



Diagnostic Imaging of Severe Pneumonia COVID-19: A Comprehensive Systematic Review

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Article History :

Received date : 2024/11/15

Revised date : 2024/12/19

Accepted date : 2025/01/25

Published date : 2025/02/13



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E-ISSN :

ISSN 3048-1368



P-ISSN :

ISSN 3048-1376



ABSTRACT

Background: COVID-19, caused by SARS-CoV-2, has become a global health crisis since its emergence in December 2019. Severe pneumonia is a critical manifestation of the disease, often necessitating diagnostic imaging for effective management. This systematic review evaluates the diagnostic imaging features of severe pneumonia in COVID-19 using chest X-ray (CXR), computed tomography (CT), lung ultrasound (LUS), and magnetic resonance imaging (MRI). **Methods:** This review follows PRISMA 2020 guidelines. Studies from 2019–2024 were screened for peer-reviewed evaluations of imaging findings in severe COVID-19 pneumonia. **Results:** Eight studies were included. Key findings demonstrated the utility of LUS in detecting early abnormalities like B-lines, critical for bedside monitoring. CXR served as a prognostic tool with radiographic severity scores correlating with adverse outcomes. CT provided detailed anatomical insights, identifying ground-glass opacities (GGO), consolidations, and disease severity markers. MRI, while less commonly used, showed comparable sensitivity and specificity to CT, with advantages in radiation-free imaging for specific populations. **Discussion:** The reviewed studies highlight the complementary roles of imaging modalities in managing COVID-19 pneumonia. Key imaging features include ground-glass opacities, consolidations, and crazy-paving patterns, predominantly in peripheral and lower lung regions. **Conclusion:** Imaging modalities play complementary roles in managing severe COVID-19 pneumonia. LUS is ideal for bedside assessments, CXR aids in prognostication, CT remains the gold standard for detailed evaluation, and MRI offers a viable alternative for radiation-sensitive cases. Understanding these modalities' applications can enhance diagnostic accuracy and clinical outcomes.

Keywords: COVID-19, severe pneumonia, imaging, chest X-ray, computed tomography, lung ultrasound, magnetic resonance imaging

INTRODUCTION

The outbreak of COVID-19 began in China in December 2019, with initial cases involving patients diagnosed with an unidentified viral pneumonia. The causative pathogen was identified as a novel betacoronavirus, initially referred to as the 2019 novel coronavirus (2019-nCoV) and later renamed SARS-CoV-2. Following the initial outbreak, the disease rapidly spread globally, impacting some countries more severely than others. By June 23, 2020, the World Health Organization (WHO) reported nearly 9 million confirmed cases and approximately 470,000 deaths worldwide.¹ In the United States alone, over 2.25 million cases and nearly 120,000 fatalities were recorded, while the United Kingdom reported over 300,000 cases and more than 42,500 deaths.^{1,2}

The primary transmission route of SARS-CoV-2 is via respiratory droplets. A key clinical manifestation is lower respiratory tract infection, which accounts for

most fatalities. Patients often present with flu-like symptoms, though dyspnea and shortness of breath are more common in COVID-19 than in typical influenza. Early studies of hospitalized patients revealed that CT imaging consistently showed pneumonia, with 17–29% progressing to acute respiratory distress syndrome (ARDS).^{2,3} A large-scale study by the Chinese Center for Disease Control and Prevention involving approximately 44,500 confirmed cases found that 81% of patients experienced mild symptoms (including no or mild pneumonia), 14% had severe disease (defined as clinical severity or >50% lung involvement on imaging), and 5% developed multiorgan failure. The overall mortality rate was estimated at 2.3%.⁴

Imaging abnormalities are common in COVID-19 patients. A study of over 1,000 patients compared CT visual assessments (interpreted by two radiologists) with reverse-transcription polymerase chain reaction (RT-PCR) testing as the reference standard. CT demonstrated

a sensitivity of 97% but a specificity of only 25%.⁵ Another comparative study of radiologists from the United States and China found moderate sensitivity and high specificity in differentiating COVID-19 from other viral pneumonias. Key distinguishing features included ground-glass opacities (GGO), vascular thickening, and peripheral lesion distributions (p-value < 0.001).⁶ Imaging findings evolve over the course of the disease, with GGO most frequently observed between days 0–4, peaking at days 6–13, and later evolving into consolidation or reverse halo signs.^{7–9}

In March 2020, major radiological societies, including the American College of Radiology and the British Society of Thoracic Imaging, advised against using CT for COVID-19 screening due to the disease's low prevalence, non-specific imaging findings, and the risk of viral transmission.^{10–12} They recommended reserving CT for hospitalized patients to guide clinical management, identify complications, or in cases where PCR testing was unavailable. Despite these recommendations, the overlap of

COVID-19 symptoms with other lung or cardiac conditions has led to increased imaging in suspected or confirmed cases. Additionally, COVID-19 has been associated with pulmonary thromboembolism.^{13,14}

The purpose of this systematic review is to comprehensively analyze the imaging characteristics of severe pneumonia in COVID-19 across four key modalities: chest X-ray, CT scan, thoracic ultrasound (USG), and MRI. Chest X-ray findings typically include bilateral, peripheral opacities, ground-glass opacities (GGO), and consolidations, with more severe cases showing a "white lung" appearance. While CT scans reveal extensive GGOs, consolidation, vascular thickening, and interlobular septal thickening, they are crucial for assessing disease extent and progression. Thoracic ultrasound often shows B-line artifacts and subpleural consolidations, valuable for bedside assessments in critically ill patients. MRI, although not commonly used for COVID-19 diagnosis, provides superior soft-tissue contrast and can reveal hyperintense signals corresponding to

GGOs and consolidations on T2-weighted images. This review will include illustrative images to clarify key imaging findings across these modalities, offering valuable insights for healthcare professionals in diagnosing and managing severe COVID-19 pneumonia.

METHODS

Protocol

This systematic review follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines to ensure transparency, consistency, and reproducibility in the analysis of imaging characteristics of severe pneumonia in COVID-19 across multiple modalities. The protocol aims to systematically review and evaluate the diagnostic imaging findings of severe pneumonia caused by COVID-19, focusing on chest X-ray, CT scan, thoracic ultrasound (USG), and MRI. This review will assess common and unique findings in each imaging modality, providing a detailed comparison and visual representation of their diagnostic significance.

Criteria for Eligibility

This review will include studies published between 2019 and 2024 that evaluate imaging findings in patients with confirmed severe pneumonia due to COVID-19. Eligible studies must be peer-reviewed and involve clinical or radiological assessments of severe COVID-19 pneumonia. Studies must include imaging results using chest X-ray, CT scan, USG, or MRI. The focus will be on diagnostic imaging features such as ground-glass opacities (GGO), consolidations, pleural effusion, and other key radiological findings.

Inclusion criteria

- **Participants:** Patients diagnosed with severe pneumonia caused by COVID-19.
- **Intervention:** Any diagnostic imaging modality, including chest X-ray, CT scan, USG, and MRI.
- **Outcomes:** Diagnostic imaging findings (e.g., GGO, consolidation, pleural effusion, and other related features).

- **Study Design:** Clinical studies involving imaging assessments of COVID-19 pneumonia.
- **Language:** Studies published in English.

Exclusion criteria

- Review articles, meta-analyses, conference abstracts, or expert opinions.
- Studies that do not provide imaging findings related to severe COVID-19 pneumonia.
- Animal studies or in vitro experiments.

Search Strategy

A comprehensive search will be conducted using electronic databases, including PubMed, Embase, Cochrane Library, Web of Science, and Scopus. Search terms will focus on COVID-19 pneumonia imaging characteristics. The following Boolean search strings will be used:

- ("COVID-19" OR "SARS-CoV-2") AND ("Severe pneumonia" OR "Lung infection") AND ("Chest X-

ray" OR "CT scan" OR "Ultrasound" OR "MRI")

- ("COVID-19 pneumonia" AND "Imaging features") AND ("Chest X-ray" OR "CT" OR "Ultrasound" OR "MRI")

("Ground-glass opacity" OR "Consolidation" OR "Pleural effusion") AND ("COVID-19 pneumonia" AND "Diagnostic imaging").

Data Retrieval

Titles and abstracts will be screened for relevance. Full-text articles that meet inclusion criteria will be reviewed, and the following data will be extracted:

- **Study characteristics:** Year, location, sample size, and duration.
- **Imaging modality used:** Chest X-ray, CT scan, USG, MRI.
- **Participant demographics:** Age, gender, and COVID-19 severity.
- **Outcomes:** Key imaging findings such as GGO, consolidation, pleural

effusion, and other notable features.

analyses will explore variations based on participant age, disease severity, and imaging modality used.

Quality Assessment and Data Synthesis

Two independent reviewers will assess the methodological quality of included studies using the GRADE framework, focusing on study design, sample size, and the reliability of imaging outcomes. Disagreements will be resolved through discussion or consultation with a third reviewer. A qualitative synthesis will summarize the findings, comparing the diagnostic effectiveness of different imaging modalities in detecting severe pneumonia in COVID-19 patients. If data homogeneity permits, a meta-analysis will be conducted to estimate pooled effect sizes for key imaging outcomes. Subgroup

Tabel 1. Search Strategy

Database	Search Strategy
PubMed	("COVID-19" AND "Severe pneumonia" AND "Chest X-ray")
Embase	("CT scan" AND "COVID-19 pneumonia" AND "Lung imaging" AND "Chest X-ray")
Cochrane Library	("Ultrasound" AND "COVID-19 pneumonia" AND "Diagnostic imaging" AND "Chest X-ray")
Web of Science	("MRI" AND "Severe pneumonia" AND "COVID-19" AND "Chest X-ray")

Identification of studies via databases and registers

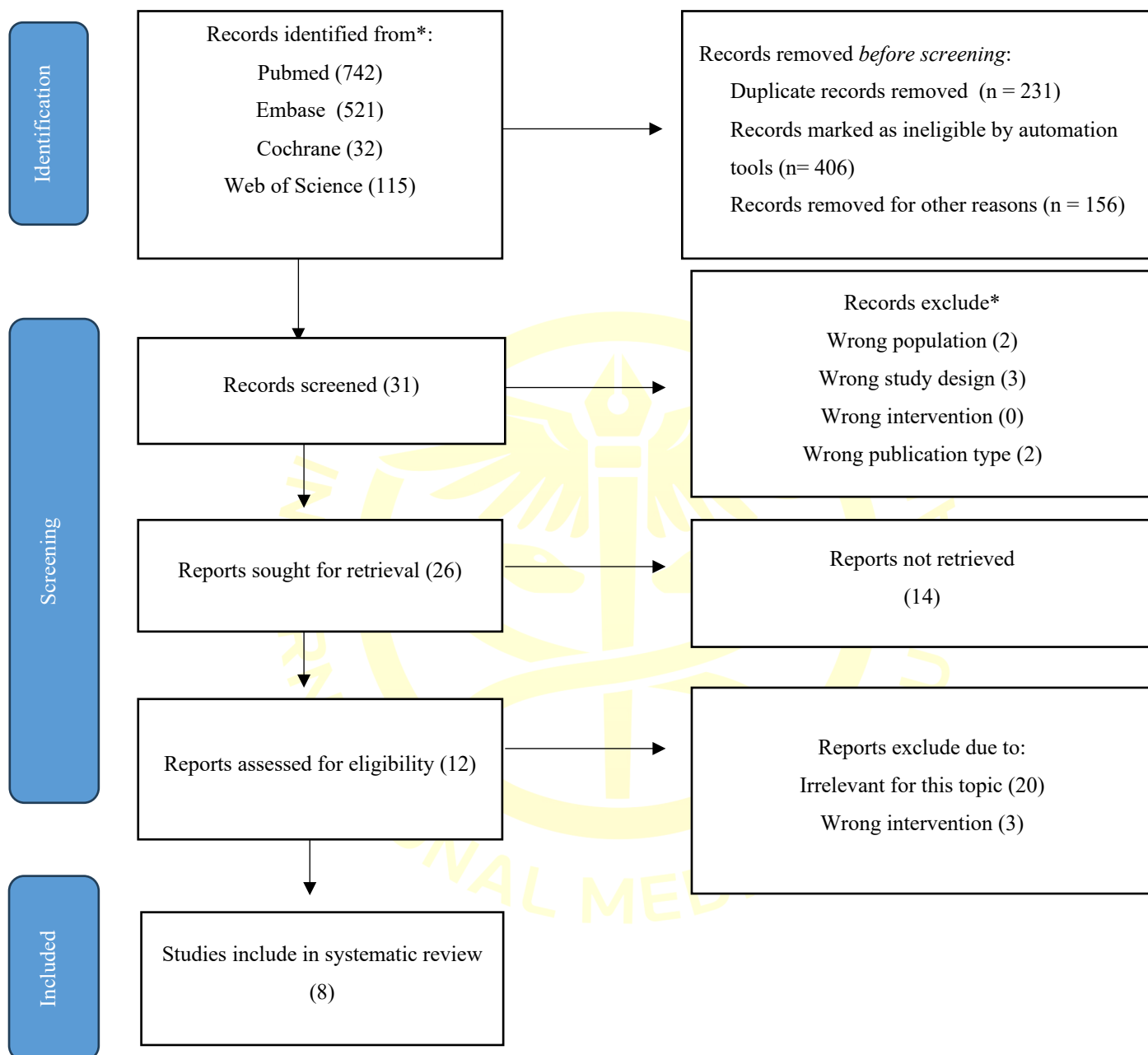


Figure 1. Article Search Flowchart

RESULT

Our research team first gathered publications from reputable sources such as Embase, PubMed, and Web of Science. After a thorough three-level screening procedure, only nine papers were determined to be directly relevant to our ongoing systematic evaluation. Following that, these sections were picked for additional research and a close reading of the entire manuscript. The material that was evaluated for this analysis is compiled in Table 2 for ease of viewing.

Table 2. The literature included in this study				
Author	Origin	Method	Sample Size	Result
Cho et al., 2022. ¹³	South Korea	Retrospective study.	Six consecutive patients with confirmed COVID-19 who underwent serial LUS.	Lung ultrasound detected early abnormal findings of representative B-lines in a patient with a normal chest X-ray, corresponding to ground-glass opacities on the chest CT scan. The ultrasound findings improved as her clinical condition improved and her viral load decreased. In another minimally symptomatic patient without significant chest X-ray findings, the ultrasound showed B-lines, an early sign of pneumonia before abnormalities were detected on the chest CT scan. In two critically ill patients, ultrasound was performed to assess for evaluation of disease severity. In both patients, the clinicians conducted emergency rapid sequence intubation based on the ultrasound findings without awaiting the laboratory results and radiological reports. In two children, ultrasound was used to assess the improvement in their pneumonia, thus avoiding further imaging tests such as chest CT.
Zhang et al., 2020. ¹⁴	China	Retrospective study.	28 patients.	Study population comprised 28 patients (14 men and 14 women; mean age $\pm$ SD, 59.8 ± 18.3 years; age range, 21–92 years). All 28 patients (100.0%, 28/28) had positive lung US findings. The most common findings were the following: B-

				lines (100.0%, 28/28), consolidation (67.9%, 19/28), and a thickened pleural line (60.7%, 17/28). A thickened pleural line was observed in a higher percentage of patients with a longer duration of the disease than in those with a shorter duration of the disease, and pulmonary consolidations were more common in severe and critical cases than in moderate cases.
Adarve et al., 2021. 15	Spain	Retrospective study.	292 patients with COVID-19.	Hospital admission was necessary in 91.4% of the patients. The RSEHA was significantly associated with the need for hospital admission ($p = 0.03$) and with the need for ICU admission ($p < 0.001$). A total of 51 (17.5%) patients died; of these, 57% had the severe pattern on the RSEHA. When we analyzed mortality by grouping patients according to their results on the RSEHA and their age range, the percentage of patients who died increased after age 70 years in patients classified as moderate or severe on the RSEHA.
Hui et al., 2020. 16	Singapore	retrospective cohort study.	358 chest radiographs were performed on 109 COVID-19 patients.	Patients who needed supplemental oxygen ($n=19$, 17.4%) were significantly older ($P<0.001$) and significantly more of them had co-morbidities ($P=0.011$). They also had higher C-reactive protein (CRP) ($P<0.001$), higher lactate dehydrogenase (LDH) ($P<0.001$), lower lymphocyte count ($P<0.001$) and lower hemoglobin (Hb) ($P=0.001$). Their initial (CRS _{initial}) and maximal CRS (CRS _{max}) were higher ($P<0.001$). Adjusting for age and baseline hemoglobin, the AUROC of CRS _{max} (0.983) was as high as CRS _{max} (0.987) and higher than the AUROC for lymphocyte count _{min} (0.897), and LDH _{max} (0.900). The AUROC for CRS _{initial} was slightly lower (0.930). CRS _{initial} ≥ 5 had a sensitivity of 63% and specificity of 92% in predicting the need for oxygen, and 73% sensitivity and 88% specificity in predicting the need for mechanical ventilation. CRS between the

				6th and 10th day from the onset of symptoms (CRSD6-10) ≥ 5 had a sensitivity of 89% and specificity of 95% in predicting the need for oxygen, and 100% sensitivity and 86% specificity in predicting the need for mechanical ventilation.
Li et al., 2020. ¹⁷	China	Retrospective study.	Eighty-three patients with COVID-19 pneumonia including 25 severe/critical cases and 58 ordinary cases were enrolled.	Compared with the ordinary patients, the severe/critical patients had older ages, higher incidence of comorbidities, cough, expectoration, chest pain, and dyspnea. The incidences of consolidation, linear opacities, crazy-paving pattern, and bronchial wall thickening in severe/critical patients were significantly higher than those of the ordinary patients. Besides, severe/critical patients showed higher incidences of lymph node enlargement, pericardial effusion, and pleural effusion than the ordinary patients. The CT scores of severe/critical patients were significantly higher than those of the ordinary patients ($P < 0.001$). Receiver operating characteristic curve showed that the sensitivity and specificity of CT score were 80.0% and 82.8%, respectively, for the discrimination of the 2 types. The clinical factors of age older than 50 years, comorbidities, dyspnea, chest pain, cough, expectoration, decreased lymphocytes, and increased inflammation indicators were risk factors for severe/critical COVID-19 pneumonia. Computed tomography findings of consolidation, linear opacities, crazy-paving pattern, bronchial wall thickening, high CT scores, and extrapulmonary lesions were features of severe/critical COVID-19 pneumonia.
Hesam-Shariati et al., 2022. ¹⁸	Egypt	Retrospective study.	Ninety patients with coronavirus were divided into three	The mean age and duration of hospitalization of patients increased with increasing the severity of the disease. The most common clinical symptoms were shortness of breath, cough, and fever. As the severity of the disease increased from mild/moderate to very severe, there was

			categories based on the severity of the disease: mild/moderate, severe, and very severe.	an increase in neutrophil counts and a decrease in lymphocytes and white blood cells (WBC) showing excessive inflammation associated with severe forms of COVID-19. Subpleural changes (81%) and ground-glass opacification/opacity (GGO) lesions (73%) of the lung were the most common features in CT images of COVID-19 patients, and interlobular septal thickening (10%) was the lowest CT feature among patients. Regarding the affected parts of the lung in COVID-19 patients, bilateral, peripheral, and multiple lesions had the highest prevalence.
Omar et al., 2020. 19	Turkey	Retrospective study.	Thirty-two patients diagnosed with COVID-19 who underwent thorax CT for COVID pneumonia and MRI for any reason within 24 hours after CT were included in the study	Seventeen of the patients were female (53%) and 15 were male (47%). The mean age of the patients was 60.5 (range, 20–85) years. A total of 31 patients (96%) had signs of pneumonia on CT. The most common finding in CT was ground-glass opacities in 29 patients (90.6%), followed by consolidation in 14 patients (43.75%). Both consolidation and ground-glass opacities were also observed in MRI in all of these patients. Nodules were detected in 12 patients (37.5%) on CT and 11 patients (34.4%) on MRI. The sensitivity and specificity of MRI in nodule detection were calculated as 91.67% and 100%, respectively.
Ardekani et al., 2023. 20	Egypt	Cross-sectional study.	the 31 parent–child dyads recruited, 28 were eligible	Thirty-seven males and sixteen females with the mean age of 47.49 ± 13.86 years old were present in this case series. Fifty-one cases had typical CT features with ground glass opacities and consolidations, readily visible on different MRI sequences. Thirteen cases had atelectasis

			for the study and 23 ultimately completed this pilot investigation	which were also easily seen on MRI. The comprehensive review of MRI features for each case and representative images has been illustrated.
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Table 3. Critical appraisal of Study

Parameters	Cho et al. (2020)	Zhang et al. (2020)	Adarve Castro et al. (2021)	Hui et al. (2020)	Li et al. (2020)	Hesam-Shariat i et al. (2022)	Ates et al. (2020)	Ardeka ni et al. (2023)	Cho et al. (2020)
1. Bias related to temporal precedence									
Is it clear in the study what is the “cause” and what is the “effect” (ie, there is no confusion about which variable comes first)?	Clear cause (COVID-19) and effect (ultrasound findings).	Clear cause and effect.	Cause and effect are identifiable but less emphasized.	Cause and effect relationship defined.	Clear distinction of variables.	Cause and effect well-delineated.	Temporal sequence clear.	Clear temporal relationship.	Clear cause (COVID-19) and effect (ultrasound findings).
2. Bias related to selection and allocation									
Was there a control group?	No control group.	No control group.	No control group.	No control group.	No control group.	No control group.	No control group.	No control group.	No control group.
3. Bias related to confounding factors									
Were participants included in any comparisons similar?	Minimal confounding due to small sample size but consistent findings.	Similar participant characteristics reduce confounding.	Risk of confounding due to broader patient heterogeneity.	Risk of confounding mitigated by adjusting for well-defined variables like age and comor	Comparisons among well-defined groups.	Comparisons based on clear severity categories.	Risk of confounding minimized.	Risk of confounding due to reduced small sample size but consistent findings.	Minimal

bidities.
s.

4. Bias related to administration of intervention/exposure

Were the participants included in any comparisons receiving similar treatment/care, other than the exposure or intervention of interest?	Consistent LUS assessment across patients.	Standardized lung US techniques.	Consistent evaluation methods.	Similar chest radiography assessments.	Similar CT assessment methods across groups.	Consistent diagnostic imaging (MRI and CT).	Consistent imaging techniques across patients.	Standardized imaging comparison.	Consistent LUS assessment across patients.
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5. Bias related to assessment, detection, and measurement of the outcome

Were there multiple measurements of the outcome, both pre and post the intervention/exposure?	Multiple serial measurements pre and post-intervention; reliable.	Uniform outcome measurement with chest X-ray scoring method system.	Reliable measurement with chest X-ray scoring system.	Reliable measurements with sensitivity and specificity analyses.	Reliable measurements with sensitivity and specificity analyses.	Pre/post reliable measurements; CT scores used consistently.	Pre/post reliable measurements; CT scores used consistently.	Reliable measurements across modalities.	Complete follow-up.
Were the outcomes of participants included in any comparisons measured in the same way?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Were outcomes measured in a reliable way?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

6. Bias related to participant retention

Was follow-up complete and, if not, were differences between groups in terms of their follow-up adequately described and analyzed?	Complete follow-up.	Follow-up complete.	Follow-up discussed; minor losses noted.	Follow-up adequate with adjustments for variables.	Follow-up thorough with comparisons.	Complete follow-up.	Complete follow-up.	Follow-up adequately described.	Complete follow-up.
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7. Statistical conclusion validity

Was appropriate statistical analysis used?	Limited due to small sample size; no advanced statistics reported.	Statistical conclusions reliable within study limits.	Statistical conclusions (significance values reported).	Advanced statistical methods (AUC, sensitivity, specificity).	Statistical analysis appropriate with clear significance.	Statistical methods clearly applied.	Valid statistics for comparison of imaging techniques.	Robust statistical analysis.	Limited due to small sample size; no advanced statistics.
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specificity values. enhance validity.

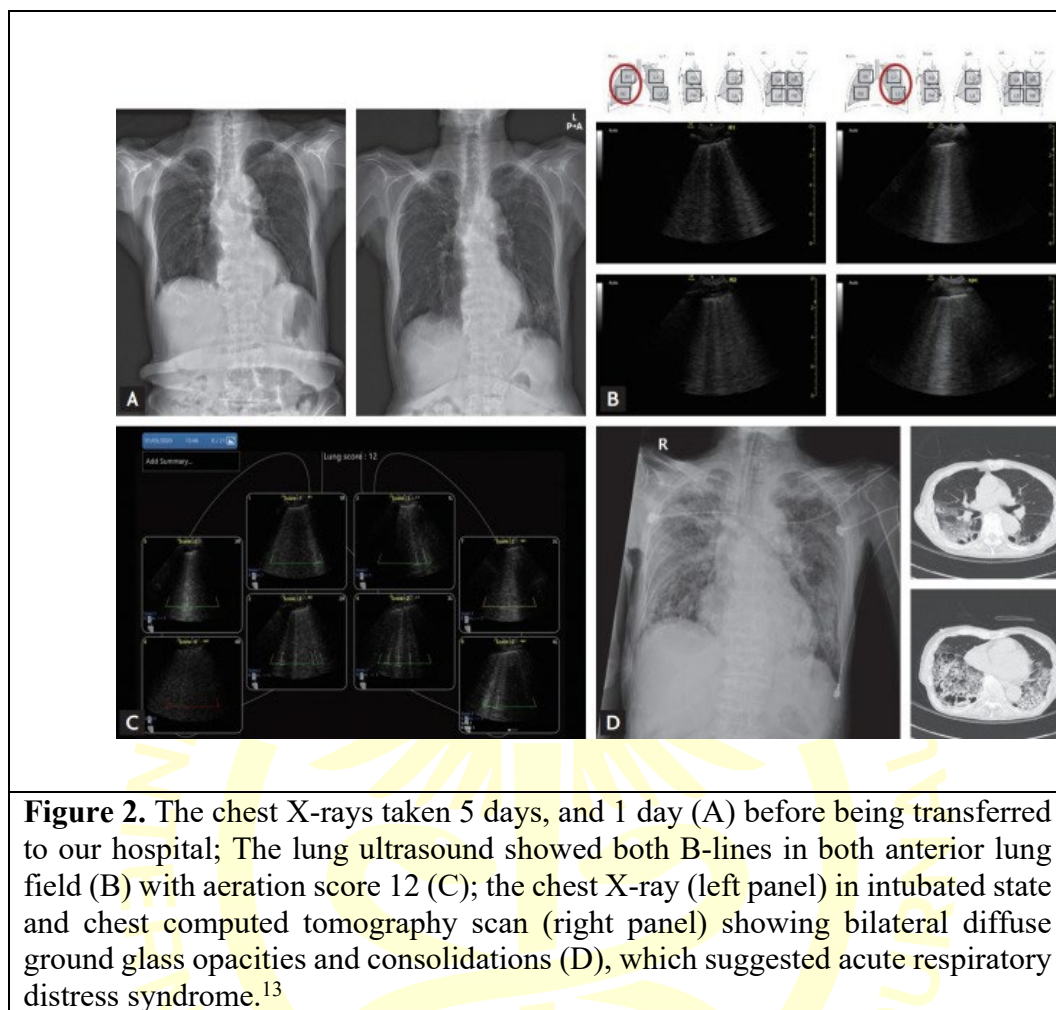
s reported .

DISCUSSION

The reviewed studies highlight the varied applications of imaging modalities in diagnosing, managing, and monitoring COVID-19 pneumonia. Each study provides unique insights into the role of different tools, including lung ultrasound (LUS), chest X-ray (CXR), computed tomography (CT), and magnetic resonance imaging (MRI), emphasizing their diagnostic accuracy, prognostic value, and clinical utility.

Utility of Lung Ultrasound (LUS)

Cho et al. (2020) conducted a retrospective study on six COVID-19 patients to evaluate LUS as a diagnostic and monitoring tool. The study demonstrated that LUS could detect early abnormalities, such as B-lines, even in patients with normal CXRs. These findings correlated with ground-glass opacities (GGOs) on chest CT scans, a hallmark of COVID-19 pneumonia. The utility of LUS extended to critical care scenarios, where it informed immediate interventions like intubation, without waiting for radiological or laboratory confirmation. In pediatric cases, LUS was instrumental in tracking pneumonia resolution, reducing the need for further radiation exposure through CT scans. These results highlight LUS as a rapid, bedside, non-invasive modality, particularly valuable for early diagnosis, real-time monitoring, and critical care decision-making.¹³



Zhang et al. (2020) studied 28 patients, showcasing LUS's high sensitivity for detecting COVID-19 pneumonia. All patients exhibited positive findings, with B-lines being universal (100%), followed by consolidations (67.9%) and pleural line thickening (60.7%). The study emphasized LUS's ability to differentiate disease stages, as thickened pleural lines were more prevalent in patients with prolonged illness, and consolidations were more common in severe cases. This reinforces LUS as an effective tool for both early detection and monitoring disease progression.¹⁴

Prognostic Role of Chest X-Ray (CXR)

Adarve Castro et al. (2021) retrospectively analyzed 292 COVID-19 patients, linking radiographic severity scores (RSEHA) to clinical outcomes. Severe patterns on RSEHA were strongly associated with hospital and ICU admissions and

higher mortality rates. Mortality rates significantly increased in patients over 70 years with moderate or severe RSEHA scores. These findings underscore the prognostic value of CXR in triaging patients and identifying those at higher risk for adverse outcomes.¹⁵

Hui et al. (2020) explored the utility of chest radiographs in predicting the need for oxygen supplementation and mechanical ventilation in 109 patients. Higher radiographic severity scores (CRS) were associated with older age, comorbidities, and elevated inflammatory markers, including CRP and LDH. CRS values on days 6–10 post-symptom onset showed high sensitivity and specificity for predicting oxygen and ventilatory support needs. These results establish CRS as a reliable, accessible tool for assessing disease severity and guiding timely interventions.¹⁶

CT in Disease Characterization and Severity Assessment

Li et al. (2020) analyzed 83 patients, comparing CT features in severe/critical cases versus mild/moderate cases. Severe patients exhibited higher incidences of GGOs, consolidations, crazy-paving patterns, and bronchial wall thickening. CT scores strongly correlated with disease severity, with high sensitivity (80%) and specificity (82.8%) for distinguishing severe cases. Age, comorbidities, and elevated inflammatory markers were identified as risk factors for severe disease. This study highlights CT's unparalleled ability to provide detailed anatomical and functional insights, crucial for distinguishing disease severity and tailoring management strategies.¹⁷

Hesam-Shariati et al. (2022) focused on 90 patients, correlating clinical severity with CT findings. Subpleural changes (81%) and GGOs (73%) were the most prevalent features, while interlobular septal thickening was rare (10%). The study emphasized CT's ability to capture bilateral, peripheral, and multiple lesions, providing a comprehensive view of lung involvement. As disease severity increased, there was a clear trend of elevated neutrophil counts and decreased lymphocyte counts, reflecting excessive inflammation.¹⁸

MRI as a Complementary Imaging Tool

Omar et al. (2020) evaluated MRI's performance against CT in detecting pulmonary abnormalities in 32 COVID-19 patients. MRI demonstrated high sensitivity and specificity in identifying GGOs, consolidations, and nodules, with a diagnostic accuracy comparable to CT. Its lack of ionizing radiation makes it a safer option, particularly in younger or vulnerable populations. However, logistical challenges such as cost and limited availability constrain its widespread use.¹⁹

Ardekani et al. (2023) compared CT and MRI findings in 53 patients. Typical features, including GGOs and consolidations, were consistently detected across modalities. MRI also identified atelectasis in 13 cases, demonstrating its diagnostic versatility. Despite MRI's diagnostic precision, the study highlighted CT's superiority in accessibility and practicality, particularly in acute settings.²⁰

The reviewed studies collectively demonstrate the complementary roles of imaging modalities in managing COVID-19 pneumonia. LUS provides a rapid, bedside option for early detection and monitoring, especially in resource-limited or pediatric settings. CXR serves as an accessible tool for prognostication and triaging. CT remains the gold standard for detailed anatomical evaluation and severity assessment, while MRI offers a radiation-free alternative in selected cases. The following sections discuss the hallmark imaging features observed in COVID-19, including ground-glass opacity (GGO), the crazy-paving pattern, consolidation, and other related findings. These descriptions highlight their prevalence, distribution, and clinical significance, providing a comprehensive understanding of how COVID-19 manifests in the lungs.

Ground-Glass Opacity (GGO)

Ground-glass opacity (GGO) is the most common imaging feature reported in COVID-19. It is defined as increased attenuation on CT scans without obscuring the bronchovascular structures. Approximately 60–70% of patients from a Wuhan study exhibited pure GGO on CT, with the right lower lobe being the most commonly affected area. GGOs typically appear bilaterally, with a peripheral and lower lobe predominance, often presenting as round or bronchocentric opacities in the posterior lungs. GGO may be challenging to detect on chest X-rays (CXR) unless accompanied by reticular interstitial thickening. In early stages, before

symptom onset, a single unifocal GGO in the lower lobes may be observed. Over time, GGO may resolve or progress into more widespread consolidation.¹⁰

GGO with Reticular Interstitial Thickening (Crazy-Paving Pattern)

The crazy-paving pattern occurs when reticular interstitial thickening overlays GGO. This pattern features thickened interlobular septal lines resembling irregularly paved stones and is frequently associated with COVID-19 during its subacute or chronic phases. It is commonly peripheral and smooth, representing interstitial inflammation. About 75% of patients exhibit GGO mixed with reticular opacities, and crazy-paving is observed in 10–20% of cases, often indicating peak disease. It is important to note that crazy-paving is not unique to COVID-19 and may appear in other infections.

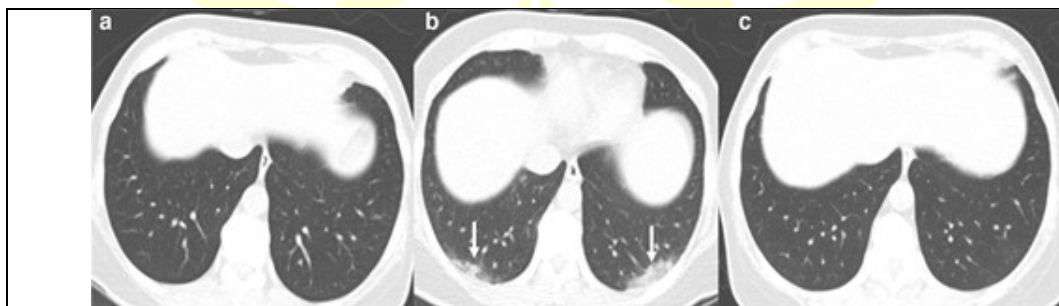


Figure 3. Chest X-ray obtained a week after diagnosis of COVID-19 infection showed multifocal, peripheral bilateral disease. CT obtained on the same day of the radiograph showed peripheral bilateral GGO with superimposed reticular interstitial thickening within the GGO giving a ‘crazy-paving’ appearance. GGO, ground-glass opacity.¹⁹

Consolidation

Consolidation, defined as homogenous lung parenchymal attenuation with obscuration of vessels and bronchi, is a sign of disease progression in COVID-19. It is commonly observed in intermediate and late stages, affecting 50–60% of patients. Similar to GGO, consolidations are predominantly peripheral and posterior, often involving the lower lungs. Air bronchograms are frequent, while cavitation is rare and may indicate bacterial superinfection. Consolidation may evolve into organized changes, bronchiectasis, or volume loss in later stages.

Reverse Halo (Atoll Sign)

The reverse halo or atoll sign features central GGO surrounded by peripheral consolidation. This pattern, indicative of alveolar inflammation and debris, may appear during disease progression or recovery. It is a specific but less common imaging finding in COVID-19.

Other Imaging Features

Additional findings include unilateral lung involvement in 15–20% of cases, nodules in up to 13%, and vascular enlargement within diseased areas, which may indicate microscopic capillary destruction. Subpleural lines associated with fibrosis may emerge during the healing phase, particularly in severe cases. Airway changes, such as bronchial wall thickening, bronchiectasis, and bronchiolectasis, are seen in 10–20% of patients, with bronchial wall thickening more prevalent in children and severe cases.

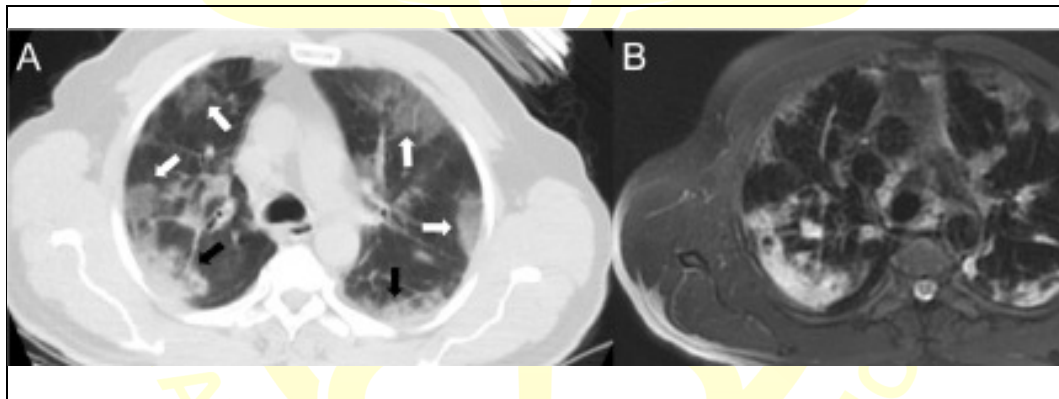


Figure 4. Images of an 81-year-old woman with peripheral-weighted diffuse involvement. In areas where there are ground-glass appearances (white arrows) on both CT (a) and MRI (b), vascular structures can be selected, while in the consolidated areas, vascular structures cannot be distinguished (black arrows).²⁰

Pulmonary Embolism and Thrombosis

COVID-19 patients exhibit a higher incidence of pulmonary embolism (PE), particularly in critically ill individuals. PE is frequently linked to pulmonary thrombosis rather than embolization. Anticoagulation therapy improves prognosis, reflecting the disease's thrombogenic state. Microthrombi and pulmonary vascular damage have been documented in autopsy studies, underlining the significance of thrombosis as a complication rather than a direct imaging finding.

Atypical Findings

Atypical imaging features include isolated lobar or segmental pneumonia without GGO, centrilobular nodules, tree-in-bud opacities, cavitations, and calcifications. Lymphadenopathy, pleural effusions, and pericardial effusions are rare but may indicate disease progression or alternative diagnoses.

This systematic review has several limitations. The heterogeneity in study populations, designs, imaging protocols, and scoring systems limited comparability and prevented meta-analysis. Small sample sizes in many studies reduced result reliability, and most were retrospective, introducing potential biases. Data on long-term outcomes and findings in special populations, such as children and immunocompromised patients, were sparse. Additionally, reliance on advanced imaging modalities like CT and MRI limits applicability in low-resource settings. Publication and language biases may also have excluded relevant non-English research.

CONCLUSION

In conclusion, the studies reviewed highlight the clinical utility of various imaging modalities such as lung ultrasound (LUS), chest X-ray, computed tomography (CT), and magnetic resonance imaging (MRI) in diagnosing and assessing the severity of COVID-19 pneumonia. These imaging techniques demonstrated their value in detecting early signs of pneumonia, monitoring disease progression, and guiding clinical decisions, including the need for oxygen therapy and mechanical ventilation. LUS and CT scans, in particular, showed consistent sensitivity and specificity, with LUS effectively detecting B-lines indicative of early pneumonia even when chest X-rays were normal. These findings suggest that LUS and CT can be crucial for rapid decision-making in managing COVID-19, especially in settings with limited access to more advanced imaging modalities.

However, the studies also highlighted significant limitations, including the retrospective nature of most research, lack of control groups, and variability in patient severity and timing of imaging assessments. These factors introduce the potential for bias, limiting the ability to draw definitive conclusions about the superiority of one imaging modality over another. The absence of randomization

and proper allocation in many studies further compounds this issue. Despite these challenges, the consistency in findings across studies provides confidence in the diagnostic value of these imaging tools. Future research should aim to address these limitations by conducting large-scale, randomized controlled trials with clear inclusion and exclusion criteria. Such studies would help clarify the comparative effectiveness of different imaging techniques and their prognostic value in predicting patient outcomes, including mortality and the need for intensive care. Additionally, longitudinal studies with complete follow-up data are needed to further evaluate the long-term benefits of imaging in COVID-19 management. In clinical practice, it is recommended that healthcare providers use a combination of imaging modalities, especially LUS and CT, for the early detection and severity assessment of COVID-19 pneumonia. These modalities should complement clinical evaluations and laboratory tests to ensure comprehensive patient management. While current findings underline the importance of imaging, further research is essential to refine their role and improve patient outcomes in the context of COVID-19 pneumonia.

DISCLOSURE STATEMENT

- Disclosure Statement : The authors have no conflicts of Interest to declare
- Funding Sources : None
- Acknowledgements : -
- Author Contribution : All authors discussed and contributed the final content for journal submission and publication

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