated area). Two passages lead to this CT scan room, of course, one being the medical personnel passage and the other being the patient passage[60].

Furthermore, they also had two buffer rooms between the potentially contaminated area and the clean area to ensure the Radiologic personnel's safety[60]. Moreover, they put further emphasis on Personal Protective Equipment (PPE) as the operators performing Biosafety Level (BSL)-2 should wear a cap, surgical mask, respirator, protective glass, isolation gowns, gloves, shoe covers, and disposable gowns at the same time the operators must strictly enforce hand hygiene. BSL-1 adds a face shield[60]. They list PPEs and also include instructions on how to put on and remove PPE[60].

KEY POINTS

◊ *The use of imaging has an indispensable value, from early detection to monitoring the disease progression.*

◊ *Given the short examination time, easy availability, and fast turnover of results, the use of imaging in COVID-19 is of enormous benefit and can serve as a warning of disease progression preceding the RT-PCR test result.*

◊ *Due to SARS-CoV-2's highly contagious nature, it is best to maintain proper decontamination protocols, which can help reduce the transmission of the virus within the hospital setting due to radiology equipment use amongst patients. This also helps in keeping patients as well as the hospital staff safe.*

The disposable sheets are disposed of in a particular trash bin after the X-ray is taken. The technologist also maintains minimal contact with the patient; however, the technologist does not change the PPE[60].To achieve disinfection, they have daily air disinfection, surface wiping disinfection, and floor disinfection.

The UV lamps are present in the contaminated area, potentially contaminated sites, buffer rooms, and clean place. During air disinfection, the air conditioners are switched off. To achieve surface wiping disinfection, they use 1000 mg/L chlorine disinfectant to wipe and disinfect the surface. After this, they use a soft cloth dipped with clean water to clean the residual chlorine disinfectant on the device's surface and then dry it naturally. To wipe non-corrosive surfaces (such as the CT scanner including gantry and scanner table), they use 75 % ethanol to wipe and disinfect the surface. After disinfection with ethanol, it is let to be dried naturally[60]. This process is carried out twice a day. They were disinfecting the floor where the ground is wiped with 1000 mg/L of chlorine-containing disinfectant, at least twice a day. In short, there are specific hazards associated with using hospital equipment in COVID-19 patients which can not only infect other hospital staff, patients, and visitors but it can also equally be distressing for the COVID-19 patients psychologically due to the additional steps taken to achieve one radiologic test as well as physically. However, imaging, such as X-ray (Figure 1) or CT scan (Figure 2) is a must in COVID-19 patients, and it shouldn't be disregarded. Therefore, the above-discussed points are crucial to consider in carrying out safe radiologic evaluations in COVID-19 patients.

9. Conclusion

There is a significant overlap in the chest CT findings of COVID-19 pneumonia and other viral pneumonia and the resources comparing them are limited. However, despite the overlap, the clinical history of the patient combined with RT-PCR can improve diagnostic accuracy.

Conflict of Interest

The authors declare that there are no conflicts of interest.

Acknowledgements

We thank and acknowledge Kinal Bhatt MD, MPH, Niravkumar Godhani MBBS, Ghanshyam Motisariya MD, Maulik Lathiya MBBS, for providing X-ray and chest CT imaging of their consented patient diagnosed with COVID-19 and imaging interpretation in support of the manuscript. We also thank Mr. Madhuri Devi for style and grammar corrections of the manuscript.

References

1. Cui J, Li F, Shi ZL. Origin and evolution of pathogenic coronaviruses. Nat Rev Microbiol. 2019 Mar;17(3):181-192.
2. Karia R, Gupta I, Khandait H, Yadav A, Yadav A. COVID-19 and its Modes of Transmission. SN Compr Clin Med. 2020;1-4.
3. Li Q, Guan X, Wu P, Wang X, Zhou L, Tong Y et al. Early Transmission Dynamics in Wuhan, China, of Novel Coronavirus-Infected Pneumonia. N Engl J Med. 2020 Mar 26;382(13):1199-1207.
4. Rothan HA, Byrareddy SN. The epidemiology and pathogenesis of coronavirus disease (COVID-19) outbreak. Journal of Autoimmunity 2020; 109:102433.

5. Ahluwalia AS, Qarni T, Narula N, Sadiq W, Chalhoub MN. Bilateral pneumothorax as possible atypical presentation of coronavirus disease 2019 (COVID-19) Respir Med Case Rep. 2020;31:101217.
6. Clark, A., Jit, M., Warren-Gash, C., Guthrie, B., Wang, H. H. X et al. Global, regional, and national estimates of the population at increased risk of severe COVID-19 due to underlying health conditions in 2020: a modeling study. The Lancet Global Health. 2020;8: e1003–e1017.
7. Waleed MS, Sadiq W, Azmat M. Understanding the Mosaic of COVID-19: A Review of the Ongoing Crisis. Cureus. 2020 Mar 22;12(3):e7366.
8. Pan Y, Yu X, Du X, Li Q, Li X, Qin T et al. Epidemiological and clinical characteristics of 26 asymptomatic SARS-CoV-2 carriers. The Journal of Infectious Diseases. 2020; 221(12).
9. Corman VM, Landt O, Kaiser M, Molenkamp R, Meijer A, Chu DK et al. Detection of 2019 novel coronavirus (2019-nCoV) by real-time RT-PCR. Eurosurveillance. 2020; 25(3):2000045.
10. Lassaunière R, Frische A, Harboe ZB, Nielsen AC, Fomsgaard A, Krogfelt KA et al. Evaluation of nine commercial SARS-CoV-2 immunoassays. Medrxiv. 2020 Jan 1.
11. Guo L, Ren L, Yang S, Xiao M, Chang D, Yang F et al. Profiling early humoral response diagnose novel coronavirus disease (COVID-19). Clinical Infectious Diseases. 2020 March 21.
12. Centers for Disease Control and Prevention Overview of testing for SARS-CoV-2. [cited 2020 Oct 30]. https://www.cdc.gov/coronavirus/2019-nCoV/hcp/clinical-criteria.html.
13. Chen Z, Zhang Z, Zhai X, Li Y, Lin L, Zhao H et al. Rapid and Sensitive Detection of anti-SARS-CoV-2 IgG, Using Lanthanide-Doped Nanoparticles-Based Lateral Flow Immunoassay. Analytical chemistry. 2020 Apr 23;92(10):7226-31.
14. Pan Y, Li X, Yang G, Fan J, Tang Y, Zhao J et al. Serological immunochromatographic approach in diagnosis with SARS-CoV-2 infected COVID-19 patients. Journal of Infection. 2020; 81(1):E28-E32.
15. Li Z, Yi Y, Luo X, Xiong N, Liu Y, Li S et al. Development and clinical application of a rapid IgM-IgG combined antibody test for SARS-CoV-2 infection diagnosis. Journal of Medical Virology. 2020 February 27.
16. Sutandy FR, Qian J, Chen CS, Zhu H. Overview of protein microarrays. Current protocols in protein science. 2013 Apr;72(1):27-1.
17. Chen Z, Dodig-Crnković T, Schwenk JM, Tao SC. Current applications of antibody microarrays. Clinical proteomics. 2018;15(1):7.
18. Oliveira BA, Oliveira LC, Sabino EC, Okay TS. SARS-CoV-2 and the COVID-19 disease: a mini-review on diagnostic methods. Revista does Instituto de Medicina Tropical de Sao Paulo. 2020;62.
19. Zhao W, Zhong Z, Xie X, Yu Q, Liu J. Relation between chest CT findings and clinical conditions of coronavirus disease (COVID-19) pneumonia: a multicenter study. American Journal of Roentgenology. 2020;214(5):1072-7.
20. Rousan LA, Elobeid E, Karrar M, Khader Y. Chest x-ray findings and temporal lung changes in patients with COVID-19 pneumonia. BMC Pulmonary Medicine. 2020 Dec;20(1):1-9.
21. Lagunas-Rangel FA. Neutrophil-to-lymphocyte ratio and lymphocyte-to-C-reactive protein ratio in patients with severe coronavirus disease 2019 (COVID-19): A meta-analysis. Journal of Medical Virology. 2020 April 3.
22. Wang C, Horby PW, Hayden FG, Gao GF. A novel coronavirus outbreak of global health concern. Lancet. 2020;395(10223):470–473.
23. Chen N, Zhou M, Dong X, Qu J, Gong F, Han Y et al. Epidemiological and clinical characteristics of 99 cases of 2019 novel coronavirus pneumonia in Wuhan, China: a descriptive study. Lancet. 2020 Feb 15;395(10223):507-513.
24. Xie X, Zhong Z, Zhao W, Zheng C, Wang F, Liu J. Chest CT for Typical Coronavirus Disease 2019 (COVID-19) Pneumonia: Relationship to Negative RT-PCR Testing. Radiology. 2020 Aug;296(2):E41-E45. doi: 10.1148/radiol.2020200343.
25. Huang P, Liu T, Huang L, Liu H, Lei M, Xu W et al. Use of Chest CT in Combination with Negative RT-PCR Assay for the 2019 Novel Coronavirus but High Clinical Suspicion. Radiology. 2020 Apr;295(1):22-23.
26. Chinese Medical Association Radiology Branch Radiological diagnosis of new coronavirus pneumonia: expert recommendations from the Chinese Medical Association Radiology Branch (first edition) Chin J Radiol. 2020;54(00): E001–E001.
27. Zhu N, Zhang D, Wang W, Li X, Yang B, Song J et al China Novel Coronavirus Investigating and Research Team. A Novel Coronavirus from Patients with Pneumonia in China, 2019. N Engl J Med. 2020 Feb 20;382(8):727-733.
28. Phan LT, Nguyen TV, Luong QC, Nguyen TV, Nguyen HT, Le HQ et al. Importation and Human-to-Human Transmission of a Novel Coronavirus in Vietnam. N Engl J Med. 2020;382(9):872-874.
29. Zuo H. Contribution of CT features in the diagnosis of COVID-19. Vassilakopoulos TI, ed. Can Respir J. 2020; 2020: 1-16.

30. Zhou A, Wang Y, Zhu T, Xia L. CT Features of Coronavirus Disease 2019 (COVID-19) Pneumonia in 62 Patients in Wuhan, China. AJR Am J Roentgenol. 2020 Jun;214(6):1287-1294
31. National Health Commission of the People's Republic of China The diagnostic and treatment protocol of COVID-19. China. 2020. http://www.gov.cn/zhengce/zhengceku/2020-02/19/content_5480948.html.
32. Giovagnoni A. Facing the COVID-19 emergency: we can and we do. Radiol Med. 2020 Apr;125(4):337-338.
33. Neri E, Miele V, Coppola F, Grassi R. Use of CT and artificial intelligence in suspected or COVID-19 positive patients Statement of the Italian Society of Medical and Interventional Radiology. Radiol Med. 2020:1-4.
34. ACR recommendations for the use of chest radiography and computed tomography (CT) for suspected COVID-19 infection. American College of Radiology. https://www.acr.org/Advocacy-and-Economics/ACR-Position-Statements/Recommendations-for-Chest-Radiography-and-CT-for-Suspected-COVID-19-infection.
35. Hui J.Y.-H., Hon TY, Yang MK, Cho DH, Luk WH, Chan RY et al. High-resolution computed tomography is useful for early diagnosis of severe acute respiratory syndrome-associated coronavirus pneumonia in patients with normal chest radiographs. J Comput Assist Tomogr. 2004 Jan-Feb;28(1):1-9.
36. Wei J, Xu H, Xiong J, Shen Q, Fan B, Ye C et al. 2019 Novel Coronavirus (COVID-19) Pneumonia: Serial Computed Tomography Findings. Korean J Radiol. 2020 Apr;21(4):501-504.
37. Xu Y-H., Dong JH, An WM, Lv XY, Yin XP, Zhang JZ et al. Clinical and computed tomographic imaging features of novel coronavirus pneumonia caused by SARS-CoV-2. J Infect. 2020 Apr;80(4):394-400.
38. Miao C, Jin M, Miao L, Yang X, Huang P, Xiong H et al. Early chest computed tomography to diagnose COVID-19 from suspected patients: A multicenter retrospective study. Am J Emerg Med. 2020 Apr 19:S0735-6757(20)30281-3.
39. Zhao W, Zhong Z, Xie X, Yu Q, Liu J. Relation Between Chest CT Findings and Clinical Conditions of Coronavirus Disease (COVID-19) Pneumonia: A Multicenter Study. AJR Am J Roentgenol. 2020 May;214(5):1072-1077.
40. Fang Y, Zhang H, Xie J, Lin M, Ying L, Pang P et al. Sensitivity of Chest CT for COVID-19: Comparison to RT-PCR. Radiology. 2020 Aug;296(2):E115-E117.
41. Sun Z, Zhang N, Li Y, Xu X. A systematic review of chest imaging findings in COVID-19. Quant Imaging Med Surg. 2020 May;10(5):1058-1079.
42. Rodriguez-Morales AJ, Cardona-Ospina JA, Gutiérrez-Ocampo E, Villamizar-Peña R, Holguin-Rivera Y, Escalera-Antezana JP et al. Clinical, laboratory and imaging features of COVID-19: A systematic review and meta-analysis. Travel Med Infect Dis. 2020;34:101623.
43. Salehi S, Abedi A, Balakrishnan S, Gholamrezanezhad A. Coronavirus Disease 2019 (COVID-19): A systematic review of imaging findings in 919 patients. American Journal of Roentgenology. 2020; 215: 87-93.
44. Borges do Nascimento IJ, Cacic N, Abdulazeem HM, von Groote TC, Jayarajah U, Weerasekara I, Esfahani Ma et al Novel Coronavirus Infection (COVID-19) in Humans: A Scoping Review and Meta-Analysis. J Clin Med. 2020 Mar 30;9(4):941.
45. Rubin GD, Ryerson CJ, Haramati LB, Sverzellati N, Kanne JP, Raoof S, Schluger NW et al The Role of Chest Imaging in Patient Management During the COVID-19 Pandemic: A Multinational Consensus Statement From the Fleischner Society. Chest. 2020 Jul;158(1):106-116.
46. Aljondi R, Alghamdi S. Diagnostic Value of Imaging Modalities for COVID-19: Scoping Review. J Med Internet Res. 2020 Aug 19;22(8):e19673.
47. Yang W, Sirajuddin A, Zhang X et al. The role of imaging in 2019 novel coronavirus pneumonia (COVID-19). Eur Radiol 2020;30:4874–4882.
48. Salameh JP, Leeflang MM, Hooft L, Islam N, McGrath TA, van der Pol CB, Frank RA et al Cochrane COVID-19 Diagnostic Test Accuracy Group, McInnes MD. Thoracic imaging tests for the diagnosis of COVID-19. Cochrane Database Syst Rev. 2020 Sep 30;9:CD013639. Update in: Cochrane Database Syst Rev. 2020 Nov 26;11:CD013639.
49. Altmayer S, Zanon Z, Pacini GS, Watte G, et al. comparison of the computed tomography findings in COVID-19 and other viral pneumonia in immunocompetent adults: a systematic review and meta-analysis. Eur Radiol. 2020 June 27: 1–12.
50. Cleverley J, Piper J, Jones MM. The role of chest radiography in confirming covid-19 pneumonia. BMJ. 2020 Jul 16;370:m2426.
51. Wong HYF, Lam HYS, Fong AH-T, et al. Frequency and distribution of chest radiographic findings in covid-19 positive patients. Radiology 2020; 295(2).

52. Rubin GD, Ryerson CJ, Haramati LB, et al. The role of chest imaging in patient management during the COVID-19 pandemic: a multinational consensus statement from the Fleischner Society. Radiology 2020; 296:172-80.
53. Fu L, Wang B, Yuan T, Chen X, Ao Y, Fitzpatrick T et al Clinical characteristics of coronavirus disease 2019 (COVID-19) in China: A systematic review and meta-analysis. J Infect. 2020 Jun;80(6):656-665.
54. Yoon SH, Lee KH, Kim JY, et al. Chest radiographic and CT findings of the 2019 novel coronavirus disease (COVID-19): analysis of nine patients treated in Korea. Korean J Radiol 2020; 21: 494-500.
55. Chen T, Wu D, Chen H, et al. Clinical characteristics of 113 deceased patients with coronavirus disease in 2019: a retrospective study. BMJ 2020; 368:m1091.
56. Ng M-Y, Lee EYP, Yang J, Yang F, Li X, Wang H et al Imaging Profile of the COVID-19 Infection: Radiologic Findings and Literature Review. Radiol Cardiothorac Imaging. 2020 Feb 13;2(1):e200034.
57. Jacobi A, Chung M, Bernheim A, Eber C. Portable chest X-ray in coronavirus disease-19(COVID-19): A pictorial review. Clin Imaging 2020;64:35-42.
58. Kooraki S, Hosseiny M, Myers L, Gholamrezanezhad A. Coronavirus (COVID-19) Outbreak: What the Department of Radiology Should Know. J Am Coll Radiol. 2020 Apr;17(4):447-451.
59. Qu J, Yang W, Yang Y, Qin L, Yan F. Infection Control for CT Equipment and Radiographers' Personal Protection During the Coronavirus Disease (COVID-19) Outbreak in China. AJR Am J Roentgenol. 2020 Oct;215(4):940-944.
60. Zhao Y, Xiang C, Wang S, Peng C, Zou Q, Hu J. Radiology department strategies to protect radiologic technologists against COVID19: Experience from Wuhan. Eur J Radiol. 2020 Jun;127:108996.
61. Bhatt K, Lathiya M, Godhani N, Motisariya G, Sanchez-Gonzalez M. COVID-19 pandemic in Dengue endemic areas: A case report. Open J Clin Med Case Rep. 2020; 1700.