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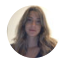
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**REVIEW ARTICLE**

# Key Radiological Features of COVID-19 Chest CT Scans with a Focus on Special Subgroups: A Literature Review

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**Abstract:** ***Background:*** In 2019, a series of novel pneumonia cases later known as Coronavirus Disease 2019 (COVID-19) were reported in Wuhan, China. Chest computed tomography (CT) has played a key role in the management and prognostication of COVID-19 patients. CT has demonstrated 98% sensitivity in detecting COVID-19, including identifying lung abnormalities that are suggestive ofCOVID-19, even among asymptomatic individuals.

***Methods:*** We conducted a comprehensive literature review of 17 published studies, focusing on three subgroups, pediatric patients, pregnant women, and patients over 60 years old, to identify key characteristics of chest CT in COVID-19 patients.

***Results:*** Our comprehensive review of the 17 studies concluded that the main CT imaging finding is ground glass opacities (GGOs) regardless of patient age. We also identified that crazy paving pattern, reverse halo sign, smooth or irregular septal thickening, and pleural thickening may serve as indicators of disease progression. Lesions on CT scans were dominantly distributed in the peripheral zone with multilobar involvement, specifically concentrated in the lower lobes. In the patients over 60 years old, the proportion of substantial lobe involvement was higher than the control group and crazy paving signs, bronchodilation, and pleural thickening were more commonly present.

***Conclusion:*** Based on all 17 studies, CT findings in COVID-19 have shown a predictable patternof evolution over the disease. These studies have proven that CT may be an effective approach for early screening and detection of COVID-19.

**Keywords:** COVID-19, SARS-CoV-2, computed tomography, X-Ray, lung, pneumonia, viral, pandemic

## 1. INTRODUCTION

In 2019, a series of novel pneumonia cases were reported in Wuhan, China. These cases later became known as severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) [1]. Coronaviruses are a family of viruses that cause illnesses, including severe acute respiratory syndrome and the Middle East respiratory syndrome [1].

SARS-CoV-2 is the virus that causes the coronavirus disease 2019 (COVID-19). By February 17$^{th}$, 2020, 72,436 laboratory cases were confirmed in 31 provinces in China [1]. By March 27$^{th}$, 2020, a total of 509,164 confirmed cases were reported worldwide, according to the World Health Organization (WHO). Given these statistics, the WHO declared the COVID-19 outbreak a pandemic. One year later, in the United States, over 538,000 deaths with over 29 million documented cases were reported [1].

Since the beginning of the outbreak, computed tomography (CT) has played a crucial role in detecting COVID-19 patients due to the primary involvement of the lungs in this disease. Studying CT findings of COVID-19 is particularly challenging because some features may overlap with other pathologies, particularly other types of viral pneumonia.

Information regarding the diverse presentation and impact of COVID-19 continues to be revealed as more research is published, so this review intends to serve as an update on previous studies focusing on COVID-19 CT radiological findings.

### 1.1. The Additive Role of CT in Clinical Diagnosis

Viral nucleic acid detection by reverse transcription polymerase chain reaction (RT-PCR) is the method of choice for COVID-19 diagnosis. RT-PCR detects viral nucleotides from specimens obtained by na-

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so/oropharyngeal swab, bronchoalveolar lavage, or tracheal aspirate [2].

However, it has shown as low as 60-71% sensitivity for detecting COVID-19, leading to a number of false negatives, which could ultimately put communities and individuals at risk because of delayed treatment and lack of necessary self-isolation. RT-PCR is also a more time-consuming method as it generally has long turnaround times [2].

Chest CT is a non-invasive and widely available diagnostic tool for detecting pneumonia [3]. While CT may not be a first-line diagnostic method, as the only way to confirm COVID-19 is with RT-PCR, CT plays a key role in the management of COVID-19 patients and prognostication [3]. Ali *et al*. [4] reported that follow-up chest CT scans suggested an improvement in the condition of 42% of patients before their RT-PCR re-testing results turned negative. CT has demonstrated up to 98% sensitivity in detecting findings that are potentially related to COVID-19, including lung abnormalities that can be suggestive of COVID-19, even among asymptomatic individuals [3].

Additionally, CT allows physicians to observe the progression of imaging features throughout the disease's course [5]. CT's high sensitivity for screening potential COVID-19 may also be an effective approach for early screening and detection of COVID-19 [6].

## 2. METHODOLOGY

### 2.1. Literature Search and Study Selection

This literature review identified 17 studies that evaluated COVID-19 chest CT imaging patterns (Table **1**). Six of the studies concentrated on key sub-populations: two studies focus on children, two focus on pregnant women, and two focus on elderly patients. Each study included a cohort of patients who were subject to an RT-PCR test and a chest CT scan that were analyzed by experienced radiologists. Through RT-PCR testing, they were classified as either COVID-19 positive or negative. A site ID number(1-17) was assigned to each study, and the studies were referenced according to their site ID number in subsequenttables.

## 3. RESULTS

Seventeen studies, with a total of 1,413 patients, were included in the final review. Several key conclusions that remained consistent throughout these studies were: 1) ground glass opacities (GGOs) are the most common CT finding, 2) consolidation without GGOs is very unlikely, 3) crazing paving patterns, reverse halo, and pleural thickening indicate more severe cases of COVID-19 and become apparent in the later stages of disease progression, 4) COVID-19 tends to affect the lower lobes more than theupper lobes, and 5) it is more common for lesions to be seen in a peripheral distribution pattern.

### 3.1. Ground Glass Opacities are the Most Common COVID-19 CT Finding

In all 17 studies, the most common finding in COVID-19-positive patients was GGO, ranging from 52.8%- 98.2% of patients showing some GGO presence. GGOs are unspecified findings defined as "hazy lung opacities that do not obscure the underlying vascular or bronchial margins" [4]. GGOs are a subgroup of reticular and linear opacities due to a decrease in the gas to soft tissue ratio.

They can be classified by their size into fine, medium, or coarse, and the "fine" lines are referred to as ground glass [6]. Definitions of different subtypes of GGO are listed in Table **2**, and a summary of all GGO findings is reported in Table **3**.

GGOs have been reported in both asymptomatic and symptomatic COVID-19 populations. In one clinical study of 58 asymptomatic COVID-19 patients conducted by Meng *et al*. [7], it was found that GGOs were the main CT manifestation (94.8%): pure GGO (51.7%), GGO with fine reticulation (12.1%), GGO with subpleural curvilinear line (10.3%), GGO with air bronchogram (8.6%), GGO with halo sign (8.6%) and GGO with a vascular enlargement (3.5%) [7].

Chung *et al*. [8] reviewed 21 symptomatic COVID-19 patients, reporting GGO in 18 subjects, with the remaining three patients having normal chest CT scans. Of these three patients, one progressed three days later and developed a single GGO in the right lower lobe, and another received a follow-up chest CT four days after initial imaging that remained normal [8].

Song *et al*. [9] similarly reported high rates of GGO in 51 COVID-19 patients, 98% of whom had contact with at least one person from Wuhan, China. Simple GGO was present in 77% of patients, GGO with reticular and/or interlobular septal thickening was seen in 75% of patients, and GGO with consolidation was reported in 59% of patients [9].

In another study directed by Shi *et al*. [5], 81 patients with confirmed COVID-19 pneumonia underwent serial chest CT scans between December 20$^{th}$, 2019 and January 23$^{rd}$, 2020. Regardless of when CT was acquired after symptom onset, GGO remained the predominant finding (65%) with consolidation and reticular patterns becoming more prominent through the disease course. GGO was reported at the highest rates in subclinical cases prior to symptom onset (93%) compared to 33% for CT performed 2-3 weeks after symptom onset [5]. In subclinical cases, the typical manifestation of CT images was predominantly unilateral and multifocal GGO. In the first week after the onset of symptoms, lesions progressed to becomebilateral in 19/21 patients and diffuse patterned in 11/21 patients but remained predominantly of GGO appearance. In the second week after symptom onset, GGOs continued to decrease in frequency (57%), and consolidation patterns were also noted (30%). In the third week after symptom onset, GGOs decreased further (33%), and reticular patterns (33%) became more common [5].

Zhao *et al*. [10] also found GGO as the predominant CT finding (86.1%) in a cohort of 101 COVID-19 patients. Mixed GGO with consolidation was found in 64.4% of patients, and 7.9% of patients showed no

**Table 1. A summary of the studies used in this review, including a given reference number, title, journal, author, date published, number of patients, and sex and age of the patients.**

| Study ID | Title | Journal | Author | Site Location | Date Published | Number of Patients | Sex M/F | Age (Mean) |
|---|---|---|---|---|---|---|---|---|
| 1 | CT Imaging and Clinical course of asymptomatic cases with COVID-19 pneumonia at admission in Wuhan, China | The Journal of Infection Vol. 81 | Meng *et al*. [1] | Wuhan, Hubei, China | 2020 April 12 | N=58 | 26 M 32 F | 42.60±16.56 |
| 2 | CT Imaging Features of 2019 Novel Coronavirus (2019-nCoV) | Radiology Vol. 295 | Chung *et al*. [2] | Zhuhai, Guangdong, China; Nanchang, Jiangxi, China; Qingdao Shandong, China | 2020 February 4 | N=21 | 13 M 8 W | 51±14 |
| 3 | Emerging 2019 Novel Coronavirus (2019-nCoV) Pneumonia | Radiology Vol. 295 | Song *et al*. [3] | Shanghai, China | 2020 February 6 | N=51 | 25 M 26 W | 49±16 |
| 4 | Radiological Findings from 81 patients with COVID-19 pneumonia in Wuhan, China: a descriptive study | The Lancet. Infectious Diseases Vol. 20 | Shi *et al*. [4] | Wuhan, Hubei, China. | 2020 February 24 | N=81 | 42 M 39 W | 49.5±11 |
| 5 | Relation Between Chest CT Findings and Clinical Conditions of Coronavirus Disease (COVID-19) Pneumonia: A Multicenter Study | American Journal of Roentgenology Vol. 214 | Zhao *et al*. [5] | Hunan, China | 2020 October 5 | N=101 | 56 M 45 W | 44.44 ± 12.32 |
| 6 | Clinical and laboratory data, radiological structured report findings and quantitative evaluation of lung involvement on baseline chest CT in COVID-19 patients to predict prognosis | La Radiologia Medica Vol. 126 | Salvatore *et al*. [6] | Avellino, Italy | 2020 October 12 | N=103 | 62 M 41 W | 68.8 |
| 7 | Performance of Radiologists in Differentiating COVID-19 from NON-COVID-19 Viral Pneumonia at Chest CT | Radiology RSNA Vol. 296 | Bai *et al*. [7] | Hunan, China | 2020 March 10 | N=219 | 119 M 100 W | 45 ±15 |
| 8 | Temporal Changes of CT Findings in 90 Patients with COVID-19 Pneumonia: A Longitudinal Study | Radiology RSNA Vol. 296 | Wang *et al*. [8] | Wuhan, Hubei, China | 2020 March 19 | N=90 | 33 M 57 W | 45±14 |
| 9 | Radiological findings spectirum of asymptomatic coronavirus (COVID-19) patients | Egyptian Journal of Radiology and Nuclear Medicine Vol. 51 | Ali *et al*. [9] | Cairo, Egypt | 2020 August 18 | N=44 | 16 M 28 W | 35.7 |
| 10 | CT Findings in a novel Coronavirus Disease (COVID-19) Pneumonia at Initial Presentation | Biomed Research International Vol. 2020 | Xiang *et al*. [10] | Yichang, Hubei, China | 2020 August 18 | N=53 | 31 M 22 W | 53±14 |
| 11 | Time Course of Lung Changes at Chest CT during Recovery from Coronavirus Disease 2019 (COVID-19) | Radiology RSNA Vol. 295 | Pan *et al*. [11] | Wuhan, Hubei, China | 2020 February 13 | N=21 | 6 M 15 F | 40±9 |
| 12 | Clinical characteristics and intrauterine vertical transmission potential of COVID-19 infection in nine pregnant women: a retrospective review of medical records | The Lancet Vol. 395 | Chen *et al*. [12] | Wuhan, Hubei, China | 2020 February 12 | N=9 | 9 F | 27 |
| 13 | Clinical and CT Imaging Features of of the COVID -19 Pneumonia: Focus on Pregnant Women and Children | Journal of Infection Vol. 80 | Liu *et al*. [13] | Shanghai, China; Wuhan, Hubei, China | 2020 March 1 | N=59[1] | 5 M 41 F | 30 |
| 14 | A comparative Study of Chest Computed Tomography Features in Young and Older Adult with CoronaVirus Disease (COVID-19) | Journal of Thoracic Imaging Vol. 35 | Zhu *et al*. [14] | Wuhan, Hubei, China | 2020 July | N=72 | 42 M 30 W | 55.6±12.8 |
| 15 | Clinical and CT Findings of COVID-19: differences among 3 age groups | BMC Infectious Diseases Vol. 20 | Wang *et al*. [15] | Zhejiang, China; Hangzhou, China; Bengbu, China | 2020 June 22 | N=307 | 156 M 151 F | 57.65±15.754 |
| 16 | Imaging Features of Pediatric Covid-19 on Chest Radiography and Chest CT: a Retrospective, Single -Center Study | Academic Radiology Vol. 28 | Bayramoglu *et al*. [16] | Istanbul, Turkey | 2020 Oct 5 | N=74 | 36 M 38 F | 11 12 |
| 17 | A Single Center Retrospective Study of COVID-19 Features in children: A descriptive Investigation | BMC Medicine Vol. 18 | Ma *et al*. [17] | Wuhan, China | 2020 May 6 | N=50 | 28 M 22 F | |

[1] 41 pregnant women, 11 non-pregnant adults, and 4 children

**Table 2. Definitions of subtypes of ground glass opacities (GGOs). Definitions are provided by Radiopaedia [18].**

| - | Simple GGO (Pure GGO) | GGO with Fine Reticulation | GGO with Subpleural Curvilinear Line | GGO with Air Bronchogram | GGO with Halo Sign | GGO with Vascular Enlargement |
|---|---|---|---|---|---|---|
| Definition | GGO with no solid components. | A crazy-paving appearance that consists of a "net-work of smooth linear patterns su-perimposed on the section of GGO." | Thin curvilinear opacities, 1-3 mm in thickness, less than 1 cm from and parallel to the pleural surface. | Gas-filled bronchi surrounded by alveoli filled with fluid, pus or other material found in the area of GGO. | Nodules or masses surrounded by ground glass. | The dilatation of pulmonary vessels around and within the lesions in an unnatural way on CT images. |

**Table 3. Distribution and frequency of GGO patterns across 10 of the 17 studies.**

| Study ID | Number of Patients with GGO | Percent of Pa-tients with GGO | Simple/ Pure GGO | GGO with Fine Reticula-tion | GGO with Subpleural Curvilinear Line | GGO with Air Bronchogram | GGO with Halo Sign | GGO with Vascular Enlargement |
|---|---|---|---|---|---|---|---|---|
| 1 | 55/58 | 94.8% | 30/58 (51.7%) | 7/58 (12.1%) | 6/58 (10.3%) | 5/58 (8.6%) | 5/58 (8.6%) | 2/58 (3.5%) |
| 2 | 18/21 | 85.7% | 12/21 (57%) | N/A | N/A | N/A | N/A | N/A |
| 3 | N/A | N/A | 39/51 (77%) | 38/51 (75%) | N/A | 41/51 (80%) | N/A | N/A |
| 4 | 53/81 | 65.4% | N/A | 3/81 (3.7%) | N/A | 38/81(46.9%) | N/A | N/A |
| 5 | 87/101 | 86% | N/A | 49/101 (48.5%) | N/A | N/A | N/A | 72/101 (71.3%) |
| 6 | 86/98 | 87.76% | 10/98 (10.2%) | N/A | N/A | N/A | N/A | N/A |
| 7 | 200 /256 | 91% | N/A | N/A | N/A | N/A | N/A | N/A |
| 8 | 35 of 78 scans<br>49 of 79 scans | 45% (12-17 days after symptom onset)<br>62% (0-5 days after symptom onset) | N/A | N/A | N/A | N/A | N/A | N/A |
| 9 | 41/44 | 93% | 28/44 (63%) | 8 /44 (18.1%) | 1/44 (2.27%) | N/A | 4/44 (9.09%) | N/A |
| 10 | 28/53 | 52.8% | N/A | N/A | N/A | N/A | N/A | N/A |

abnormal CT findings. Zhao's study also evaluated the differences between an emergency group and a non-emergency group and found that diffuse lesions in the emergency group (78.6%) were more common than in the non-emergency group (24.1%) [10].

Salvatore *et al*. [11] reviewed 98 patients for whom CT imaging was obtained within two days of clinical evaluation and RT-PCR testing. A 5-level severity score wasused to assess lung involvement. The score accounted for GGO and consolidation for each lobe: "none (0%), mild (1- 25%), moderate (26-50%), severe (51-75%) and critical (76-100%)." GGO with or without consolidations was the main CT finding. Simple GGO was present in 10.2% of the patients, while a combination of GGO and consolidations was found in 87.8% of patients [11].

In a study conducted by Bai *et al*. [2], 219 COVID-19 patients were differentiated from non-COVID-19 viral pneumonia using chest CT. The most discriminating features for COVID-19 pneumonia included "peripheral distribution (80% *vs*. 57%, P< .001)" and "GGO (91% *vs*. 68%, P< .001)" [2].

Wang *et al*. [12] examined 90 patients who underwent CT examinations. Ten patients received their first CT before symptom onset, with six having normal chest CT scans and four having either GGO or consolidation. Pure GGO was the most prevalent finding during the course of illness. When combined, GGO and consolidation accounted for 83%-85% of all CT findings in the early stages of the disease. Pure GGO was only seen before symptom onset in 2 cases. Pure GGO dropped significantly from 65% on illness days 0-5 to 40% on illness days 6-11. The percentage of pure GGO gradually increased from illness days 6-11 to 51% on illness days 11-18, 71% on illness days 18-23, and 70% on illness days 24 or higher. On the other hand, patients with GGO with superimposed inter-lobular crazy paving patterns peaked at illness days 6-11. The percentage of "irregular lines and interfaces superimposed on GGO" increased significantly from 8% on days

0-5 to 28% on days 6-11 (P=.02) and became the most common GGO pattern subsequently [12].

Ali *et al*. [4] identified that the most prominent radiological feature was also GGO (93.2%). Simple GGO was found in 28/44 patients (63.6 %), GGO with thickened interlobular septae (18.8%), GGO with curvilinear subpleural line (2.27%), and GGO with halo sign (9.09%) were also reported [4].

Xiang *et al*. [13] collected data from 53 COVID-19 patients, aiming to analyze features of COVID-19 pneumonia in cases without severe basic pulmonary disease.In their study, 45.3% of patients showed GGO with consolidation, and 52.8% showed isolated GGO [13].

Similar to Wang *et al*. [12], Pan *et al*. [14] conducted a study on 21 patients with confirmed COVID-19 to evaluate the degree of abnormalities present in each lung lobe according to days since symptom onset: 0-4 days (n=24), 5-8 days (n=17), 9-13 days (n=21), and ≥14 days (n=20). Each of the five lung lobes was visually scored from 0 to 5, with "0 indicating no involvement; 1, less than 5% involvement; 2, 5%-25% involvement; 3, 26%-49% involvement; 4, 50%-75% involvement; and 5, more than 75% involvement." The total CT score (0-25) was the sumof individual lobar scores [14].

In 18 patients, the total CT score increased aroundday 10 after symptom onset and then gradually decreased [14]. The most common CT findings on days 0-4 were GGO (75%). During 5-8 days after symptom onset, GGO in 14/17 scans advanced to more lung lobes. After 9-13 days following symptom onset, consolidation increased for 19/21 scans, and GGO decreased for 15/21 scans. Twenty-one patients showed small subpleural GGO on chest CT that grew larger with crazy paving patterns and consolidation over time [14]. This study evaluated the frequency of GGO and other findings by stages, so it is not included in Table **3**.

### 3.2. Consolidation is the Second Most Prevalent CT Finding

Consolidations result from the replacement of alveolar air spaces with pathological fluids. These fluids can include cells, pus, or blood, which ultimately leads to an increase in parenchymal density that blocks the vessels and bronchial walls. Consolidations may be patchy, multifocal or segmental, with subpleural or peribronchovascular distribution. Consolidation is more commonly seen in conjunction with GGO and can be suggestive of disease progression [9, 11,14] (Fig. **1**). As consolidations have been more commonly seen in middle-late disease progression and patients aged 50 years or older, they may be a warning sign of severe prognosis [13]. A summary of distribution and frequency of consolidation across all sites is reported in Table **4**.

Across all studies, consolidation alone was not a common CT finding; as few as 1.9% of patients demonstrated consolidation in the absence of GGO [14].

Song *et al*. [9] found more consolidation lesions and fewer GGO lesions in patients who received CT four or more days after disease onset (61%) than in patients who were scanned earlier in the disease course (21%), suggesting that consolidation increases as the disease progresses. In addition, there were more consolidation lesions, including GGO with consolidation and pure consolidation, in older patients (45%) than in younger patients (23%). The authors concluded that consolidation indicates COVID-19 progression and could serve as an alertto start more intensive treatment [9].

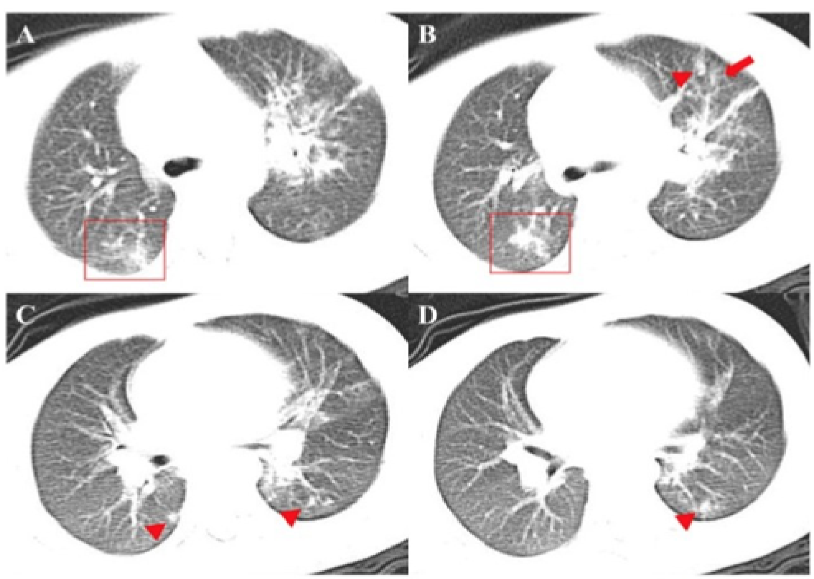


**Fig. (1). "**Chest CT images of a 2-year-old female patient show multiple patchy/nodular ground-glass opacity and consolidation, with blurry margins; the patchy/nodular consolidation is mostly located in the mid and inner zones of both lower lung lobe (**A**-**D**, red boxes and triangles), with high density inside the lesions and relatively low density in the periphery, presenting a "halo sign" appearance; the GGO was located in the outer zone of the left upper lobe (**B**, red arrow)." Figure and caption have been reproduced from [31] under Creative Commons Attribution 4.0 International (CC BY 4.0) License (http://creativecommons.org/licenses/by/4.0/). (*A higher resolution / colour version of this figure is available in the electronic copy of the article*).

**Table 4. Distribution and frequency of consolidation across 10 out of 17 studies.**

| Study ID | Number of Patients with Consolidation | Percentage of Patients with Consolidation | Pure Consolidation | Consolidation with Ground Glass Opacities |
|---|---|---|---|---|
| 1 | 3/58 | 5.2% | N/A | N/A |
| 2 | 6/21 | 29% | 0/21 (0%) | 6/21 (29%) |
| 3 | 28/51 | 55% | N/A | 30/51 (59%) |
| 4 | 14/81 | 17.3% | N/A | N/A |
| 5 | 44/101 | 43.6% | N/A | 65/101 (64.4%) |
| 6 | N/A | N/A | 2/98 (2.0%) | 86/98 (87.8%) |
| 7 | 150/256 | 69% | N/A | N/A |
| 9 | 3/44 | 6.81% | N/A | N/A |
| 10 | N/A | N/A | 1/53 (1.9%) | 24/53 (45.3%) |

**Table 5. Frequency of other radiological features.**

| Study ID | Crazy Paving Pattern | Smooth or Irregular Septal Thickening | Air Bronchogram | Reversed halo Sign | Halo Sign | Pleural Thickening | Pleural Effusions |
|---|---|---|---|---|---|---|---|
| 1 | N/A | N/A | 5 (8.6%) | N/A | 5 (8.6%) | N/A | N/A |
| 2 | 4/21 (19%) | N/A | N/A | N/A | N/A | N/A | 0 (0%) |
| 3 | N/A | 11/51 (22%) | 41/51 (80%) | N/A | N/A | N/A | 3/51 (6%) |
| 4 | 8/81 (10%) | 28/81 (35%) | 38(47%) | N/A | N/A | N/A | 4/81 (5%) |
| 5 | N/A | 49/101 (48.5%) | N/A | N/A | N/A | N/A | 14/101 (13.9%) |
| 6 | 55/98 (56.1%) | N/A | N/A | 20/98 (20.41%) | N/A | N/A | N/A |
| 7 | 11/219 (5%) | 77/219 (35%) | 30/219(14%) | 11/219 (5%) | 56/219 (26%) | 32/219 (15%) | 9/219 (4%) |
| 8 | N/A | N/A | N/A | N/A | N/A | N/A | 6/90 (7%) |
| 9 | N/A | 8/44 (18.8%) | N/A | N/A | 4/44 (9%) | N/A | N/A |
| 10 | 14/53 (26.4%) | | 6/53 (11.3%) | N/A | N/A | N/A | 1/53 (1.9%) |

Meng *et al*. [7] and Ali *et al*. [4] reported consolidation in low rates for asymptomatic patients (5.2% and 6.81%, respectively). Meng *et al*. [7] also noted that consolidations were more prevalent after the onset of symptoms and were commonly seen with other complex CT findings, including crazy paving patterns and reticular findings. Shi *et al*. [5] reported that in the first week after symptom onset, there was a transition of CT findings to consolidation and mixed-pattern development. The second week after symptom onset, while GGO was still prominent (57%), consolidation became the second most common pattern (30%). In the third week after symptom onset, GGOs decreased, while consolidation and mixed patterns became more common [5].

Similarly, in a study by Xiang *et al*. [13], more patients showed consolidation in conjunction with GGO (45.3%) than pure consolidation (1.9%) [13]. Chung *et al*. [8] reported that, of the 18 patients with GGOs, 12 had only GGO without consolidation, and no patient demonstrated consolidation without GGO [8].

According to Wang *et al*. [12], consolidation was the second most frequent finding during illness on days 0-5 and 6-11, 23% and 24%, respectively. However, Pan *et al*. [14] reported higher percentages of consolidation and found that within 4 days after disease onset, 10/24 scans showed consolidation, and within 5-8 days, 8/17 scans showed consolidation. Consolidative lesions peaked 9-13 days after disease onset with 19/21 scans and then decreased after 14 days with 15/20 scans showing consolidation [14].

### 3.3. Imaging Findings in More Complicated Cases of COVID-19

Complex CT findings are mostly present in more serious cases of COVID-19 and during latent stages of disease (usually 5+ days after disease onset). These findings, which include subpleural curvilinear line, fine reticulation, air bronchogram, reverse halo sign, or vascular enlargement, might be seen accompanying GGO and consolidation and are summarized in Table **5**. A reticular pattern is a complex network of linear opacities associated with interlobular and intralobular septal thickening that together create a net-like appearance [15]. The frequency of reticular patterns increases as the disease progresses. A crazy-paving pattern refers to the presence of

GGO with superimposed intralobular and interlobular septal thickening [16].

Pan *et al*. [14] found that crazy paving patterns peaked 5-8 days after symptom onset (53%) and were not present more than 14 days after symptom onset, likely as a sign of recovery [14]. Xiang *et al*. [13] reported a crazy paving pattern in 26.4% of patients. Chung *et al*. [8] reported that 19% of patients showed crazy paving and 14% showed reticulation [8]. Wang *et al*. [12] identified GGO with a crazy paving pattern as the second most common CT finding on days 0-5 of illness (24%) [12].

Salvatore *et al*. [11] identified crazy paving patterns in 56.1% of patients with no statistical difference among patients discharged at home, hospitalized cases with stable conditions, and patients in critical conditions or who died of the disease (p>.05). This finding is not in line with other studies, as the crazy paving pattern is typically observed in morecomplicated cases of COVID-19 [11].

Xiang *et al*. [13] identified air bronchogram (11.3%), interlobular thickening (9.4%), and reticular pattern (1.9%) as additional findings. In this study, air bronchograms were seen within GGO lesions and consolidation, suggesting unobstructed proximal airways [13].

Another type of CT finding is pleural changes. Pleural changes can either be reported as pleural effusion or pleural thickening [17]. Pleural effusion refers to the filling of the pleural space with fluid. Pleural thickening is a process where the pleura is thickened, usually with scar tissue [17]. According to Shi *et al*. [5], 10% of patients showed crazy paving patterns, 47% had air bronchograms, and 35% had smooth or irregular interlobular or septal thickening. Pleural effusion (5%) and lymphadenopathy (14%) were detected one week after symptom onset. Three weeks after symptom onset, bronchiectasis 2/15 (13%), thickening of the adjacent pleura (47%), pleural effusions (13%), and lymphadenopathy (13%) were detected [5].

Song *et al*. [9] reported pleural effusion in 3/51 patients. Pleural effusions were bilateral in one patient and unilateral in three patients [9]. Xiang *et al*. [13] only reported pleural effusion in 1 (1.9%) patient. Zhao *et al*. [10] reported pleural effusion in 13.9% of patients and vascular enlargement in 71.3% of patients [10].

According to Wang *et al*. [12], small bilateral pleural effusions were found in 6/90 of the patients. In three of those six patients, pleural effusion was present in initial and follow-up CTs. However, in the other three patients, pleural effusion developed on illness days 11, 21, and 24 and lasted until the last CT scans [12].

However, Bai *et al*. [2] found that COVID-19 patients were less likely than non-COVID-19 patients to have air bronchogram (14% *vs*. 23%, p=.01), pleural thickening (15% *vs*. 33%, p<0.001), or pleural effusion (4% *vs*. 39%, p<.001) [2].

A halo sign is a nodule or mass surrounded by GGO; however, it is not specific to COVID-19 and is not a common CT finding. The reverse halo sign is seen as a ring-like area of consolidation with a superimposed rounded GGO [16].

Ali *et al*. [4] noted that while reverse halo sign was not seen in any patient, GGO with halo sign was seen in 9.09% of patients. In a separate study, GGO with halo sign was observed in 8.6% of patients.

Bai *et al*. [2] found that COVID-19 patients were more likely than non-COVID-19 patients to have reverse halo sign (5% *vs*. 1%, p=.005), fine reticular opacity (56% *vs*. 22%, p<0.001) and vascular thickening (59% *vs*. 22%, p< .001) [2].

### 3.4. Lobe Involvement and Distribution Pattern of Lesions

COVID-19 patients tend to show GGO and crazy paving patterns with a peripheral distribution pattern and lower lobe involvement. Table **6** summarizes transverse distribution patterns (peripheral *vs*. central). Table **7** summarizes the number of lobes involved. Table **8** provides the distribution type (unilateral *vs*. bilateral), and Table **9** summarizes the frequency of lobe involvement (single lobe *vs*. multilobar distribution).

Meng *et al*. [7] reported lesions with primary distribution in the periphery (75.9%), usually involving one or two lung lobes (65.5%) in asymptomatic COVID-19 patients. GGO lesions were more likely to be seen in the lower lobes (left-62.1%, right-68.9%) compared to the upper lobes (left-53.4%, right-51.7%). A majority of patients (75.9%) were presented with peripherally distributed lesions.

Lung lesions are defined as peripheral if located within 3 centimeters of a costal pleural surface. Comparatively, 24.1% of patients had involvement of two lobes, and 34.5% of patients had more than two lobes involved [7].

Ali *et al*. [4] reported that CT findings presented with only peripheral distribution (77.3%) and bilateral position (45.5%) with lower lobe predominance (left-72.7%,right-50%) [4].

Both Ali *et al*. [4] and Meng *et al*. [7] found a dominance of unilateral distribution, 54.4% and 58.6%, respectively, which was not consistent with the majority of other studies.

Chung *et al*. [8] showed increasing involvement of multiple lobes with 5%, 10%, 14%, 19%, and 38% having lesions affecting one, two, three, four, and five lobes, respectively. A peripheral location of the opacities was also reasonably common (33%). They also evaluated the most commonly affected lobes for the 21 patients: right upper lobe (14), right middle lobe (12), right lower lobe (16), left upper lobe (14), and left lower lobe (14). Of the 18 patients with CT manifestations, 16 had bilateral involvement. This study confirmed that bilateral distribution was more dominant than unilateral distribution, and the rightlower lobe was most affected [8].

Song *et al*. [9] identified 86% of patients with lesions involving both lungs and 63% with lesions involving four to five lobes. Regarding distribution, 90% of patients had

**Table 6. Summary of transverse distribution pattern of pulmonary lesions.**

| Study | Peripheral | Central |
|---|---|---|
| 1 | 44/58 (75.9%) | 14/58 (24.1%) |
| 2 | 7/21 (33%) | N/A |
| 3 | 44/51 (86%) | 5/51 (10%) |
| 4 | 44/81 (54.3%) | 10/81 (12.4%) |
| 5 | 88/101 (87.1%) | 1/101 (1.0%) |
| 6 | 73/98 (74.5%) | N/A |
| 7 | 176/256 (80%) | 3/256 (1%) |
| 9 | 34/44 (77.3%) | 14/44 (24.1%) |
| 10 | 38/53 (71.7%) | N/A |

**Table 7. Summary of location of lobes involved.**

| Study | Left Upper Lobe | Left Lower Lobe | Right Upper Lobe | Right Middle Lobe | Right Lower Lobe |
|---|---|---|---|---|---|
| 1 | 31/58(53.4%) | 36/58(62.1%) | 30/58(51.7%) | 12/58(20.7%) | 40/58(68.9%) |
| 2 | 14/21 (67%) | 14/21 (67%) | 14/21 (67%) | 12/21 (57%) | 16/21 (76%) |
| 3 | N/A | N/A | N/A | 30/51 (59%) | N/A |
| 9 | 14/44 (31.8%) | 32/44 (72.7%) | 14/44 (31.8%) | 2/44 (4.5%) | 22/44 (50%) |

**Table 8. Bilateral *vs*. unilateral distribution in the lungs.**

| Study | Bilateral Distribution | Unilateral Distribution |
|---|---|---|
| 1 | 24/58 (41.4%) | 34 (58.6%)<br>R lung: 20/58 (34.5%)<br>L lung: 14/58 (24.1%) |
| 2 | 16/21 (76%) | 2/21 (9.5%)<br>R lung: 2 (100%) |
| 3 | 44/51 (86%) | 7/51 (14%) |
| 4 | 64/81 (79%) | 17/81 (21%) |
| 5 | 83/101 (82.2%) | 10/101 (9.9%) |
| 6 | 76/98 (77.6%) | N/A |
| 7 | 165/256 (75%) | 41/256 (19%) |
| 9 | 20/44 (45.5%) | 24/44 (54.5%) |
| 10 | 45/53 (84.9%) | N/A |

**Table 9. Summary of frequency of lobe involvement.**

| Study | Single Lobe Involvement | Multiple Lobe Involvement | 2 Lobes Involved | 3 or More Lobes Involved |
|---|---|---|---|---|
| 1 | 22/58 (37.9.%) | 36/58 (62.1%) | 14/58 (24.1%) | 20/58 (34.5%) |
| 2 | 1/21 (5%) | 15/21 (71%) | 2/21 (10%) | 15/21 (71.4%) |
| 3 | 4/51 (8%) | 46/51 (90%) | 8/51 (16%) | 38/51 (74.8%) |
| 5 | 6/101 (5.9%) | 55/101 (54.5%) | N/A | N/A |
| 6 | N/A | 51/98 (52.0%) | N/A | N/A |
| 7 | 15/256(7%) | 134/256 (61%) | N/A | N/A |
| 8 | 15/90 (17%) | 75/90 (85%) | N/A | N/A |
| 10 | 8 (15.1%) | 45/53 (84.9%) | N/A | N/A |

lesions distributed across the lower lobes, 80% had posterior lesions, and 86% had peripherally distributed lesions. Additionally, 84% showed lesions in the upper lobe, 59% showed lesion distribution in the middle lobe, and 90% showed lesions distributed in the lower lobe [9].

The primary distribution patterns observed in a study conducted by Shi *et al*. [5] were bilateral (79%), peripheral (54%), ill-defined (81%), predominantly involving the right lower lobe, which had 225/849 (27%) affected segments and 36 (44%) showed the diffuse distribution of lesions. Shi *et al*. [5] noted that the right lower lobe was most commonly affected, with more segments involved in symptomatic patients than asymptomatic patients ($p<.0001$). This study examined the mean involvement of lung segments rather than lobes. The group of patients with CT acquired more than 1-2 weeks after symptom onset had the highest mean number of involved segments [5]. Salvatore *et al*. [11] found similar results, citing that COVID-19 lesions were bilateral in 77.6% of patients with peripheral distribution in 74.5% and multiple lobe localizations in 52.0% [11].

Zhao *et al*. [10] observed that patients with COVID-19 were more likely to have peripheral distribution (87.1%), lower lung predominance (54.5%), bilateral involvement (82.2%), and multifocal distribution (54.5%) [10].

Wang *et al*. [12] observed that unilateral involvement was more common in patients in the early and recovery phases of COVID-19. All patients had bilateral lung involvement on illness days 12-17 until days 18-23 [12].

Xiang *et al*. [13] studied 53 patients with a total of 399 involved lung segments and reported that lower lobes were the most commonly involved (left lower lobe-104 segments, right lower lobe-107 segments). Multilobe and peripheral involvements were very common, with 86.8% of cases showing multilobar involvement with a predominance of lower lobes. Only 8 patients had a single lobe affected. Additionally, among 18 patients with lung opacity, 16 had bilateral distribution [13].

Pan *et al*. [14] reported that the mean number of involved lung segments in their study was 10.5, with the lower lobes, most commonly right, predominantly affected.

From these studies, the main pattern reported was a majority of lower lobe involvement. Several studies also noted a dominance in the right lower lobe specifically. Most patients showed multilobar involvement with an increased likelihood of COVID-19 affecting more than two lobes with a peripheral distribution pattern.

### 3.5. Imaging Features of Children Diagnosed with Covid-19

Pediatric cases need to be considered separately from adult cases of COVID-19 due to differential disease progression. A recent review approximated that 16% of children with SARS-CoV-2 infection are asymptomatic [18]. Later evidence proposes, however, that up to half of pediatricinfections could present without any clinical symptoms [19].

A review of 11 case series, including a total of 33 children (1 day to 16 years old), summarized that radiological findings among children were milder than thoseof adult populations but with similar patterns. These findings included unilateral or bilateral infiltrates on chest CT with occasional GGO or consolidations. Moreover, halo signs account for up to 50% of pediatric cases, and they can be considered typical findings in children [20]. Fig. (**1**) shows a 2-year-old's CT scan showing GGO and halo sign appearance.

A case study was conducted at the radiology department of Istanbul University, where 74 children diagnosed with COVID-19 underwent 69 chest radiographs and 37 chest CT scans [21].

The most common CT patterns in pediatric populations were GGO or consolidation (51.3%), most often in the lower lobes (48.65%) with a peripheral distribution pattern. GGO with or without consolidation (45.94%) was more common than consolidation alone (16.2%) [21].

However, the opacity patterns were found to be minimal compared to adults. Peribronchial thickening was uncommon in adult populations and non-specific for COVID- 19 but was seen in children with COVID-19 (10.9%). On theother hand, interlobular septal thickening was less common in children compared to adults [21].

In another retrospective study conducted by Ma *et al*. [22] at Wuhan Children's Hospital, 43 children had abnormal CT findings, including GGO (67%) with bilateral (21%) lower lobes involvement (65%).

The authors of this study identified abnormal findings as predominantly subpleural (95%) and posterior (78%) [22]. Fig. (**2**) depicts typical radiological CT findings among COVID-19-positive children, and Fig. (**3**) shows the chest CT scans of three patients at initial presentation andprior to discharge.

Although CT can have a crucial role in diagnosing and managing pediatric patients, it is important to understand the possible negative consequences of CT in children: unnecessary exposure to ionizing radiation must be avoided. According to Ma *et al*. [22], using CT is not recommended for follow-up in pediatrics unless required forevaluation of the status of pneumonia.

### 3.6. Imaging Features in Pregnant Women

A recent study published by Chen *et al*. [23] included nine pregnant COVID-19 patients who were in their third trimester. In this study, clinical features were similar to those of non-pregnant adults. All had pneumonia, but none required mechanical ventilation, and none died. Eight patients showed typical COVID-19 findings, *i.e.*, multiple patchy GGO shadows [23]. Patchy consolidation and multiple bilateral GGOs were the most common radiological findings with six patients showing bilateral GGO, one patient showing only left-sided patchy GGO, one patient demonstrating patchy consolidation in the right lung and slightly infiltrated shadows around the left bronchus, and lastly, one patient showing only right-sided subpleural patchy consolidation. All radiological

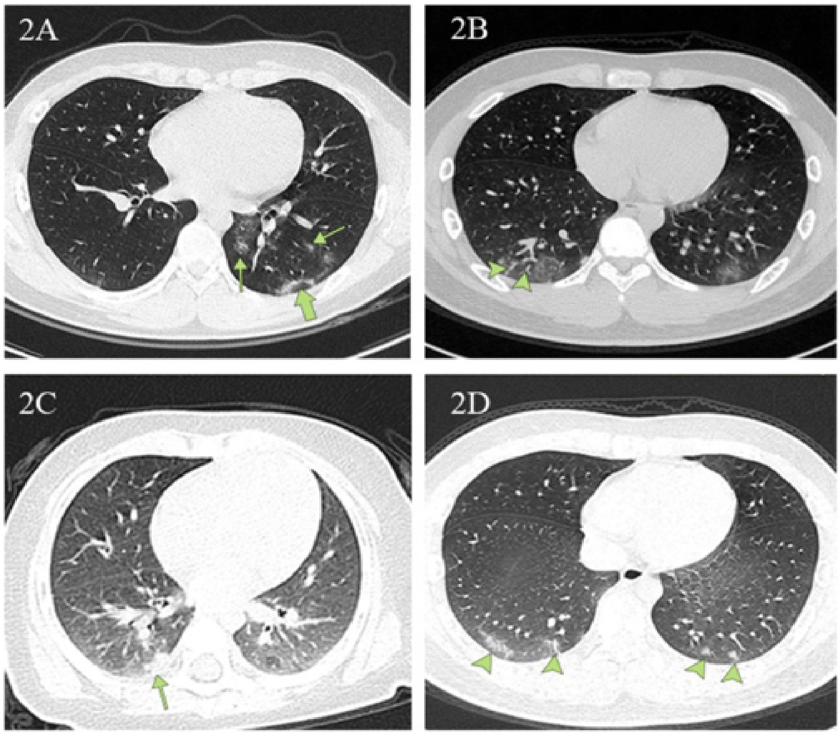


**Fig. (2).** "Chest CT images depicting typical radiographic findings of COVID-19 pneumonia in children. **(A)** A unilateral chest CT from a 14-year-old boy with cough. Ground-glass opacities under and parallel to the pleura (thick green arrow) in the inferior lobes of the left lungs. Ground-glass opacities distributed along the bronchovascular bundle (thin green arrow). (**B)** Bilateral ground-glass opacities with vascular thickening (arrowheads) in the subpleural area from a 13-year-old boy with fever and cough. **(C)** Local patchy shadowing (green arrow) image from a 6-month-old girl with a fever and cough. **(D)** Lesions in the lower lobe of both lungs (green arrows) on chest CT obtained from a 15-year-old boy with fever and cough." Figure and caption have been reproduced from [22] under Creative Commons Attribution 4.0 International (CC BY 4.0) License. (http://creativecommons.org/licenses/by/4.0/). (*A higher resolution / colour version of this figure is available in the electronic copy of the article*).

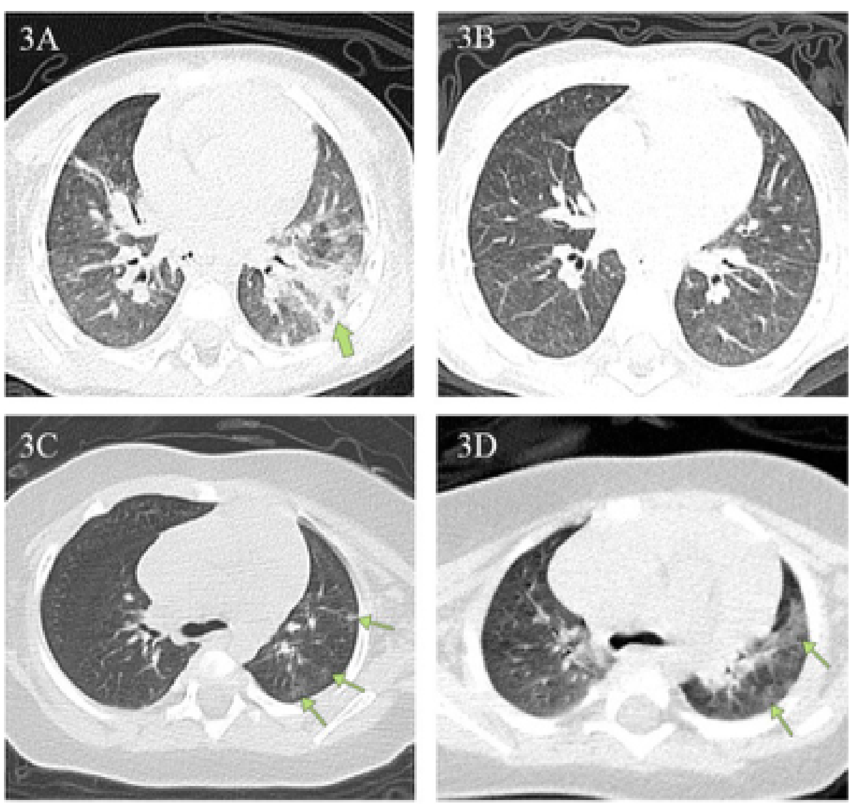


**Fig. (3) contd….**


**Fig. (3). "**Chest CT findings at initial presentation and at discharge. **(A**, **B)** Chest CT scans obtained from a 1-year-old boy, presenting with fever and diarrhea, at arrival **(A)** and after **(B)** treatment. The first CT scan shows a large, patchy shadow in the left inferior lobe (green arrow). The second CT scan shows no lesions. The patient was hospitalized for 17 days prior to discharge. **(C, D)** Chest CT scans from a 4-month-old girl, who presented with fever and cough at arrival. The first CT scan reveals multiple ground-glass opacities under the pleura in the left superior lobe (green arrows). The second CT scan reveals that the range of original lesions was enlarged and extended to the center. The girl was hospitalized for 13 days and subsequently discharged. **(E, F)** Chest CT scans from a 14-year-old boy, presenting with rhinorrhea and cough at arrival and discharge. The first CT scan reveals a patchy shadow in the left middle lobe (arrowhead). There were no obvious changes in the areas of pulmonary consolidation on the second CT scan. The boy was hospitalized for 11 days and then discharged." Figure and caption have been reproduced from [22] Under the terms of the Creative Commons Attribution 4.0 International (CC BY 4.0) License. (http://creativecommons.org/licenses/by/4.0/). (*A higher resolution / colour version of this figure is available in the electronic copy of the article*).

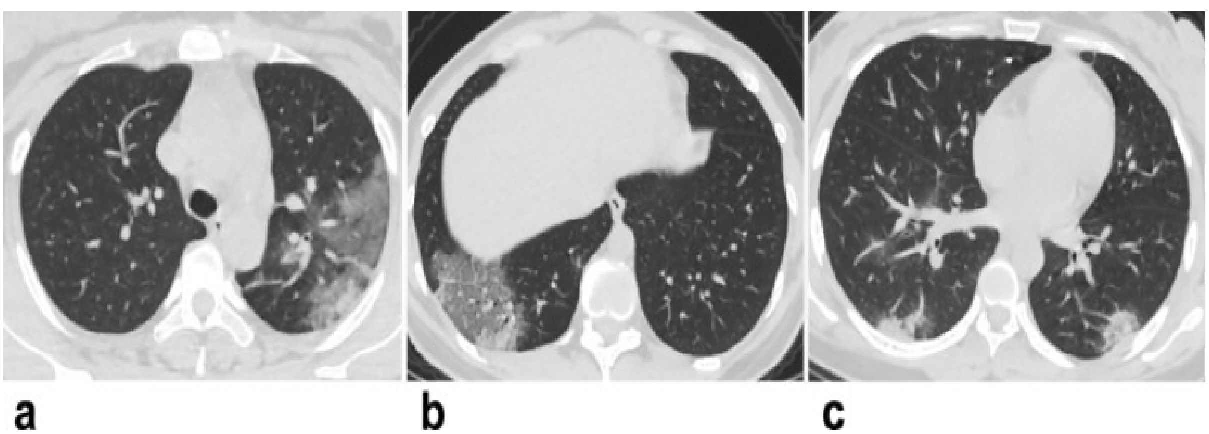


**Fig. (4).** "Chest CT images of three pregnant women with laboratory-confirmed COVID-19 pneumonia. **(A)** A 28-year-old female with 34 weeks plus 5 days pregnancy, presenting fever and loss of appetite for 2 days, GGO with consolidation in peripheral distribution was detected at CT in the left upper lobe. **(B)** A 30-year-old female with 33 weeks of pregnancy, presenting fever and fatigue for 4 days, GGO with consolidation and reticulation were identified with peripheral distribution in the right lower lobe. **(C)** A 30-year-old female with 31 weeks pregnancy, presenting fever and cough for 2 days; complete consolidations were detected with peripheral distribution in the lower lobes of bilateral lungs." Figure and caption have been reproduced from [3] under the terms of Creative Commons Attribution-NonCommercial-NoDerivatives *4.0* International (CC BY-NC-ND license). (http://creativecommons.org/licenses/by-nc-nd/4.0). (*A higher resolution / colour version of this figure is available in the electronic copy of the article*).

findings were consistent with those of non-pregnant adult women [23].

Another cohort of 59 patients included 41 pregnant women to compare imaging findings with non-pregnant patients. The most common CT manifestations were "pure GGO, GGO with consolidation, GGO with reticulation, and complete consolidation." Peripheral distribution was seen in both pregnant and non-pregnant groups [3] (Fig. **4**). Consolidation, including mixed GGO with consolidation and pure consolidation, was significantly more common in pregnant patients (P = .007, P < .001), while GGO and GGO with reticulation were more common in non-pregnantpatients (P = .001, P < .001) [3].

### 3.7. Imaging Features in Patients Over 65

Patients over 65 were evaluated to see if severe radiological findings in CT scans increased with age. In a study by Zhu *et al*. [24], chest CT of 72 symptomatic COVID-19 patients were examined, including 44 younger patients (age=47.5±8.7) and 28 older patients (age=68.4±6.0). No notable difference was seen in the time from onset of symptoms to CT examination between thegroups (p=.297) [24].

The authors concluded that the proportion of substantial pulmonary involvement was higher in the elderly group (71.4%) compared to the younger adult population (36.4%) (p=0.009). Pleural thickening (71.4%) and subpleural line (50%) were also more likely to occur in older patients (P=.011 and P=.030) [24].

In the elderly group, 53.6% showed pure GGO, and 89.3% showed GGO with consolidation. Reticular pattern, or honey combing, was seen in 71.4% of elderly patients. In the younger group, 47.7% showed pure GGO, and 77.3% showed GGO with consolidation. Reticular patterns were seen in 54.5% of the younger patients. Thesefindings were not statistically significant [24].

The ratio of subpleural line and pleural thickeningwas higher in the older group (p=.030, p=.011). Among the younger group, 36.4% had all lobes affected, whereas 67.9% of the elderly group showed whole lung distribution (p=.009) [24].

In another study [25], CT data for three patient groups were grouped according to age (Group 1: age<40, n=107; Group 2: 40≤ age<60, n=137; Group 3: age>60, n=66). Group 3 showed a greater number of affected lobes and total lesions (P < .01). Subpleural involvement, pleural thickening, crazy paving pattern, and bronchodilation were also more commonly found in Group 3 (P < .05). Group 1 more commonly presented non-subpleural distribution, single lesions, and involvement of 2 or fewer lobes. Pleural thickening varied between Group 3 (16.7%) and Groups 1 (3.8%) and 2 (15.3%) [25].

## 4. DISCUSSION

CT evaluation of patients allows radiologists to identify key abnormalities in patients' lungs that are important to distinguish COVID-19 from other common acute respiratory diseases. CT is also a crucial modality for assessing disease severity, prognostication, and patient follow-up. However, many chest CT findings in COVID-19 are non-specific and found in other types of viral pneumonia.

CT should only be used in conjunction with another line of screening, preferably RT-PCR. Together, CT and RT-PCR ensure that, regardless of symptom presentation, patients receive a correct diagnosis. This is critical, as symptoms of COVID-19 may appear between 2-14 days after exposure [26]. Case reports have shown that clinical symptoms may precede imaging manifestations or vice versa.

According to Meng *et al*. [7], out of 58 asymptomatic patients with abnormal CT, 27.6% later presented with symptoms. The average number of days before symptom onset was 3.71±2.86, with patients in the lesion progression subgroup experiencing fewer days before symptom onset (3.25±2.77 days) [7]. Thus, patients with more severe cases of COVID-19 tend to experience symptom onset faster than those with less severe radiological signs [7].

CT findings in COVID-19 have shown a predictable pattern of evolution over the disease. Across all 17 studies, bilateral GGO and consolidation with multilobar and peripheral and lower lobe distribution were seen as the main features of COVID-19 pneumonia at initial CT scan.

Pan *et al*. [14] reported a predominance of small subpleural GGOs in the early stages of the disease, with superimposition of consolidation and crazy-paving appearing up to two weeks after symptom onset. Wang *et al*. [12] confirmed the high prevalence of GGOs and noted that GGOs decreased during the course of the disease; the authors also reported the presence of superimposed consolidation as the second most common finding [12].

Vijayakumar *et al*. [27] evaluated adults 3 months and 1 year following discharge from Chelsea and Westminster Hospital and found that post-discharge (median 45 days), 56% of patients showed persistent abnormalities and 48% had GGOs [27]. Thirty-two of the patients had a 1-year follow-up CT, and 81% showed improvement in lung abnormalities [27]. Chen *et al*. [28] also analyzed lung abnormalities following hospital discharge. During the 1-year follow-up, out of 36 patients, 47% observed minimal residual opacities. Reticular patterns were the most commonly observed pattern 1 year from onset of symptoms [28].

Consolidation may also serve as a measure of COVID-19 progression and could alert physicians to start more intensive treatments. Song *et al*. [9] noted that consolidation and more areas of lung involvement were more common in older patients. Thus, radiologists may be able to predict the severity of COVID-19 by evaluating the progression of consolidations.

Meng *et al*. [7] articulated the evolution of GGOs: the lesion starts as a small round lesion in the center of the secondary lung lobule and then extends to the whole secondary pulmonary lobules, forming a patchy lobular appearance [7]. This is why GGO often appears as the first radiological finding. As time after the onset of illness increases, GGO tends to peak and subsequently decrease in prominence as mixed patterns, including crazy-paving appearance; reversed halo sign and consolidation become more apparent [29]. Shi *et al*. [5] also noted that, after reexamination of patients, lesions fused to form larger patchy, crazy paving, or diffusion patterns. Multilobar and bilateral distribution were also more common in follow-up CT scans [5].

Similarly, Pan *et al*. [14] noticed peak involvement of lobes during 9-13 days after symptom onset. At this stage, consolidation became more common and increased in density, alongside additional findings, including diffuse GGO, crazy paving pattern, and residual parenchymal bands. Following this stage, most patients began to recover, with only the most severe cases of COVID-19 seeing extensive paving patterns and persistent GGOs [14].

Regarding CT findings for children and pregnant women, CT findings were consistent with adult populations. Among children, there was a predominance of lesions in the subpleural area, with findings, including consolidation, GGO, and halo sign [20,22]. Pregnant women did show a predominance of consolidation, including mixed GGO with consolidation [3]. While the elderly population showed more extensive lobe involvement than the adult population, GGO and consolidation remained consistent over time. One notable difference was that pleurall thickening was more common in the elderly group [24,25]. Older patients also had a higher risk of developing CT abnormalities 1 year after discharge [28].

## CONCLUSION

In summary, CT has proven to be a highly sensitive (up to 98%) method for detecting COVID-19, including identifying lung abnormalities that are suggestive of COVID-19, even among asymptomatic individuals. Thus, CT may be an effective approach for early screening of COVID-19.

## LIMITATIONS

It should be noted that several of these studies included a small sample size. Additionally, as knowledge regarding the diagnosis of COVID-19 continues to evolve rapidly, new evidence may emerge regarding the imaging characteristics of this disease. Lastly, even though all CT scans in each study were carefully reviewed by trained and experienced radiologists because they were not classified by the same team of radiologists, there is bound to be unintentional variation in the identification of the CT characteristics.

## FUTURE WORK

This paper is part of a larger project, the COVID-19 Data Archive (COVID-ARC), developed at the Laboratory of Neuro Imaging (LONI) at the University of Southern California (USC) and funded by the National Science Foundation (NSF). COVID-ARC is a data archive that stores multimodal (*i.e*., demographic information, clinical outcome reports, imaging scans) and longitudinal data related to COVID-19 and provides various statistical and analytic tools for researchers [30]. This platform encourages collaboration among researchers worldwide as all data are aggregated, curated, and harmonized on one web-accessible platform. The work from this project helps to prepare scientists for future pandemics by putting the infrastructure in place to enable researchers to aggregate data and perform analyses quickly in the event of an emergency [30]. We are also applying machine learning methods to pooled imaging datasets to identify more wide-scale trends in imaging findings. This review paper's goals are similar to the overarching goals of COVID-ARC to consolidate research and provide a literature review that encompasses the work of researchers over the past year studying features and patterns of COVID-19 in chest CT scans.

## LIST OF ABBREVIATIONS

CT = Computed Tomography

GGOs = Ground Glass Opacities

## CONSENT FOR PUBLICATION

Not applicable.

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## CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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Declared none.

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