Chinese Journal of Academic Radiology (2021) 4:248–256
https://doi.org/10.1007/s42058-021-00075-1

ORIGINAL ARTICLE

# Chest CT performance and features of COVID-19 in the region of Abu Dhabi, UAE: a single institute study

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Received: 23 September 2020 / Revised: 14 April 2021 / Accepted: 7 June 2021 / Published online: 17 June 2021


## Abstract

**Objective** We aim to investigate high-resolution CT features of COVID-19 infection in Abu Dhabi, UAE, and to compare the diagnostic performance of CT scan with RT-PCR test.

**Methods** Data of consecutive patients who were suspected to have COVID-19 infection and presented to our hospital were collected from March 2, 2020, until April 12, 2020. All patients underwent RT-PCR test; out of which 53.8% had chest CT scan done. Using RT-PCR as a standard reference, the sensitivity and specificity of the CT scan were calculated. We also analyzed the most common imaging findings in patients with positive RT-PCR results.

**Results** The typical HRCT findings were seen in 50 scans (65.8%) out of total positive ones; 44 (77.2%) with positive RT-PCR results and 6 (31.6%) with negative results. The peripheral disease distribution was seen in 86%, multilobe involvement in 70%, bilateral in 82%, and posterior in 82% of the 50 scans. The ground glass opacities were seen in 50/74 (89.3%) of the positive RT-PCR group. The recognized GGO patterns in these scans were: rounded 50%, linear 38%, and crazy-paving 24%. Using RT-PCR as a standard of reference, chest HRCT scan revealed a sensitivity of 68.8% and specificity of 70%.

**Conclusion** The commonest HRCT findings in patients with COVID-19 pneumonia were peripheral, posterior, bilateral, multilobe rounded ground-glass opacities. The performance of HRCT scan can vary depending on multiple factors.

**Keywords** COVID-19 · HRCT · Ground glass opacity · RT-PCR

**Abbreviations**

| | |
|---|---|
| COVID-19 | Coronavirus disease 2019 |
| CRP | C-reactive protein |
| CT | Computed tomography |
| GGO | Ground-glass opacity |
| HRCT | High-resolution computed tomography |
| PACS | Picture archiving and communication systems |
| RT-PCR | Reverse transcription-polymerase chain reaction |
| CAD | Coronary artery disease |
| SOB | Shortness of breath |
| WHO | World Health Organization |

This article is not under consideration for publication elsewhere. This publication is approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out.

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## Introduction

Viral illnesses continue to arise and constitute a significant issue to public health according to the World Health Organization (WHO). Multiple viral epidemics such as the Severe Acute Respiratory Syndrome coronavirus (SARS-CoV) and H1N1 influenza in 2009, have been recorded in the last 20 years. In late December 2019, pneumonia cases of unknown cause have been reported in Wuhan, China. The cause was attributed later to the coronavirus disease 2019

(COVID-19) as named by the World Health Organization and in early March 2020, this outbreak was declared as a global pandemic. On January 29, the Ministry of Health and Prevention (MoHAP) confirmed the UAE's first case of COVID-19 disease.

The disease presentation is variable, ranging from no symptoms to severe respiratory distress and even death. A non-contrast high-resolution CT chest imaging can have a key role in managing and monitoring the course of the disease as well as early disease recognition, especially when RT-PCR results are falsely negative [1]. The WHO advised the use of chest imaging as part of the diagnostic workup of COVID-19 disease whenever RT-PCR testing is not available, in case of delayed test results, and when there is a clinical suspicion of COVID-19 with initial negative RT-PCR testing [2].

Abnormal radiological findings have been increasingly reported in the literature. CT scans of the chest have shown a high sensitivity and features which can be considered specific for COVID-19 pneumonia [3, 4]. On the other hand, many studies have shown variable sensitivity and specificity of chest scans with increasing false-negative rates [5].

We aim in this study to investigate the high-resolution CT features of COVID-19 infection in Abu Dhabi, UAE, and to compare the diagnostic performance of CT scan with RT-PCR test.

## Methods

### Data collection

This retrospective cross-sectional study was approved by the Ethics Review Committee of the Department of Health-Abu Dhabi, UAE. The informed consent was waived off as per the committee. We have collected clinical and laboratory data for analysis, derived from an electronic medical record system, from March 2, 2020, until April 12, 2020, of consecutive patients presented to the emergency department and suspected to have COVID-19 infection, enrolled in a continuous manner. Criteria for suspicion was: fever > 37.5°, respiratory symptoms, contact with COVID19 patient, and history of travel. Chest CT scan was done at the time of presentation whenever RT-PCR results were not available or were initially negative with high clinical suspension, patients presenting with severe disease, and patients with comorbidities. Scan images were collected and evaluated using the Picture Archiving and Communication Systems (PACS).

### HRCT scanning

All chest HRCT scans were performed on the day of patients' presentation using a VCT GE 64 scanner. Patients were placed in a supine position. Scanning parameters were: scan direction (craniocaudally), tube voltage (120 kV), tube current (100–600 mA)-smart mA dose modulation, slice collimation (64 × 0.625 mm), width (0.625 X 0.625 mm), pitch (1), rotation time (0.5 s), scan length (60.00–I300.00 s). The CT scanning range is from lung apices to lung bases.

### HRCT image analysis

Two radiologists with more than 8 years of experience evaluated each image jointly and agreed on the findings with no prior knowledge of PCR test results. The scans were first assessed whether negative or positive. CT positive scan is identified as any detected finding compared to a normal CT chest. Positive scans were further classified into typical, indeterminate, and atypical classes according to the Radiological Society of North America (RSNA) Expert Consensus [6]. The evaluated radiological features were: ground-glass opacities GGO, different GGO patterns, presence of peripheral, bilateral, posterior, multilobe (> 2) distribution, consolidation, lymphadenopathy, bronchiectasis, nodules surrounded by GGO, interlobular septal thickening, pericardial effusion, pleural effusion, and cavitation. The criterion for determining different GGO types depends on different patterns of GGO seen in the assessed scans.

The different GGO patterns were described based on features observed in the assessed scans, similar to what was reported by Caruso et al. [7]. Special attention to different GGO patterns was paid as it can be linked to different disease severities.

### Statistical analysis

Descriptive statistics of patients' demographic, clinical, laboratory and imaging characteristics are reported as means (standard deviation (SD)) and numbers and relative frequencies. Continuous variables were compared using a *t* test and categorical variables will be compared using the Chi-Square test or Fisher's exact test. Using RT-PCR test results as the gold standard, the sensitivity and specificity were calculated to estimate the diagnostic performance of chest HRCT images. The analysis was performed using STATA version 16.1 (Stata Corp, College Station, TX, USA), and a $p$ value less than 0.05 defined statistical significance.

## Results

### Baseline information

Our population included 173 consecutive patients who were suspected to have COVID-19 infection. The infection was confirmed in 104 (60.1%) and excluded in 69 (39.9%) of the patients using RT-PCR as a gold standard test. Two nasopharyngeal RT-PCR tests were performed within 48 h. Three patients who tested initially negative and had typical CT scan findings tested positive on the repeated RT-PCR. Those patients were considered as confirmed COVID-19 cases.

The mean age was 38.6 ± 1.5 years in the RT-PCR positive group [73 men (70.2%), 31 women (29.8%)] and 39.5 ± 2.4 years in the negative one [41 men (59.4%), 28 women (40.6%)]. Comorbidities were seen in 32 patients (30.8%) with positive RT-PCR. Recent travel history (within 30 days) and direct exposure to known COVID-19 patients were strongly associated with RT-PCR positive results ($n = 63$, 60.6%, $p$ value < 0.0001). 149/173 patients were symptomatic; in which 84 patients were found to have positive RT-PCR results. The time of presenting symptoms varied between one to fourteen days. Common presenting symptoms in this group were fever, dry cough and shortness of breath [$n = 56$ (53.9%, $p$ value 0.001), $n = 48$ (46.2%, $p$ value 0.001) and $n = 27$ (26.0%), respectively]. Lymphopenia was found in 43 (41.4%) patients with RT-PCR positive test, elevated CRP in 55 patients (51.9%), high d-dimer in 35 patients (33.7%), and elevated serum amylase and lipase in 11 patients (10.6%), (Table 1).

### HRCT evaluation

Excluding one scan due to significant motion artifact; a total of 93 patients (53.8%) who had HRCT scan done were included in the assessment. The scans were positive in 74 patients (79.6%) and negative in 19 patients (20.4%), (Fig. 1).The positive CT findings were classified into typical, indeterminate, and atypical according to the Radiological Society of North America (RSNA) Expert Consensus [6]. Typical findings were seen in 68% of positive scans, indeterminate in 12%, and atypical in 20%. The findings in the RT-PCR positive group were typical $n = 44$ (77.2%), indeterminate $n = 6$ (10.5%), and atypical $n = 6$ (10.5%). In RT-PCR negative group: typical $n = 6$ (31.6%), indeterminate $n = 3$ (15.8%), and atypical $n = 9$ (47.4%). It is worth mentioning that 14/19 of the patients with negative scan results, tested positive by RT-PCR.

Ground glass pattern was seen in 59 scans out of 74 positive ones. 50/74 scans (89.3%) were for patients with positive RT-PCR results, and 9/74 were for patients with negative RT-PCR results. Out of the 50 scans showing GGO, the recognized patterns were: rounded 50% (36.2–63.8), linear 38% (25.4–52.4), and crazy-paving 24% (14.0–38.1), (Fig. 2). Although the linear pattern was the second most common pattern seen in diseased patients, it can be non-specific as was also seen in 7 patients (38.9%) who tested negative by RT-PCR. The peripheral disease distribution was seen in 86% (73.0–93.3), multilobe involvement in 70% (55.7–81.3), bilateral in 82% (68.5–90.5), posterior in 82% (68.5–90.5), nodules surrounded by GGO in 0%, interlobular septal thickening in 42% (28.9–56.3), consolidation in 12% (5.4–24.6), bronchiectasis in 2% (0.3–13.5), pericardial and pleural effusion in 0%, and cavitation in 2% (0.3–13.5), (Table 2).

### CT diagnostic performance

The diagnostic performance of CT including the sensitivity and specificity was calculated based on typical and atypical CT features for COVID-19 infection, using RT-PCR as a standard of reference. The results showed a sensitivity of 68.8% (95% CI 55.94–79.76%), specificity of 70% (95% CI 45.72–88.11%), and accuracy of 69.05% (CI 58.02–78.69%).

## Discussion

The symptoms in patients with COVID-19 infection are usually developed in response to the direct viral destruction of lung epithelial cells or T-cell mediated immunological response [8]. In this study, and similar to the results of the systematic review performed by Grant et al. of 24,410 adults with confirmed COVID-19 infection from 9 countries; cough and fever were the most prevalent symptoms [9]. The mean age of infected patients can vary between different regions. The young age (mean 38.6 ± 1.5 years) in this cohort can be explained by the high prevalence of immigrant workers in our region, mainly of the male gender. The finding is similar to a study that took place in the same region with a larger cohort of 791 patients, where the mean age was found to be (35.6 ± 12.7 years) [10].

Moreover, laboratory results can reflect the general effect of the disease in the body. CRP can be elevated in multiple conditions, like infection and inflammation [11]. It has been suggested that raised CRP and d-dimer levels are linked to a poor outcome in patients with COVID-19 disease. [12]. Similarly, lymphopenia can be a good indicator of disease severity [13]. It was also suggested that CRP to lymphocyte ratio can be a better marker than lymphocyte count alone for assessment of the disease severity in the early stage of disease [14]. In addition, 10.6% of patients in our study presented with elevated serum amylase and lipase. Virus-related pancreatic injury with rising pancreatic enzymes and even pancreatitis were also described in the literature [15, 16]. However, this doesn't necessarily be an indicator of pancreatic injury [17].

The ground-glass opacity appears as a mild increase in lung density due to pulmonary interstitial thickening or partial filling of the alveoli [18, 19]. Multiple studies have further characterized the GGO pattern in patients with COVID-19 pneumonia [7]. The crazy-paving pattern and consolidation were more common in later stages of the

**Table 1** Characteristics of baseline data for suspected and confirmed COVID-19 infected patients

| | All patients | PCR positive patients | PCR negative patients | *p* value |
|---|---|---|---|---|
| *N* | 173 (100.0) | 104 (60.1) | 69 (39.9) | |
| Comorbidities | | | | |
| Hypertension | 22 (12.7) | 11 (10.6) | 11 (15.9) | 0.300 |
| Diabetes mellitus | 22 (12.7) | 11 (10.6) | 11 (15.9) | 0.300 |
| CAD | 9 (5.2) | 4 (3.9) | 5 (7.3) | 0.486 |
| Renal disease | 5 (2.9) | 0 (0.0) | 5 (7.3) | 0.009 |
| Immunocompromised | 8 (4.6) | 3 (2.9) | 5 (7.3) | 0.181 |
| Smoking | 11 (6.4) | 9 (8.7) | 2 (2.9) | 0.203 |
| Asthma | 7 (4.1) | 6 (5.8) | 1 (1.5) | 0.245 |
| Other lung diseases | 3 (1.7) | 1 (1.0) | 2 (2.9) | 0.564 |
| Other health problems* | 31 (17.9) | 19 (18.3) | 12 (17.4) | 0.883 |
| History of travel/Exposure | 78 (45.1) | 63 (60.6) | 15 (21.7) | < 0.0001 |
| Symptoms | | | | |
| Fever | 75 (43.4) | 56 (53.9) | 19 (27.5) | 0.001 |
| SOB | 40 (23.1) | 27 (26.0) | 13 (18.8) | 0.277 |
| Chest pain | 8 (4.6) | 7 (6.7) | 1 (1.5) | 0.147 |
| Runny nose | 16 (9.3) | 11 (10.6) | 5 (7.3) | 0.595 |
| Dry cough | 63 (36.4) | 48 (46.2) | 15 (21.7) | 0.001 |
| Productive cough | 19 (11.0) | 10 (9.6) | 9 (13.0) | 0.480 |
| Sore throat | 31 (17.9) | 24 (23.1) | 7 (10.1) | 0.030 |
| Diarrhea | 13 (7.5) | 12 (11.5) | 1 (1.5) | 0.014 |
| Nausea or vomiting | 12 (6.9) | 11 (10.6) | 1 (1.5) | 0.021 |
| Body aches/fatigue | 24 (13.9) | 18 (17.3) | 6 (8.7) | 0.109 |
| Lab results* | | | | |
| Lymphocytes | | | | |
| Normal | 113 (65.3) | 58 (55.8) | 55 (79.7) | 0.002 |
| Low | 55 (31.8) | 43 (41.4) | 12 (17.4) | |
| High | 5 (2.9) | 3 (2.9) | 2 (2.9) | |
| CRP | | | | |
| Normal | 95 (54.9) | 49 (47.1) | 46 (66.7) | 0.011 |
| High | 78 (45.1) | 55 (51.9) | 23 (33.3) | |
| D-dimer | | | | 0.019 |
| Normal | 126 (72.8) | 69 (66.4) | 57 (82.6) | |
| High | 47 (27.2) | 35 (33.7) | 12 (17.4) | |
| Serum lipase | | | | 0.003 |
| Normal | 162 (93.6) | 93 (89.4) | 69 (100.0) | |
| High | 11 (6.4) | 11 (10.6) | 0 (0.0) | |
| Serum amylase | | | | 0.029 |
| Normal | 161 (93.1) | 93 (89.4) | 68 (98.6) | |
| High | 12 (6.9) | 11 (10.6) | 1 (1.5) | |

Numbers listed (in brackets) represent percentages

All percentages are column percent

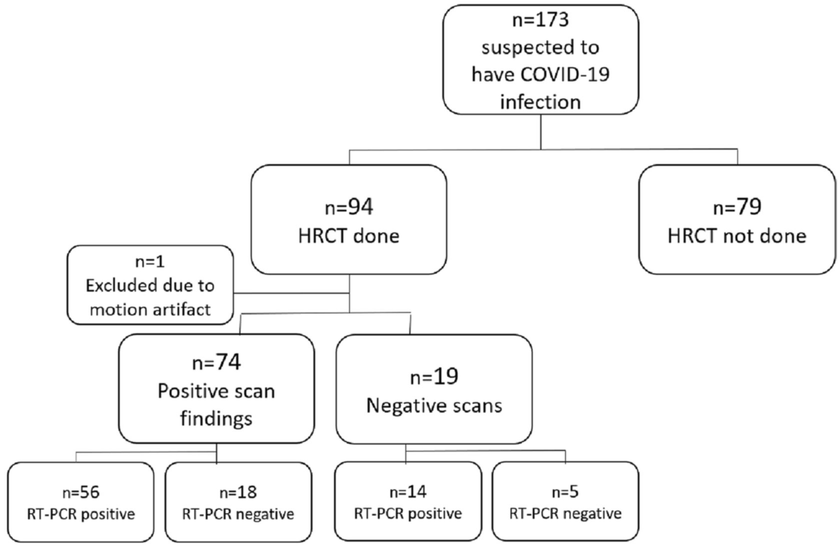
Other health problems included: dementia, chronic sinusitis, history of stroke, G6PD deficiency, dyslipidemia, generalized anxiety disorder, autism and secondary hyperparathyroidism

Normal referenced lab values: CRP (< 5 mg/L), Lipase (< 60 IU/L), Amylase (< 100 units/L), D-dimer (< 0.5 mcg/mL), Lymphocytes ($1.5–4 \times 10^9$ /L)

disease [20]. Studies showed that round GGOs tended to progress into patchy GGOs and consolidation as the disease progresses and the crazy-paving pattern significantly decreases with disease regression. Similarly, the linear opacities are more noticed with higher CT severity scores [21].

Pleural effusion can be occasionally observed with disease progression, however, when present, it requires more

**Fig. 1** Cohort selection and distribution



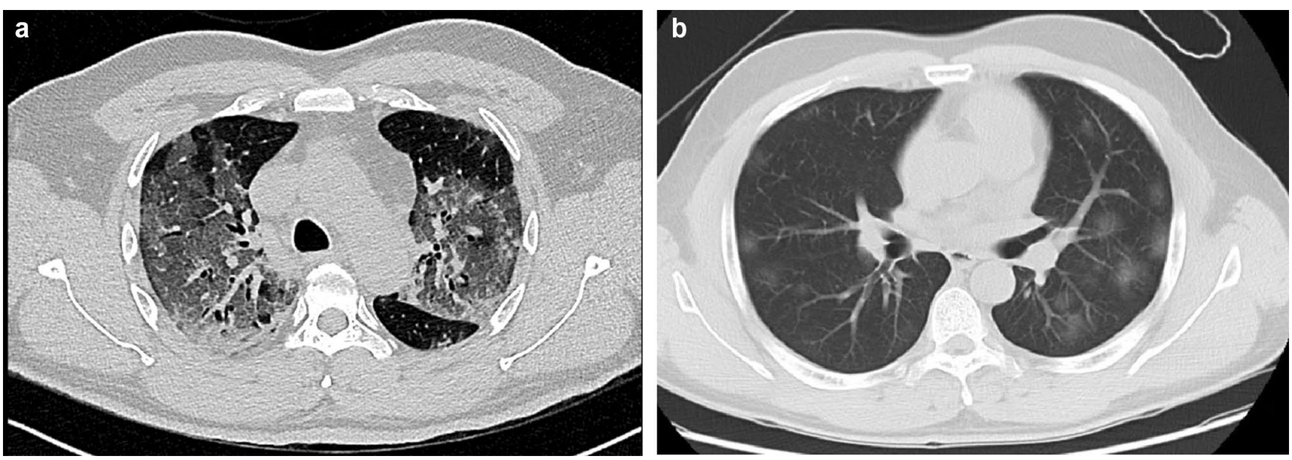




**Fig. 2** Axial thin-sections of unenhanced CT scan of two patients with COVID-19 pneumonia (**a**) scan shows bilateral ground-glass opacities with septal thickening (crazy-paving pattern) (**b**) scan shows bilateral ground-glass opacities with rounded morphology

attention as it can be an indicator of poor prognosis in patients with COVID-19 infection [22, 23]. Cavitation is a rare CT feature in COVID19 disease often seen in other pathologies like fungal and mycobacterial infections. Its etiology in COVID19 pneumonia is not clearly understood but can be related to diffuse alveolar damage, intra-alveolar hemorrhage and necrosis of parenchymal cells based on prior autopsy reports [24]. Superimposed bacterial and fungal infections can be also observed [25].

While lymphadenopathy is considered as an atypical feature for COVID 19 pneumonia, it was found that enlarged mediastinal lymph nodes in addition to older age and consolidation pattern on CT scan, are independently associated with increased mortality [26]. Similarly, and despite being uncommon, pericardial effusion ranging from minimal to tamponade, can be seen particularly in COVID-19-related cardiac diseases such as pericarditis [27]. Follow-up studies suggested that evolution to a fibrosing lung pattern can be linked to the onset of bronchiectasis during the disease [28].

Although GGO can be seen in various pathologies, its pattern and distribution along with the clinical picture can favor one diagnosis over the other. The typical findings in patients with negative RT-PCR results can be attributed to other pathologies mimicking the typical CT appearance; such as influenza pneumonia, organizing pneumonia-like in drug toxicity, and connective tissue disease [29]. Recently, new publications aim to differentiate Influenza A from COVID-19 pneumonia by identifying specific CT imaging features [30, 31]. In our analysis, among the six patients who were found to have typical CT findings for COVID-19 pneumonia but negative RT-PCT results; one patient was confirmed to have Influenza pneumonia (Fig. 3). Another had Mycoplasma pneumonia with a background of cardiogenic pulmonary edema (Fig. 4).

**Table 2** CT features in patients with PCR confirmed COVID-19

| | | |
|---|---|---|
| CT features | | |
| GGO | 50 | 100% |
| GGO pattern | | |
| Crazy paving | 12 | 24% (14.0–38.1) |
| Rounded | 25 | 50% (36.2–63.8) |
| Linear | 19 | 38% (25.4–52.4) |
| Peripheral GGO | 43 | 86% (73.0–93.3) |
| Multilobe involvement (> 2) | 35 | 70% (55.7–81.3) |
| Bilateral distribution | 41 | 82% (68.5–90.5) |
| Posterior involvement | 41 | 82% (68.5–90.5) |
| Consolidation | 6 | 12% (5.4–24.6) |
| Lymphadenopathy | 3 | 6% (1.9–17.4) |
| Bronchiectasis | 1 | 2% (0.3–13.5) |
| Nodules surrounded by GGO | 0 | |
| Interlobular septal thickening | 21 | 42% (28.9–56.3) |
| Pericardial effusion | 0 | |
| Pleural effusion | 0 | |
| Cavitation | 1 | 2% (0.3–13.5) |
| Consolidation | 6 | 12% (5.4–24.6) |
| Lymphadenopathy | 3 | 6% (1.9–17.4) |

Remarkably, a third patient who presented with dry cough, SOB, lymphopenia, elevated CRP and d-dimer, tested negative for COVID-19 infection by RT-PCR initially at the time of CT scan. The repeated test after 3 days showed a positive result. Furthermore, one patient was asymptomatic and the other two patients, although were mildly symptomatic, have no follow-up information in our records. Cases with distinguishing imaging features for COVID-19 pneumonia seen on CT scans in asymptomatic patients have been reported [32]. The false-negative PCR results can be attributed to several factors such as: poor quality of the specimen, collecting the specimen too early or late in the course of infection, inappropriate handling and shipping of the specimen, and technical reasons inherent in the test. It is recommended to repeat the test when there is a high index of suspicion for COVID-19 infection [33]. The British Society of Thoracic Imaging suggested that the main role for CT imaging in the diagnosis of COVID-19 is when PCR test is unavailable or the patient is seriously ill; where imaging can guide individual patient management choices, deal with complications or look for a different diagnosis. Studies also suggested that the sensitivity of RT-PCR can be negatively associated with the proportion of elderly patients [34].

On the other hand, and despite the relatively high false-negative rate ($n=14$, 20%) which is seen in our analysis, this can still be explained by several factors. One is the young patient cohort, which is probably related to the high prevalence of immigrant workers in our region presenting with mild symptoms. Another aspect is the early large prompt screening program that was initiated in the United Arab Emirates. This brings the discussion forward on how these factors can affect the diagnostic performance of CT scan when compared with the RT-PCR test.

Multiple studies have reported the sensitivity and specificity of CT scans in diagnosing COVID-19 pneumonia. The results were variable. Isikbay et al. have analyzed and described chest CT findings in patients with COVID-19 infection aboard the "Diamond Princess" cruise ship. Low sensitivity of 61 and 20% false-negative rate in symptomatic patients were reported [3, 35, 36]. This supports the

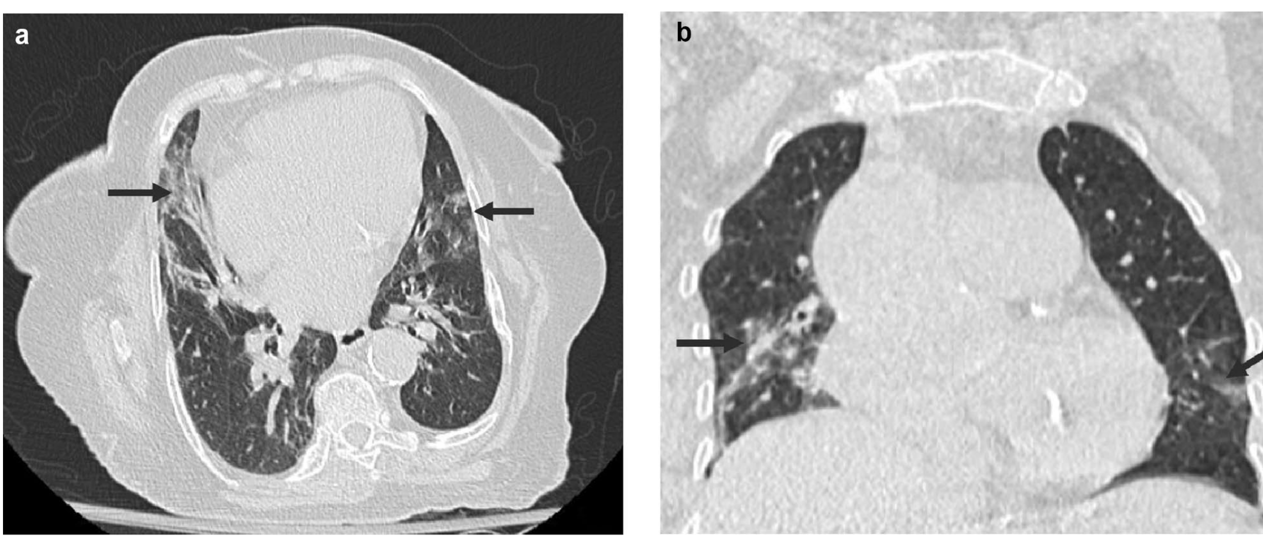



**Fig. 3** Axial (**a**) and coronal (**b**) thin-sections of unenhanced CT scan which was reported as typical for COVID-19 pneumonia. Note the bilateral peripheral linear GGO (arrows). The patient was confirmed to have Influenza pneumonia and his two RT-PCR tests were negative for COVID-19 pneumonia

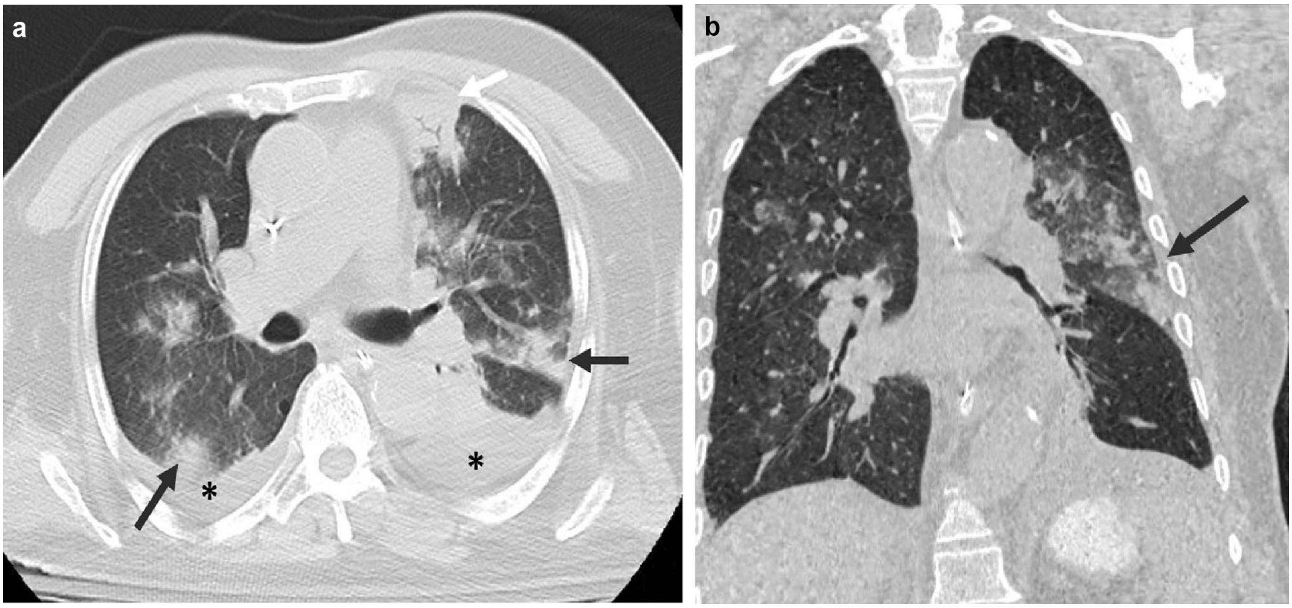



**Fig. 4** Axial (**a**) and coronal (**b**) thin-sections of unenhanced CT scan which was reported as a combination of typical and atypical patterns for COVID-19 pneumonia (concurrent pathologies). Note the bilateral peripheral GGO (black arrows), consolidation (white arrow), and bilateral pleural effusion (Asterix). The patient was known to have heart failure and confirmed to have Mycoplasma pneumonia. His two consecutive RT-PCR tests were negative for COVID-19 pneumonia

European and American societies' consensus, recommending that CT scans should not be used to screen for or as a first-line test to diagnose COVID-19 disease [37]. The authors also suggested that sensitivities differ based on the selected cohort and the patient's disease stage at which imaging was done. This heterogeneity can be also related to the experience of the radiologists and the severity of the epidemic, explaining the higher sensitivity values in Wuhan [38]. Moreover, CT sensitivity and specificity can be highly affected by the adopted CT positivity threshold [39]. A lower threshold would increase the sensitivity at expense of specificity, and vice versa. The sensitivity of CT scan can also be affected by the proportion of patients with comorbidities and the proportion of asymptomatic patients. Some studies have also found that there is no statistical difference in the diagnostic performance between initial RT-PCR and chest CT scan [40].

Our study has some limitations. The small cohort and the fact that the sample was taken during the early stages of the disease, just before the peak of the epidemic in our region, might have influenced the results. Moreover, the results may be biased using the RT-PCR test as a standard of reference. Some studies have suggested that the RT-PCR test carries false negative and positive rates [41, 42]. Additionally, the diagnostic performance of CT scan varies depending on the chosen threshold. Finally, histopathologic results from lung biopsies were not available to be correlated with imaging findings.

In summary, the study showed variable imaging patterns of COVID-19 disease affecting the lungs. The peripheral, posterior, bilateral, multilobe rounded ground-glass opacities, were the commonest features seen in patients with COVID-19 pneumonia in the region of Abu Dhabi, UAE. The diagnostic performance of a chest CT scan can be variable based on multiple factors.

**Acknowledgements** The authors would like to thank Mr. George Roy, Senior CT radiographer for providing the technical information. We would like also to acknowledge the radiological medical and technical team of the Radiology Department of Sheikh Khalifa Medical City-Abu Dhabi.

**Funding** This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

## Declarations

**Conflict of interest** No conflict of interest needs to be disclosed.

**Ethical approval** The research did not involve Human Participants and/or Animals.

**Informed consent** The informed consent was waived off as per the Ethics Review Committee of the Department of Health-Abu Dhabi, UAE.

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