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Radiological Assessment of Lung Diseases in Patients with COVID-19: *(Review Artical)*

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Abstract

Background: The emergence of COVID-19 in late 2019 led to a global public health emergency. The virus responsible for the infection, SARS-CoV-2, belongs to the beta-coronavirus family. The reverse transcription-polymerase chain reaction (RT-PCR) test is currently the most reliable method for detecting the virus in respiratory samples. Imaging findings of COVID-19, particularly in the lungs, have been extensively studied, with chest computed tomography (CT) and X-ray being commonly used modalities. Other imaging techniques, such as lung ultrasonography and positron emission tomography-computed tomography (PET-CT), have also shown promise in assessing COVID-19 patients.

Aim of Study: This study aims to explore the functions of current imaging modalities and identify the prevailing radiological symptoms of COVID-19.

Methods: The study involves a review and analysis of existing research on imaging modalities used in COVID-19. The search terms used include COVID-19, radiology, chest X-ray, lung ultrasonography, computed tomography, and positron emission tomography-computed tomography.

Results: COVID-19 pneumonia is typically characterized by bilateral and peripheral distribution of ground-glass opacities and consolidations in imaging findings. Chest CT and X-ray have been widely used to assess COVID-19 patients and identify relevant radiological features. Lung ultrasonography, a developing method, has demonstrated a strong ability to detect even small changes in the lungs, making it valuable for initial assessment of SARS-CoV-2 infection. PET-CT integration allows for precise localization of affected areas and monitoring of treatment outcomes.

Conclusion: Current imaging modalities, including chest CT, X-ray, lung ultrasonography, and PET-CT, play important roles in the assessment and management of COVID-19 patients. These modalities provide valuable information about the radiological manifestations of the disease, aiding in diagnosis, monitoring, and treatment evaluation.

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Introduction

ON December 31, 2019, a total of 27 cases of pneumonia with an unknown cause were discovered in the city of Wuhan, located in Hubei Province, China. A novel pathogen, exhibiting genetic similarities to the beta-coronavirus family, which includes the coronaviruses responsible for previous epidemics such as severe acute respiratory syndrome coronavirus (SARS-CoV) and Middle East respiratory syndrome (MERS-CoV), was identified from respiratory samples. This new pathogen has been designated as severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2). In January 2020, the World Health Organization designated the illness as Coronavirus disease 2019 (COVID-19) and announced it as a worldwide public health emergency [1,2]. As of early December 2020, there had been a cumulative total of 65.8 million diagnosed cases and 1.5 million confirmed fatalities since the commencement of the pandemic [3].

Multiple papers published in 2020 have extensively discussed the symptoms and radiological findings of COVID-19, as well as numerous diagnostic methods used to identify it. Regarding its clinical presentation, it often lacks specificity and exhibits variability across people. In around 80%-90% of instances, the condition is characterized by moderate symptoms or may even be asymptomatic. However, in the remaining around 10% of instances, often weak individuals with prior medical issues have a severe progression of infection characterized by difficulty breathing, low oxygen levels, and widespread lung damage on radiological images [4]. The reverse transcription-polymerase chain reaction (RT-PCR) assay is now considered the most reliable diagnostic method for detecting SARS-CoV-2 RNA in respiratory samples. This test demonstrates a significant occurrence of inaccurate negative findings, which may be ascribed to mistakes in the retrieval of nasopharyngeal swab samples and the timing of sample collection [5], since its sensitivity fluctuates depending on the duration after exposure. Therefore, according to some studies, the RT-PCR test has a sensitivity of 33% four days after exposure, 62% on the day clinical symptoms appear, and 80% three days after the symptoms start [6].

The simultaneous increase and fast dissemination of COVID-19, along with the absence of RT-PCR testing kits in some impacted regions, has necessitated the development of novel diagnostic and screening approaches [7]. The use of radiological diagnostics is crucial in the first evaluation of the extent and intensity of the infection. It serves as a critical tool in guiding treatment decisions and monitoring the progression of the condition [8]. Until now, a significant portion of the literature has mostly concentrated on describing the most often seen radiological abnormalities in chest computed tomography (CT). Additionally, other diagnostic methods, including as chest X-ray, lung ultrasonography (LUS), and combination positron emission tomography-computed tomography (PET-CT), have shown to be helpful in evaluating and treating individuals with COVID-19 [5]. In the end, medical professionals will choose an imaging technique based on its benefits, the knowledge acquired with each diagnostic procedure, and the local resources at their disposal [9].

Aim of work:

This study seeks to elucidate the diagnostic efficacy of several imaging modalities and delineate the prevailing radiological abnormalities in COVID-19.

Thoracic radiography:

The use of chest X-ray is common due to its affordability and widespread accessibility, enabling the examination of many ailments in a straightforward and expeditious way. In addition, the availability of portable X-ray machines has facilitated their use in critical care units (ICUs). Clinicians must possess a comprehensive understanding of both the benefits and constraints of this imaging approach when it comes to detecting COVID-19 pneumonia [10]. Several studies have shown that chest radiography is a valuable technique for both diagnosing and monitoring the lung damage caused by SARS-CoV-2 infection. The American College of Radiology (ACR) supports the use of portable X-rays to prevent overcrowding in imaging departments and reduce the danger of contamination caused by moving COVID-19 patients throughout the hospital, hence limiting the spread of the disease [11].

Research published in 2020 indicates that chest X-rays have a limited ability to identify lung infiltrates in the early stages of COVID-19 infection, as well as in mild cases of the illness [12]. Regarding this matter, a retrospective research conducted by Wong et al., [13] examined 64 patients and found that chest radiography had a sensitivity of only 69%, while the RT-PCR test had a sensitivity of 91%. The study also revealed that 9% of cases originally tested negative by RT-PCR despite abnormalities being discovered by X-ray. Ng et al., [14] and Kim et al., [15] both discovered that chest X-ray had a limited ability to accurately detect lung changes resulting from SARS-CoV-2 infection. In early February, Chen et al., [16] conducted a research that revealed a 100% sensitivity rate when using chest radiography. Out of the 99 patients, 74 had bilateral pneumonia and 25 had unilateral involvement. Nevertheless, these findings might be attributed to the strain that the healthcare system was under at that period, when the radiological examination of COVID-19 patients who tested positive was restricted to only severe and advanced cases. Due to these reasons, the European Society of Radiology and the European Society of Thoracic Imaging advise against using it as the primary method for diagnosing COVID-19 pneumonia. Instead, they suggest limiting its use to monitoring patients who are already admitted to the ICU and are too fragile to be transferred for a chest CT scan [11].

The severity of COVID-19 pneumonia cannot be ascertained just by a positive SARS-CoV-2 nasopharyngeal swab. Therefore, it is essential to do an additional radiological examination. In a recent study, Cellina et al., [17] conducted a retrospective analysis to determine the prognostic predictive value of radiographic imaging in the early stages of COVID-19. The study included 246 patients and found a significant correlation between the extent of lung parenchymal involvement, measured by the percentage of areas affected by ground-glass opacities (GGOs) or consolidation, and the severity of the disease.

The predominant findings seen in the chest radiographs of individuals with COVID-19 are ground-glass opacities (GGOs), sometimes accompanied by reticular opacities, and lung consolidation. These symptoms, similar to other atypical viral pneumonias, often affect several lobes and both sides of the lungs, with a preference for the lower lobes. A prominent indication of COVID-19 pneumonia is the presence of pulmonary infiltrates located in the peripheral and multifocal areas (Fig. 1). Radiological abnormalities may quickly progress into a consolidative pattern, often reaching their most severe and extensive involvement of the lung tissue within 6-12 days after the symptoms first appears. Pleural effusion is a very uncommon occurrence in individuals infected with SARS-CoV-2. However, if it does occur, it is often discovered at the advanced phases of the illness. Occasionally, lung cavitation pictures and pneumothorax might be seen in certain instances with COVID-19 [18]. In a retrospective study conducted by Lomoro et al., [19], the chest X-rays of 32 patients were examined. The study found consolidations in 46.9% of the cases and ground-glass opacities (GGOs) in 37.5% of the cases. However, no pleural effusion was detected in any of the patients. The results were mostly distributed bilaterally in 78.1% of the cases, whereas unilateral distribution was seen in only 6.2% of the cases. In addition, the lower lobes were impacted in the majority of cases (52%), followed by 34.4% of patients who had comparable involvement in both the upper and lower lobes. Only 3.1% of patients had involvement in the top lobes.

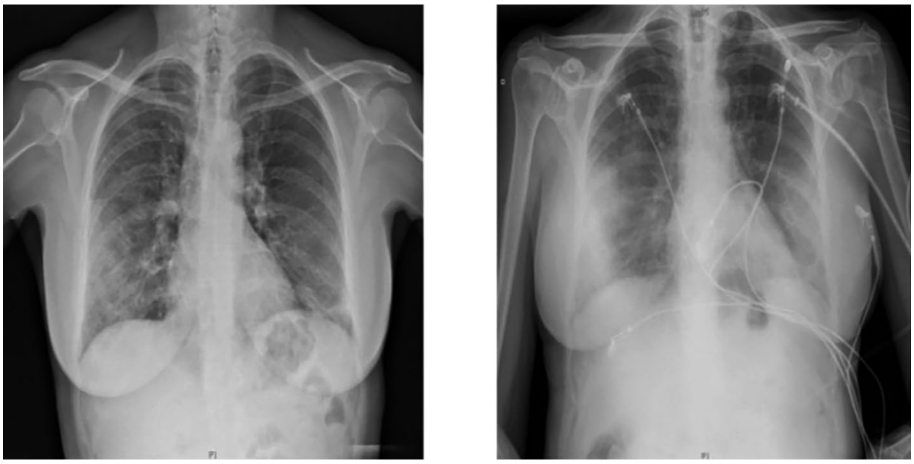

Fig. (1): Chest X-ray findings in a 60-year-old woman with confirmed severe acute respiratory syndrome coronavirus-2 pneumonia (positive RT-PCR test).

Lemmers et al., [20] observed pneumomediastinum and subcutaneous emphysema in 13% of the patients in their research, highlighting the significance of these disorders during the COVID-19 pandemic. Initially, it was thought that this was caused by barotrauma resulting from mechanical ventilation in severely ill respiratory patients. However, it is now believed that these observations can be explained by the Macklin effect. This effect is characterized by the rupture of fragile pulmonary alveoli in these patients, which releases air that dissects through the pulmonary interstitium towards the mediastinum.

In conclusion, the available results indicate that chest radiography is very beneficial in patients with SARS-CoV-2 infection, particularly in those with significant lung involvement and in the latter stages of the illness. Additionally, it may function as an initial imaging tool in situations where there are limited resources, playing a crucial role in the surveillance of patients and the assessment of any potential related complications [21].

Lung Ultrasonography during the COVID-19 Pandemic:

Following the influenza A pandemic (H1N1) in 2009 and the avian influenza epidemic (H7N9) in 2013, LUS has emerged as an important diagnostic tool for promptly identifying interstitial lung disease [22,23]. The latest data on COVID-19 confirms that it is a secure and easily accessible developing technology that may be used for patients who are either suspected or proven to have SARS-CoV-2 infection. This technique is applicable for both the first assessment and the following follow-up of patients. Conventionally, ultrasonography does not often detect a healthy lung. As an organ with air, it cannot transmit ultrasound and so cannot provide anatomical pictures. However, when the lung tissue is filled with fluid or cellular components, its impedance changes, causing artifacts that allow for the detection of abnormal symptoms. The simplest forms of these artifacts are A lines, which are transversal hyperechoic lines that run along to the pleural line. These lines are spaced apart by the same distance as the pleural line and the skin. Pleural reverberation is the manifestation of the pleural line's echo in a healthy lung, indicating the presence of normal lung aeration.

B lines are vertical hyperechogenic artifacts that originate from the pleural line and are considered a major extra artifact in lung ultrasound (LUS). They elongate in a manner like the tail of a comet, reaching into the inner tissue and concealing A lines as they progress, while also moving in rhythm with pleural sliding [24]. The key ultrasonography indicator of interstitial lung illness is thought to be the presence of these structures, which become more numerous as the amount of air decreases and lung density rises. When there are more than three B lines per intercostal gap, it is regarded to be a pathogenic condition. Under typical circumstances, the pleural line appears as a thin, regular, and highly echogenic structure. However, when inflammation is present, neighboring pulmonary consolidations may cause thickness and/or fragmentation. Furthermore, there might be a reduction in pleural slippage.

An outstanding benefit of LUS is its easy accessibility and immediate nature, since it produces pictures at the patient's bedside in real-time. Furthermore, this technology is non-invasive and harmless, making it suitable for safe use in certain populations, including pregnant women and pediatric patients. Moreover, LUS has a heightened sensitivity and surpasses chest X-rays in identifying the first phases of interstitial lung disease [25]. The primary constraint of LUS is its reliance on the operator, since its dependability is intricately linked to the expertise and proficiency of doctors. However, in the hands of skilled individuals, the whole investigation may be completed within a few minutes, resulting in speedier findings compared to other imaging procedures.

COVID-19 lung ultrasound patterns:

Prior to the onset of the COVID-19 pandemic, earlier research indicated that the results from lung ultrasound (LUS) were closely aligned with those from chest CT scans in individuals with viral pneumonia [26]. Similarly, there is a strong association between both imaging modalities in patients with SARS-CoV-2 pneumonia [27-31]. The typical ultrasonography findings seen in individuals with SARS-CoV-2 infection are shown in Fig. (2) [32,33]. Gattinoni et al., [34] classify the hyperinflammatory phase of COVID-19 into two distinct ultrasound patterns: One pattern is characterized by widespread lung infiltrates (type L), with lung compliance that is either normal or slightly reduced, limiting the ability to recruit alveoli. The second pattern consists of extensive consolidations (type H), with significantly reduced lung compliance, and exhibits clinical and prognostic similarities to acute respiratory distress syndrome (ARDS). None of the observed results so far are specific enough to be considered diagnostic for COVID-19; as a result, LUS cannot definitively establish the presence of the disease. Therefore, it is crucial to combine the pictures with a clinical evaluation and the outcome of a nasopharyngeal swab test.

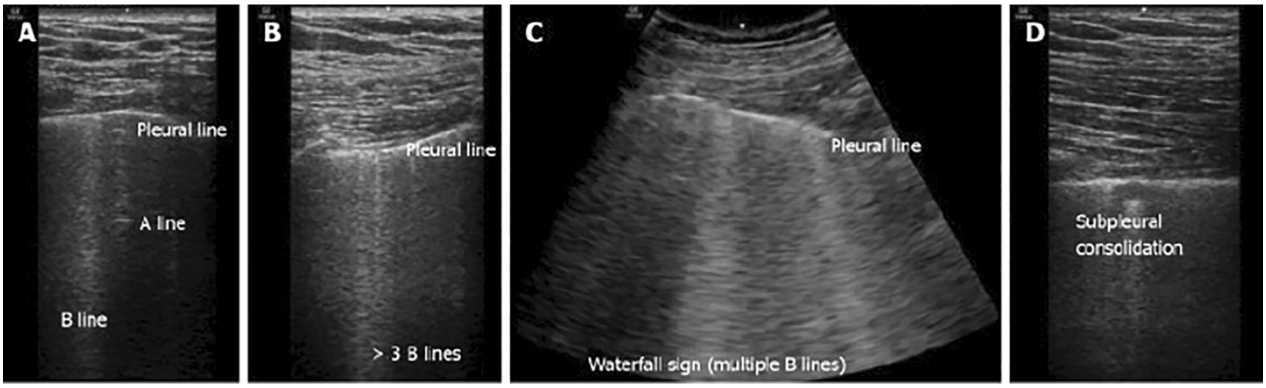

Fig. (2): Illustrations depicting the primary alterations in lung ultrasonography seen in individuals with coronavirus illness 2019.

Authors have recently made a noteworthy discovery that seems to be particularly relevant to COVID-19: The phenomenon known as the 'light beam' [35]. The observed structure is a dense and continuous collection of B lines that emerges from a section of the pleural line that seems to be intact. Typically, it is detected in the first phases of the illness and is associated with early ground-glass opacities on a chest CT scan. The results of LUS differ depending on the stage of the illness [36]. Therefore, it is typical to find unilateral or bilateral focal B lines in the first days after the appearance of symptoms. As the condition advances, the lung tissue gets denser and the number of B lines rises. B lines are widespread and develop on both sides of the lungs. These lines originate with a thickened and uneven pleural line, accompanied by minor consolidations near the outer layer of the lungs. Ultimately, B lines may merge together, resulting in a consolidation or hepatisation pattern of the lung tissue, often known as a 'white lung'. This is especially seen in regions that are deteriorating, and it is associated with respiratory failure.

Due to its heightened sensitivity, LUS enables the identification of both worsening and improvement in lung lesions throughout the terminal phase of the illness. Therefore, throughout the recovery phase, there is a gradual decrease in B lines and consolidations. Furthermore, A lines reappear once again, in conjunction with the enhancement of aeration [31].

LUS is also effective for evaluating other rare occurrences that may occur with SARS-CoV-2 pneumonia. These occurrences include pleural effusion, pneumothorax (which may be caused by mechanical ventilation or the insertion of a central venous catheter), and pulmonary embolism (PE). CT pulmonary angiogram is the most reliable method for diagnosing pulmonary embolism (PE). However, in critically ill and unstable patients with suspected PE, ultrasounds can offer important insights into the presence of right ventricular dysfunction, acute pulmonary hypertension, or deep vein thrombosis in the lower limbs.

Protocol for ultrasound scanning:

The Bedside Lung Ultrasound in Emergency Protocol (BLUE protocol) is widely recognized as one of the most effective methods for assessing patients with acute respiratory failure utilizing lung ultrasound (LUS) [37]. Regarding COVID-19, a significant problem is establishing a standardized approach that enables comparisons across different research groups. Specific scanning techniques have been developed for clinical practice, particularly in intensive care units (ICUs), to measure the degree of lung involvement caused by COVID-19 [29,38-40]. We emphasize the proposition made by Soldati et al., [38], which defines seven exploration regions in each hemithorax, resulting in a total of 14 zones. The hemithorax is split into two halves by three longitudinal lines - the sternal, anterior, and posterior axillary lines - and a transverse line at the level of the nipple. This division divides the hemithorax into a superior and an inferior region. Each section mentioned is assigned a score ranging from 0 to 3, based on the most common discoveries within them, resulting in four distinct patterns [40].

Upon completion of the expedition, the scores awarded to each explored region are totaled, resulting in the final score. Regarding patterns B1 and B2, it is crucial to carefully observe the pleural line. The existence of pleural lesions is an indicator of severity, shown by the addition of the letter 'p' to the score. In essence, this scale enables the assessment of the degree of lung involvement in COVID-19 and offers valuable clinical and prognostic data. Hence, it has the potential to aid in the identification of patients who require hospitalization and to forecast their response to certain treatments, such as prone posture or mechanical breathing. For instance, if there is a gradual decrease in the number of B lines, the reappearance of A lines, or the regression of consolidations, it may indicate a positive clinical improvement and provide justification for advancing in the reduction of medical intervention.

The potential applications of LUS in the COVID-19 pandemic can be summarized as follows: (1) LUS can be used during triage to assess the risk and initial lung involvement in patients suspected or confirmed to have SARS-CoV-2 infection. (2) In patients with symptoms consistent with COVID-19 but a negative nasopharyngeal swab (RT-PCR) and inconclusive chest X-ray, ultrasound findings that suggest lung abnormalities can indicate that the RT-PCR result may be a false negative. (3) LUS can be employed during hospital admission to monitor the progression or regression of lung lesions. Repeated ultrasound examinations can provide accurate information that can be used to determine ventilation strategies and evaluate patients' response to them. For instance, individuals with consolidations in the posterolateral region might potentially experience advantages from being positioned in a prone posture at an early stage [41,42]. Similarly, individuals with coalescent B lines could potentially enhance lung aeration by adjusting the positive end-expiratory pressure (PEEP). Furthermore, in patients who are very unwell and experiencing respiratory or hemodynamic instability, lung ultrasound (LUS) may be highly valuable in promptly identifying problems such as bacterial pneumonia and pneumothorax, and providing guidance for medical options. Consequently, LUS is gaining more importance as a diagnostic tool because of its heightened sensitivity, safety, immediacy, and accuracy. Based on this premise, it has the potential to have a significant impact on the treatment and care of patients with COVID-19. Nevertheless, the limited specificity of this diagnostic method hinders doctors from differentiating COVID-19 from other viral diseases. Thus, it is necessary to assess LUS pictures in combination with clinical and microbiological data.

The significance of chest CT scan in assessing COVID-19 pneumonia:

The use of chest CT scan is crucial in the therapy of SARS-CoV-2 infection. This technique enables the identification and assessment of unique pulmonary symptoms, determines their intensity, and facilitates the monitoring of their development. It also helps differentiate between early and advanced phases by analyzing radiological observations. Nevertheless, the precise definition of its significance as a screening tool in COVID-19 pneumonia has not been clearly established [43].

Recent investigations on COVID-19 pneumonia suggest that chest CT is a more sensitive, practical, and quick diagnosis method compared to the RT-PCR test, particularly in the first phases of the illness. Ai et al., [44] found that chest CT had a sensitivity of 97% when compared to RT-PCR as a reference, whereas RT-PCR done in patients with suspected SARS-CoV-2 infection had a sensitivity of 59%. Nevertheless, the specificity of chest CT was about 25%. In addition, a meta-analysis done by Kim et al., [45] yielded comparable findings, indicating a greater sensitivity of chest CT (94%) compared to RT-PCR (89%). Nevertheless, a low level of specificity (37%) was observed, possibly attributable to the similarity between the nonspecific manifestations of COVID-19 pneumonia and those of other viral pneumonias. Consequently, chest CT scans may yield a high number of false positive results, particularly in regions with a low incidence of the disease.

Conclusion:

Chest X-ray and CT scans are crucial in identifying anomalous lung alterations and serve as the primary imaging techniques for diagnosing COVID-19 pneumonia. Additional radiological modalities, such as lung ultrasonography and PET-CT, may provide further information for the initial evaluation and monitoring of therapy effectiveness. Furthermore, as we go through the pandemic, we anticipate that there will be further investigation into the radiological observations of COVID-19, which will assist in identifying diagnostic imaging characteristics and informing treatment decisions.

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تقييم الأشعة لأمراض الرئة فى المرضى الذين يعانون من COVID-19 : مراجعة

الخلفيـة: ظهـور COVID-19 فـى نهايـة عـام ٢٠١٩ أدى إلـى حـدوث حالـة طـوارئ صحيـة عامـة علـى مسـتوى العالـم. الفيـروس المسـؤول عـن العـدوى، SARS-CoV-2، ينتمـى إلـى عائلـة بيتا-كورونـا. اختبـار البلمـرة المتسلسـلة العكسـية - سلسـلة البوليميـراز (RT-PCR) هـو حاليًا الطريقـة الأكثر موثوقيـة لاكتشـاف الفيـروس فـى عينـات الجهـاز التنفسـى. تم دراسـة النتائـج التصويريـة لـ COVID-19، خاصـة فـى الرئتـين، بشـكل واف واسـتخدام الصـدر المقطعـى بالحاسـوب (CT) والأشـعة السـينية كوسـائل شـائعة الاسـتخدام. أظهـرت تقنيـات تصويـر أخـرى، مثـل الأمـواج فـوق الصوتيـة للرئـة وجهـاز الاسـتقطاب الموجـى بالتصويـر بالإصـدار الموجـى-الحاسـوبى (PET-CT)، قـدرة واعـدة فـى تقييـم مرضـى COVID-19.

هـدف العمـل: يهـدف هـذا الدراسـة إلـى استكشـاف وظائـف وسـائل التصويـر الحاليـة وتحديـد الأعـراض الإشـعاعية السـائدة لـ COVID-19.

الطـرق: تتضمـن الدراسـة اسـتعراضاً وتحليـلاً للأبحـاث الحاليـة حـول وسـائل التصويـر المسـتخدمة فـى COVID-19. تشـمل مصطلحـات البحـث COVID-19، الأشـعة، أشـعة الصـدر، الأمـواج فـوق الصوتيـة للرئـة، الحاسـوب المقطعـى، وجهـاز الاسـتقطاب الموجـى بالتصويـر بالإصـدار الموجـى-الحاسـوبى.

النتائـج: تتميـز التهـاب الرئـة النـاتج عـن COVID-19 عـادة بالتوزيـع الثنائـى والطرفـى للعتامـات الشـفافة والتكثيفـات فـى النتائـج التصويريـة. تم اسـتخدام صـدر CT والأشـعة السـينية علـى نطـاق واسـع لتقييـم مرضـى COVID-19 وتحديـد الميـزات الإشـعاعية ذات الصلـة. أظهـرت الأمـواج فـوق الصوتيـة للرئـة، وهـى طريقـة متطـورة، قـدرة قويـة علـى اكتشـاف التغييـرات الصغيـرة حتـى فـى الرئتـين، ممـا يجعلهـا قيمـة للتقييـم الأولـى للعـدوى بـ SARS-CoV-2. يسـمح تكامـل PET-CT بتحديـد دقيـق للمناطـق المتضـررة ومراقبـة نتائـج العـلاج.

الاسـتنتاج: وسـائل التصويـر الحاليـة، بمـا فـي ذلـك CT الصـدر، والأشـعة السـينية، والأمـواج فـوق الصوتيـة للرئـة، وPET-CT، تلعـب أدوارًا هامـة فـى تقييـم وإدارة مرضـى COVID-19. توفـر هـذه الوسـائل معلومـات قيمـة حـول التظاهـرات الإشـعاعية للمـرض، ممـا يسـاعد فـى التشـخيص والمراقبـة وتقييـم العـلاج.