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Radiological manifestations of COVID-19 variants and their impact on patient management

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***Abstract*---**Background: The COVID-19 pandemic has significantly impacted the field of radiology, leading to changes in the utilization and application of various imaging modalities. Initially, chest computed tomography (CT) was widely employed for screening and diagnosing COVID-19. However, the current recommendation is to use CT primarily for high-risk patients, individuals with severe disease, or in regions where polymerase chain reaction (PCR) testing is not widely accessible. Aim of Work: The aim of this research paper is to examine the evolving role of radiology, particularly chest radiography, in the management of COVID-19 patients, as well as to highlight the operational changes and technological advancements that have been implemented in the field of radiology during the pandemic. Methods: This research paper is a comprehensive review of the existing literature on the changing role of radiology in the COVID-19 pandemic. It synthesizes the available information on the utilization of various imaging modalities, such as chest radiography and CT, for the screening, diagnosis, and monitoring of COVID-19 patients. Additionally, it explores the operational changes and technological advancements that have been implemented in the field of radiology to address the challenges posed by the pandemic. Results: The results of this review indicate that chest radiography has become the primary imaging modality for monitoring the progression of COVID-19 in hospitalized patients who exhibit signs of clinical deterioration. The use of teleradiology and virtual care clinics has significantly improved the capacity to practice social distancing, and these technologies are expected to continue playing crucial roles in the delivery of diagnostic imaging and patient care. Conclusion: The COVID-19 pandemic has led to significant changes in the role and utilization of radiology. While chest CT was initially employed for screening and diagnosis, it is now primarily recommended for high-risk patients or in regions with limited access to PCR testing. Chest radiography has become the main imaging modality for monitoring disease progression in hospitalized COVID-19 patients. Additionally, the implementation of teleradiology and virtual care clinics has enhanced the delivery of diagnostic imaging and patient care, and these advancements are likely to continue in the future. As our understanding of the virus's pathophysiology and risk factors for complications deepens, there will be increasing opportunities to improve the use of imaging in detecting extrapulmonary manifestations and complications of COVID-19.

***Keywords*---**Radiology, COVID-19, Chest radiography, Teleradiology, Virtual care.

Introduction

In December 2019, the initial accounts of respiratory infections caused by a new kind of coronavirus were documented [1]. The virus, currently identified as severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), rapidly disseminated worldwide, leading to the emergence of coronavirus disease-2019 (COVID-19). On March 11, 2020, the World Health Organization formally declared it a global pandemic [2]. As of now, there have been over 100 million confirmed cases and 2.2 million deaths globally due to COVID-19. Currently, it ranks as the third most common cause of mortality in the United States, following cancer and cardiovascular disease. It is responsible for over 27 million illnesses and over 440,000 deaths in the country [3,4].

Since the beginning of the pandemic, radiographic imaging has been crucial in the diagnosis and treatment of COVID-19. Nevertheless, the function of imaging has transformed over the course of the pandemic. This review aims to discuss the changing role of imaging in the diagnosis and treatment of COVID-19. Furthermore, our objective is to examine the existing status of severity grading systems for COVID-19 in medical imaging, analyze the practical difficulties and readiness measures in response to COVID-19 within the radiology profession, and explore the potential prospects and future advancements of radiological imaging in relation to COVID-19.

The Role of Radiologists

During the beginning of the pandemic, imaging techniques like as chest radiography (CXR) and chest computed tomography (CT) were mainly used for diagnosing and screening COVID-19 [5]. The limited availability of real-time polymerase chain reaction (RT-PCR) assays was due to ongoing development and lack of widespread distribution [6,7]. The sensitivity of chest CT was shown to be higher than that of CXR (95% vs 69%). However, the decision to adopt either of these imaging techniques is not exclusively based on their sensitivities. Other factors such as the availability of each technology and the potential risk of exposing personnel to other individuals throughout the study also play a role [5]. Moreover, initial findings indicated that chest CT scans had a high level of sensitivity in detecting COVID-19 in patients, which led to the recommendation of using it as a screening tool [8]. On the other hand, a subsequent study conducted by Bernheim et al [9] found that out of 121 individuals assessed within two days of symptom onset, all except one patient tested positive for RT-PCR but had negative chest CT results.

With the increased availability of testing kits in communities, the importance of imaging as the main method for diagnosing and screening COVID-19 decreased in comparison to RT-PCR [7]. The Fleischner Society recently issued a consensus statement outlining specific situations in which imaging may be used in COVID-19 patients and when radiologists should be consulted. The decision to use imaging depends on factors such as the severity of the disease, the likelihood of infection before testing, and the availability of necessary resources like personal protective equipment, testing kits, and staff.

Imaging is recommended for patients with confirmed or suspected COVID-19 in specific situations. These situations include: patients who have tested positive for COVID-19 or have a high likelihood of having the disease, but have not been tested, and have risk factors that increase the chances of disease progression (such as being over 65 years old, having a weakened immune system, or having other health conditions like diabetes, hypertension, chronic lung disease, or cardiovascular disease); patients with moderate to severe symptoms of COVID-19, regardless of their test results; and patients with moderate to severe symptoms in areas where COVID-19 is widespread and testing resources are limited, regardless of their test results. Figures1 and 2 provide a full description of a revised algorithm that is specifically designed for the imaging process involved in the evaluation and treatment of COVID-19 disease.

Radiologists and medical imaging have played a crucial role in the screening and diagnosis of patients with COVID-19. Additionally, they have been essential in monitoring the evolution of the disease, predicting the outcome, assessing the response to treatment, and establishing the severity of the disease [10]. Aside from chest X-ray (CXR) and chest computed tomography (CT), other imaging techniques like ultrasound, magnetic resonance imaging (MRI), and 18F-fluorodeoxyglucose (18F-FDG) positron emission tomography (PET) have been documented for their utility in the treatment of COVID-19 patients. In the following text, we will provide a detailed description of the many imaging techniques employed for COVID-19 patients. This will include information about their specific uses, benefits, drawbacks, as well as the distinct characteristics of the disease that may be observed through each modality.

Present Situation

Chest X-ray (CXR)

Chest X-ray (CXR) is well recognized as a cost-effective and readily available imaging technique. As a result, it is frequently employed as the first step in evaluating patients suspected of having COVID-19. The overall sensitivity of chest X-ray (CXR) is between 69% and 74%, with a reduced sensitivity during the early stages of the disease [1]. Additionally, its high portability renders it advantageous for people who are unable to move or confined to bed. CXR can also be utilized to conveniently track the advancement of a sickness and may be employed for patients who are displaying indications of deteriorating clinical condition while in the hospital [10,11]. The utility of chest X-ray (CXR) also lies in assessing for alternative illnesses that may manifest with symptoms resembling those of COVID-19.

The pulmonary imaging findings on chest X-ray (CXR) closely resemble those shown on computed tomography (CT) scans. These findings are often bilateral, located towards the back and outer regions of the lungs, with a higher concentration in the lower lung areas. The most frequently observed abnormalities in the interstitial region are reticular and reticulonodular patterns. The most frequently observed findings in the alveolar region are hazy pulmonary opacities that resemble the ground-glass opacities (GGOs) detected on CT scans. These can be accompanied with or without consolidation [12,13]. The advancement of the disease can be detected by the pulmonary opacities becoming more widespread and the interstitial markings thickening. The most pronounced indications of illness are evident 10-12 days following the onset of symptoms [14].

Computed Tomography

The sensitivity of chest CT for COVID-19 is 94%, meaning it correctly identifies 94% of positive cases. The specificity is 37%, indicating that it accurately identifies 37% of negative cases. The positive predictive value ranges from 1.5% to 30.7%, meaning that the likelihood of a positive result being a true positive is within that range. The negative predictive value ranges from 95.4% to 99.8%, indicating the likelihood of a negative result being a true negative is within that range. Therefore, in regions with a low incidence of COVID-19, employing CT scans will result in a higher occurrence of incorrect positive results. Nevertheless, due to its heightened sensitivity, it may be justifiable to employ it when there is a high occurrence of the disease and a negative or inaccessible PCR test [15,16].

The exceptional sensitivity of chest CT enables radiologists to identify cases of COVID-19 in patients who are undergoing CT scans for other reasons. This enables the timely identification and control of the virus in individuals who do not exhibit any symptoms, estimated to be between 18% and 33% of persons infected with SARS-CoV-2 [17-19]. Moreover, CT can be employed to assess specific consequences arising from COVID-19 that may not be detectable on CXR, including pulmonary thromboembolism, lung abscesses, acute respiratory distress syndrome (ARDS), myocarditis, and acute lung edema [20,21]. Although CT scans offer enhanced sensitivity, higher resolution, and improved clarity in detecting both pulmonary and extrapulmonary manifestations, it is crucial to acknowledge that their use requires more hospital staff and personal protective equipment. This leads to increased costs and a greater risk of transmission to hospital employees [22].

The two most often observed pulmonary findings on chest CT scans are ground-glass opacities (GGOs) and reticular opacities. These findings usually affect both lungs and have a multifocal pattern, appearing in the outer regions near the pleura and towards the back of the lungs [9,15,23-26]. Consolidations are commonly seen either alone or together with ground-glass opacities (GGOs), in which case they are referred to as "mixed lesions". On chest CT scans, it is common to observe ground-glass opacities (GGOs) that have superimposed intralobular lines and interlobular septal thickening. This pattern is referred to as the crazy paving pattern. Additional significant observations of the disease include thickening of the pleura close to the affected area, thickening of the septa inside the lobes of the lungs, air-filled bronchi visible on imaging, a pattern known as the reverse halo sign, and a variation of the reverse halo sign called the bullseye sign [28-30]. Typically, pleural effusions and lymphadenopathy are not present [24].

The computed tomography (CT) results of patients with COVID pneumonia exhibit a dynamic nature and evolve through a sequence of four distinct stages, starting from the beginning of symptoms [31]. The initial stage (0-4 days) is primarily marked by the appearance of ground-glass opacities (GGOs). In the progressive phase (5-8 days), there is a noticeable growth in the size and quantity of ground-glass opacities (GGOs). These GGOs gradually turn into several, consolidated areas and exhibit a pattern known as crazy paving. During the peak period, which typically occurs between 9 to 13 days, there is a greater degree of lung involvement and the appearance of denser consolidations. After the peak period, there is an absorption stage characterized by the gradual reabsorption of consolidations and the emergence of fibrotic bands, which indicate the healing of the lungs [25,31]. Long after symptoms have resolved, there is still evidence of lung abnormalities, as shown by research where 94% of patients had lingering CT findings 25 days after the onset of symptoms [32]. Traction bronchiectasis and peribronchovascular thickening are frequently observed during the healing process [33].

Medical imaging technique

Ultrasound is widely recognized for its benefits in medical imaging due to its lack of ionizing radiation exposure to patients and its convenient portability, allowing for bedside examinations [34]. Amidst a pandemic, conducting bedside ultrasound provides benefits as it eliminates the need to relocate the patient within the hospital, hence reducing the risk of virus transmission to other individuals, particularly fellow patients. Additionally, this allows the staff members participating in the patient transfer to allocate their time and attention to their other duties. Moreover, ultrasonography is widely recognized for its very cost-effective nature, immediate availability of data, and its suitability for people who should not be subjected to radiation, such as pregnant individuals [22,34-36].

Typical observations detected on lung ultrasound in individuals with COVID-19 consist of non-specific findings such as the existence of B-line artifacts, an irregularly thickened pleura, and consolidations near the pleura. B-line artifacts are hyper-echoic artifacts that are vertically oriented and originate from either the pleura or areas of consolidation. These lines suggest the presence of fluid buildup in the lung interstitial space or alveoli [12,37]. A-lines are visible during the recovery phase of the disease [38].

Although ultrasound has demonstrated potential as a valuable imaging technique for COVID-19 patients, the primary evidence supporting its use is derived from limited case series, instructional materials, and opinion articles. However, there is a lack of comprehensive research investigating its effectiveness on a wide scale. The current guidelines from the major radiological associations regarding lung imaging in COVID-19 do not officially recommend the use of ultrasound. Instead, ultrasound is primarily considered an exploratory tool at this stage **[**39].

Medical specialty that uses radioactive substances to diagnose and treat diseases. When imaging COVID-19 patients, 18F-FDG PET has a high ability to accurately detect the disease, but it is not very good at distinguishing it from other conditions. It is primarily used to incidentally detect signs of COVID-19 in imaging tests [23,40]. As an illustration, a medical report described a patient who had an 18F-FDG PET/CT scan to check for the return of non-small cell lung cancer. The report mentioned that there were unexpected areas of ground-glass opacity (GGO) in both lower lobes of the lungs, which were most likely caused by an acute-inflammatory process. Subsequently, the patient was diagnosed with SARS-CoV-2 infection and saw a decline in their clinical condition, necessitating the provision of intensive-care unit (ICU) level treatment. This example demonstrates the significance of radiologists having a vigilant attitude towards unexpected results observed during PET imaging. Identifying the virus at an early stage can result in better clinical outcomes, particularly in individuals who are very prone to serious complications [41].

Furthermore, 18F-FDG PET has demonstrated potential not only in detecting diseases at an early stage, but also in forecasting the extent of a lesion and the duration of its healing process. This is achieved by establishing a correlation between the uptake of 18F-FDG and erythrocyte sedimentation rates [42]. Moreover, the utilization of PET imaging could be advantageous in gaining a deeper comprehension of the neurological problems triggered by SARS-CoV-2 infection. For instance, it can assist in determining the specific brain regions that are impacted, the specific brain cells that are involved, and it can also help in identifying individuals who are at risk of having neurological complications [43]. However, the expenses, increased radiation exposure, lengthy scanning time, and requirement for several medical personnel and excessive usage of personal protective equipment (PPE) all provide reasons against use PET imaging for diagnostic purposes [44]. Additional investigation is necessary to explore the usefulness of PET imaging in evaluating the functionality of lesions and forecasting the severity of diseases.

MRI

Comparatively, when it comes to pulmonary symptoms, MRI of the chest does not yield any supplementary findings in patients with COVID-19 in comparison to CT scans. It has limited availability, higher cost, and longer imaging acquisition time [23,45,46]. MRI is mostly used to assess problems related to the neurological and cardiac systems, such as acute necrotizing encephalopathy or myocarditis, in patients with COVID-19[1]. In addition, for patient populations who should not be exposed to ionizing radiation, such as small children and pregnant patients, MRI may be a suitable alternative [47].

Scoring systems for assessing the severity of COVID-19 through medical imaging. The ability to accurately measure the extent of disease severity in COVID-19 patients using medical imaging techniques allows healthcare professionals to detect and treat individuals with severe illness in urgent situations. Pre-COVID-19 severity assessments have been applied, and new grading systems have been devised expressly for COVID-19 patients [48]. CXR has limited sensitivity in the early stages of COVID-19, but it can be utilized in emergency situations and for ICU patients to monitor the rapid advancement of lung damage in later stages of the disease. The chest radiography severity grading system for severe acute respiratory infections was created in 2015. Its primary purpose was to assist non-radiologist doctors in evaluating patients with acute respiratory conditions [49]. Yoon et al [50] utilized this scoring system to evaluate the extent of pulmonary complications in patients with COVID-19 [48]. The Radiographic Assessment of Lung Edema categorization method was formulated in March 2020 by Wong et al

[15], but it was modified from a comparable scoring system established by Warren et al in 2018. The only scoring system developed exclusively for COVID-19 patients was suggested by Borghesi in March 2020 [51]. The median score of patients from the original study was 6.5. However, the CXR score among patients who died was noticeably greater compared to those who were discharged from the hospital [51].

Complexities

COVID-19 infection can lead to various sequelae, and utilizing imaging techniques for their identification and surveillance can enhance patient outcomes and overall survival [52]. If pleural effusions, multiple lung nodules, tree-in-bud opacities, and lymphadenopathy are detected on imaging in a patient with isolated COVID-19 pneumonia, it should raise suspicion for a bacterial superinfection. This consequence has been observed in 14% of patients in the ICU. ARDS, a severe consequence observed in COVID-19 patients, is more prevalent among those in critical condition. It is characterized by significant reduction in oxygen levels in the arteries and respiratory failure. Confirmation of ARDS can be done using CT imaging, which reveals widespread bilateral regions of ground-glass opacities (GGOs). Approximately 13% of COVID-19 patients have been found to develop pulmonary emboli, with the majority of cases observed in severely ill individuals. If there is a strong suspicion of this problem, CT-angiography should be used to confirm it and determine the appropriate therapeutic treatment course [53]. Due to the fact that COVID-19 can induce both large and small blood vessel issues, individuals in the recovery stage of the disease may potentially develop chronic thromboembolic disease (CTED) or chronic thromboembolic pulmonary hypertension (CTEPH). When investigating suspected chronic thromboembolic disease (CTED) and chronic thromboembolic pulmonary hypertension (CTEPH), it is recommended to use ventilation/perfusion scintigraphy instead of CT, since it has a higher sensitivity for detection [54].

Given the diverse range of diseases that COVID-19 can result in, it is essential for radiologists to have a comprehensive understanding of the underlying mechanisms that lead to malfunction in several organ systems. This knowledge will enable them to more consistently identify problems and prompt a thorough investigation for other potential complications when one is detected [38]. As further research is conducted and our comprehension of the underlying mechanisms and symptoms of COVID-19 disease advances, the use of imaging techniques will also develop in identifying, diagnosing, and tracking the progression of extrapulmonary manifestations and complications in COVID-19 patients [38].

Teleradiology and Virtual Care

Teleradiology is a component of telemedicine that focuses on analyzing diagnostic imaging at a location that is separate from where the picture was taken **[55]**. The radiologist's interpretation of the imaging works can be classified as either intramural, meaning they work for the institution where the image was taken, or extramural, meaning they work for a group or practice that is not affiliated with the institution where the image was acquired. Teleradiology was initially employed in the 1990s to facilitate distant access to emergency radiology services inside the same institution. Nevertheless, technological advancements and market demand rapidly drove its expansion and usefulness in various areas of diagnostic imaging. By the year 2024, the worldwide teleradiology industry is estimated to grow to a size of $8.2 billion [56,57]. Teleradiology has understandably emerged as a crucial resource for the radiology sector amidst the COVID-19 pandemic. It enables the separation of radiologists from patients who are suspected or confirmed to have COVID-19 in the clinical environment, and also reduces the amount of hospital workers. Moreover, a well-structured and adequately staffed teleradiology system can facilitate better readiness to handle an increase in imaging demands caused by a surge in COVID-19 patients. Considering the advantages mentioned, it is crucial to take into account the difficulties that teleradiology encounters in areas such as licensing and credentialing, technology and system integration, and staffing models [57]. By addressing these issues, we can enhance the seamless incorporation of teleradiology into routine clinical practice, leading to improved management and response to the COVID-19 pandemic as well as future pandemics.

Teleradiology has been essential in enhancing our ability to handle increases in imaging demand and minimizing the risk of viral transmission by enabling social distancing. However, virtual care in radiology has contributed to the COVID-19 pandemic in various other ways as well. IR clinics, such as, have endeavored to shift towards virtual appointments in order to mitigate the transmission of COVID-19. A recent survey of 122 patients from an Interventional Neuroradiology clinic revealed that a virtual clinic offers more advantages than only social distancing [59]. The study revealed that virtual clinics are not only more effective, but also more favored by both patients and physicians in non-urgent situations [59]. This demonstrates a significant change in the provision of healthcare for patients, which not only decreases the spread of COVID-19 but also provides more effective and desired care [60,61].

Point Of Care Diagnostics

In addition to RT-PCR, Point-of-Care Ultrasound (POCUS) is emerging as a valuable diagnostic imaging technique for COVID-19 patients. Point-of-care ultrasound (POCUS) is increasingly being adopted by the medical community for the diagnosis and subsequent therapy of COVID-19 patients due to its numerous advantages. For instance, it is rapid, cost-effective, non-ionizing, bedside-compatible, and it tackles similar clinical inquiries as chest radiography and CT scans [62]. Indeed, studies have demonstrated that lung ultrasonography is more effective than conventional chest radiography in identifying illnesses that affect the lower respiratory tract [63]. Point-of-care ultrasound (POCUS) is not only valuable for the initial diagnosis of COVID-19, but it also serves as a good tool for tracking disease progression and monitoring the development of other related complications [34]. These tasks encompass the evaluation of ARDS, cardiogenic pulmonary edema, pericardial and pleural effusions, ventricular function determination, assessment of pneumothorax, screening for deep vein thromboses, evaluation of lung recruitment during mechanical ventilation, prediction of the effectiveness of prone positioning, and assistance in weaning patients off mechanical ventilation [63,64].

An Italian study has suggested a standardized method for obtaining lung ultrasound images and a rating system specifically for COVID-19 patients **[36]**. The acquisition methodology necessitates the scanning of 14 specific regions, comprising 3 posteriors, 2 lateral, and 2 anterior locations, each for a duration of 10 seconds. The scoring procedure is as follows: 0 indicates that the pleural line is continuous and there are horizontal artifacts (A-lines); 1 indicates that the pleural line is indented and there are visible vertical areas of white; 2 indicates that the pleural line is broken and there are darker areas below the breaking point with corresponding white areas, indicating areas of consolidation; 3 indicates that the pleural line is broken and the scanned area shows dense and diffuse white lung with or without darker areas of consolidation [36]. In addition, a study conducted in the United States created a 6-zone procedure that prioritizes provider safety, efficient image acquisition, and primarily focuses on the posterior and lateral fields [64].

It is crucial to take into account the necessary logistical adaptations while employing POCUS in COVID-19 patients. Acquiring video loops instead of static photos reduces the time needed to acquire images and thereby reduces exposure time. In addition, it is recommended that POCUS examinations be conducted by two healthcare providers, with only one provider coming into touch with the patient in order to reduce the risk of transmission [65]. Moreover, it is crucial to follow the manufacturer's particular requirements for sanitizing machines, equipment, and materials to ensure the safe use of POCUS in treating patients with COVID-19 [22,66].

There exist numerous constraints with the utilization of POCUS in COVID-19 patients, as well as the current body of evidence supporting its efficacy. For instance, a significant number of the conducted trials were carried out during a time when the disease was highly prevalent. This is likely to have an impact on the accuracy of diagnosing using POCUS. Moreover, the extent to which different operators can consistently reproduce Point-of-Care Ultrasound (POCUS) results on patients with COVID-19 is still unknown. This information is particularly essential because ultrasound imaging relies heavily on the skills of the operator, and untrained providers may not be able to obtain the best quality images [137]. Although there is a lack of prospective research on the use of POCUS in COVID-19, it is generally recognized that POCUS provides doctors with significant data for managing COVID-19 patients [67]. Further investigation is required to gain a more comprehensive understanding of its involvement in the management of COVID-19 patients.

Artificial intelligence (AI)

Another promising area of study in COVID-19 imaging revolves around the utilization of artificial intelligence (AI). AI can be employed in radiology to collect and merge extensive datasets from disparate sources, which can subsequently be utilized to develop models that assist in forecasting disease diagnosis [68]. Utilizing AI, particularly in the analysis of imaging findings associated with COVID-19, is the most efficient approach to assure a prompt construction of these models [19]. The data sets should encompass not just imaging data, but also the radiology reports and clinical information, including symptoms and laboratory data [69]. It is crucial to emphasize that the extensive adoption of standardized reporting of COVID-19 imaging results is essential for the creation of deep learning networks after obtaining the dataset. These networks can eventually aid in the identification of COVID-19 by analyzing imaging characteristics and other relevant clinical data [20].

AI is commonly employed in imaging to detect COVID-19, particularly in the case of CXR and CT scans [65]. Multiple studies have shown the effectiveness of AI models in reliably distinguishing between COVID-19 and community-acquired pneumonia based on the distinct imaging characteristics observed on both chest X-rays (CXR) and computed tomography (CT) scans [66-69]. In addition to identifying and distinguishing diseases from similar presentations, AI models have been created to evaluate the extent of infection and forecast clinical outcomes by analyzing the presence of opacities, vascular alterations, and other relevant imaging observations [46]. Although there have been some hopeful developments, there is still a considerable need for improvement in the uniformity of COVID-19 imaging datasets, as well as in the identification and forecasting of COVID-19 complications, which have a substantial impact on the death rate of patients with COVID-19 [67-69].

Conclusion

The role of radiography and the radiologist has undergone changes during the COVID-19 pandemic, but their significance in diagnosing and treating patients with COVID-19 disease has consistently remained crucial. Several operational issues in radiology have been successfully addressed, and the growing popularity of teleradiology presents an opportunity to enhance preparedness for the ongoing COVID-19 pandemic and future pandemics. As our understanding of the virus's pathophysiology deepens and we gain more knowledge about the risk factors for complications, there will be more chances to improve the use of imaging in detecting extrapulmonary manifestations and complications of COVID-19. Moreover, unattributed progress in fields like standardized imaging reporting, point-of-care ultrasound (POCUS), and artificial intelligence (AI) present promising avenues for exploration that will undoubtedly result in enhanced healthcare for patients with COVID-19.

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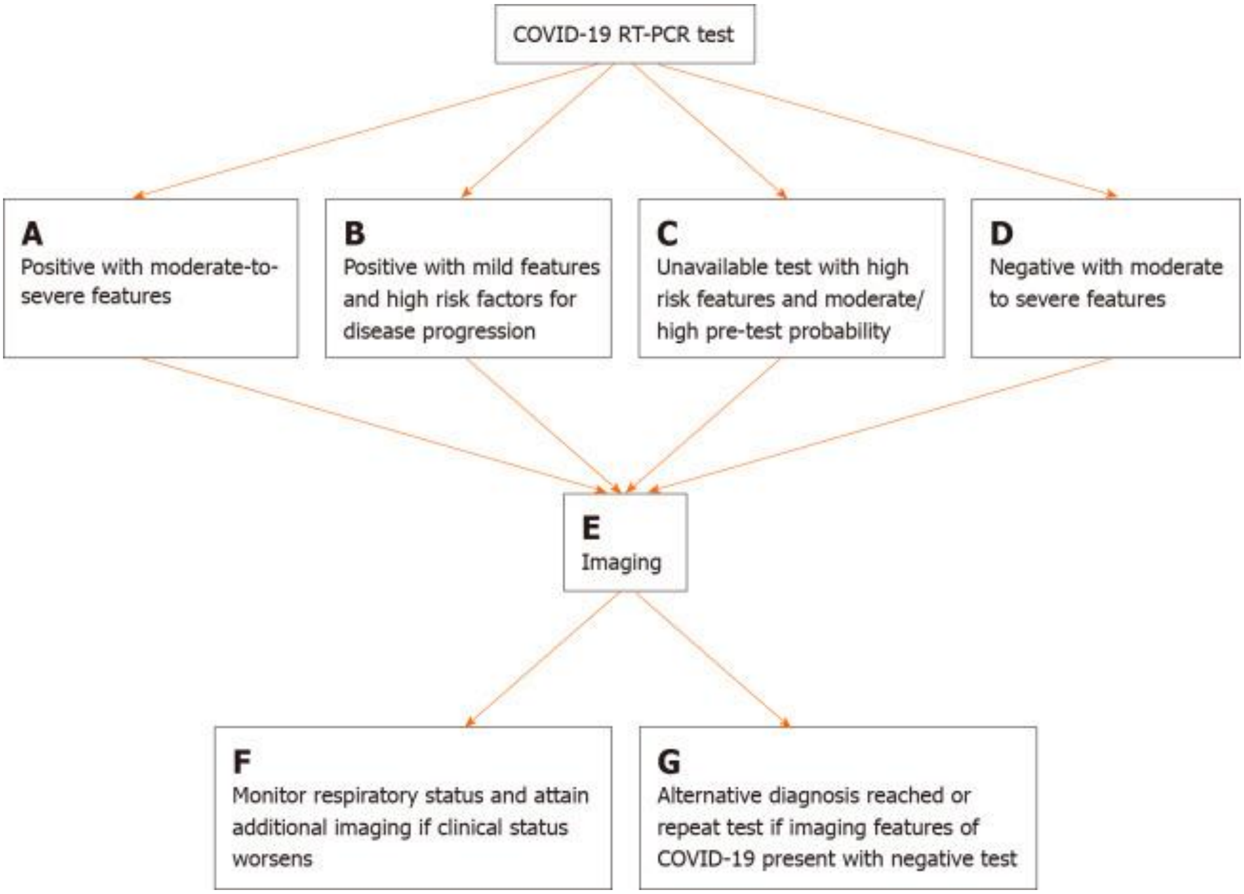

Figure 1. Flow diagram showing four cases when imaging is recommended for the diagnosis and treatment of coronavirus illness in 2019

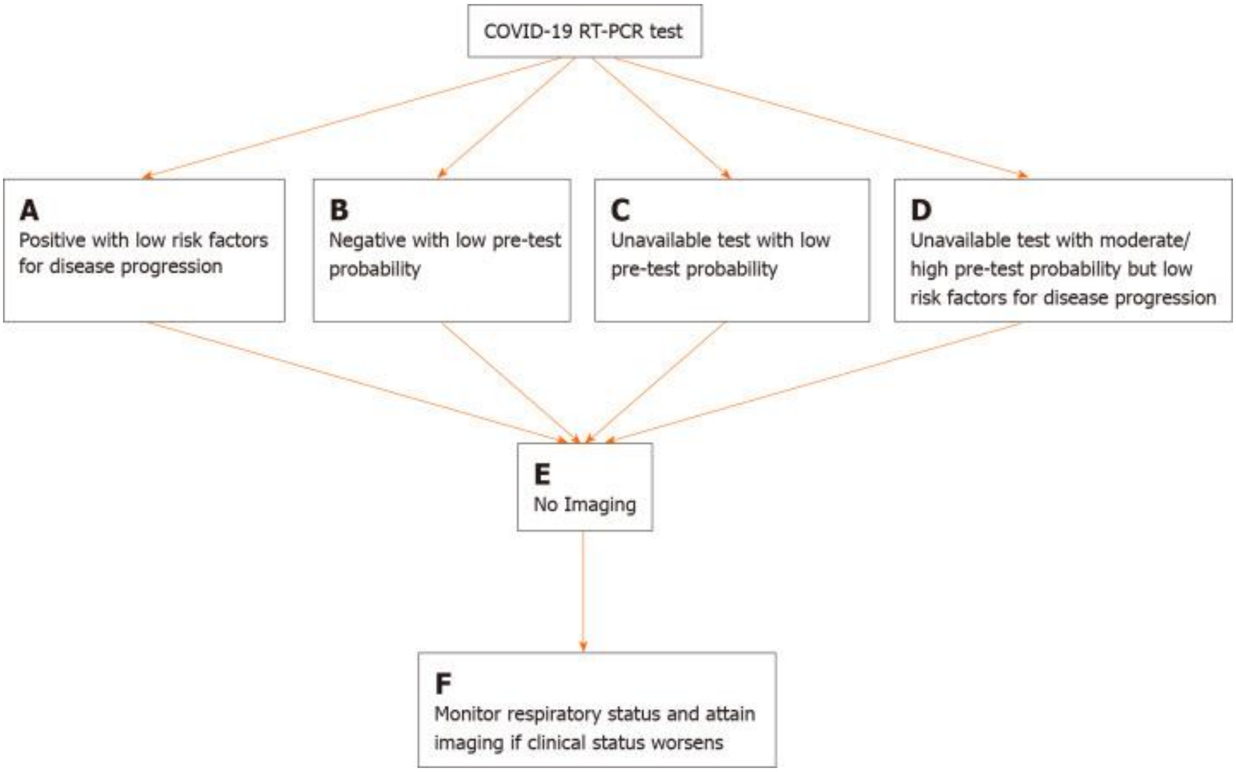

Figure 2. Coronavirus illness (COVID-19) flow diagram showing four situations when imaging is unnecessary for diagnosis and treatment