PART 1| IMAGING IN CLINICAL PRACTICE

Radiological findings of COVID-19: When to consider?

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ABSTRACT

Over the last 6 months, the world has been attacked by a new infection; COVID-19. Respiratory system is the main site of attack. Although the majority of those infected have relatively mild symptoms, many may pass into pneumonia and evolved into respiratory failure and death. The radiological findings in COVID-19 may be nonspecific and have similarities with other infectious and noninfectious diseases. In this article, we will try to go through the important radiological features and what findings should trigger thinking of it based on the updated recommendations of international radiology societies especially the British Society of Thoracic Imaging. We have to keep in mind that correlation of radiological findings with the clinical presentation and other laboratory tests is the best approach to reach the correct diagnosis.

Key words: COVID-19, GGO, Chest CT scan.

In December 2019 a pneumonia of unknown cause was detected in Wuhan in China and first reported to the WHO on 31 December 2019. WHO has declared a Public Health Emergency of International Concern on 30 January 2020 and a pandemic on 11 March 2020. The disease was found to be caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and named by WHO as COVID-19.[1] Progressively, the disease has distributed all over the world. About 5.2 million infections and 337000 deaths are reported in 216 countries, areas, and territories till 24 May 2020.[2]

It has a high infectivity rate with variable mortality rates among countries. The clinical presentation is diverse ranging from completely asymptomatic or mild nonspecific symptoms in 80 % of patients, to symptoms of lower respiratory tract infection necessitating hospital admission in about 20 %. In 5 % of patients the symptoms were very severe that need intensive care unite (ICU) admission. The case fatality rate is ~2-3 %.[3,4]

Molecular testing is required to confirm the diagnosis for SARS-COV-2. The real-time reverse transcriptase-polymerase chain reaction (RT-PCR) test is used for this purpose, it is highly specific with a sensitivity of about 60-70 %, but can give negative results initially.[5,6] Other ancillary laboratory findings are also reported but they have prognostic rather than diagnostic significance, of these are lymphopenia, increased prothrombin time, lactate dehydrogenase, troponin and some inflammatory markers like CRP, ESR, and IL6.[7]

Role of imaging in the diagnosis and management of patients with COVID 19

- Add to pre-test probability assessment for COVID-19
- Distinguish between severe and non- severe cases.
- Look for an alternative diagnosis.
- Assess deterioration or discordant clinical course
- Assess complications.

Things to remember when dealing with Imaging of patients with COVID-19:

1. Clinical suspicion of COVID-19 is IMPERATIVE; otherwise, the radiology is nonspecific and could easily represent so many other pathological processes.[6]
2. While routine screening CT scan for the identification of COVID-19 pneumonia is currently not recommended by most radiol-

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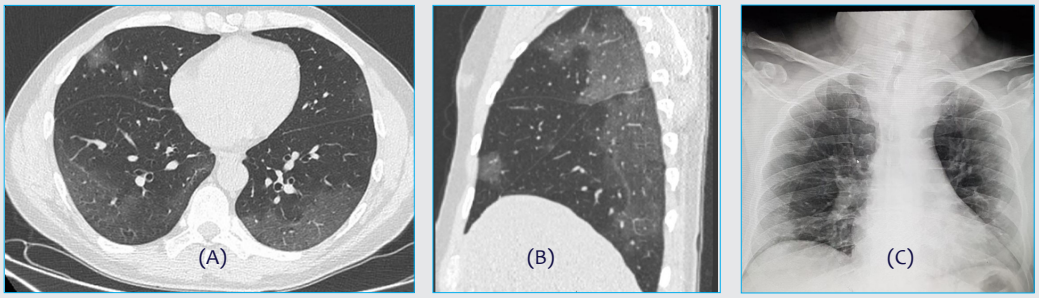


Figure 1 | Axial (A) and sagittal (B) sections of a CT scan of the chest of a patient with COVID-19 showing the classic category of COVID-19 (early stage). Patchy and bilateral GGO involving all lobes mainly the lowers. (C) chest X ray of another patient with early COVID-19 shows bilateral and peripheral opacities.

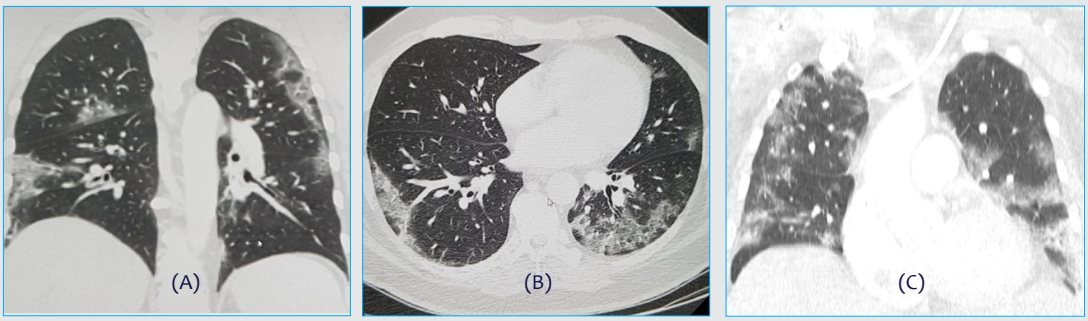


Figure 2 | A coronal (A) and axial (B) sections of a CT scan of a patient with COVID-19 shows bilateral peripheral patchy opacifications. (C) A coronal section of another patient showing the same features.

ogy societies, the number of CT scans performed in patients under investigation for COVID-19 has increased , CT scan play a role in the diagnosis of COVID-19 when the patient is seriously ill or PCR is unavailable.[8]

3. A standardized language should be followed to reduce the reporting variability and to improve communication with the referring providers.[6,8]
4. Normal CT scan does not reliably exclude COVID 19 pneumonia in early stage. Initially CT scan of the chest is normal in 50 % after 2 days of symptoms but only in 4 % after 6-12 days.[9]

THE BSTI CATEGORIES

British Society of Thoracic Imaging (BSTI) has proposed four categories[6] for the suggested standardized CT reporting language of COVID-19 based on current literatures and expert consensus.

Classic COVID-19 (100% confidence for COVID)

Features: Lower lobe predominant, peripheral predominant, multiple, bilateral foci of ground glass opacities (GGO) ± crazy-paving, peripheral consolidation, air bronchogram and reverse halo/perilobular pattern (ie organizing pneumonia pattern).

H1N1 influenza, cytomegalovirus pneumonia, and other atypical pneumonias[10] can have

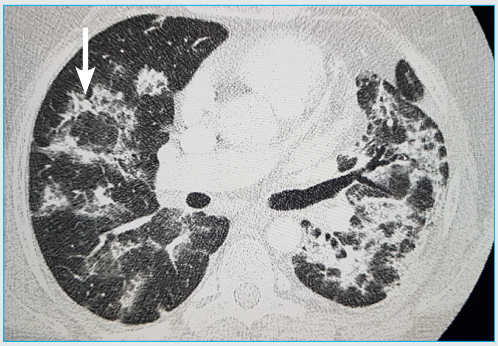


Figure 3 | Cross section chest CT scan below the biforcation of trachea of a patient with COVID-19 shows bilateral opacifications, round and irregular, typical of organizing pneumonia, located at perilobular and peripheral areas. The arrow points to the reverse halo signs (atoll sign); A central lucency surrounded by an opacity .

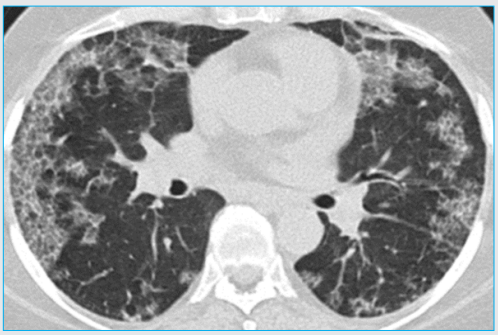


Figure 4 | Axial section of a CT scan of a patient with COVID-19 showing prominent interlobular and intralobular septal thickening on a background of bilateral, multifocal and peripheral GGO; features of crazy paving.

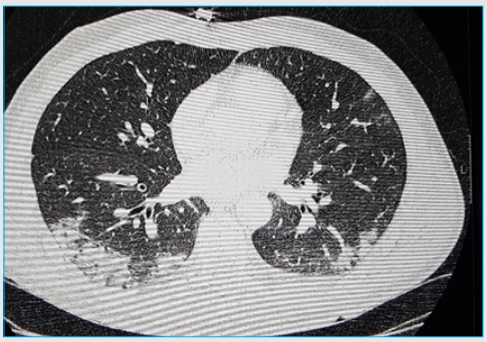


Figure 5 | Axial section of a CT chest of a patient with COVID-19 show bilateral confluent opacities seen on the periphery of the lower lobes.

similar findings. See figure 1 a,b,c.

Probable COVID-19 (71-99 % confidence for COVID-19)

Features: Lower lobe predominant mix of brochocentric and peripheral consolidation, Reverse halo /perilobular pattern, but here GGO is scarce.

These features are nonspecific and can occur in a variety of infectious and noninfectious diseases. Clinical and other laboratory correlations are needed in such cases. See figures 2, 3 ,4, and 5.

Indeterminate COVID-19 (< 70 % confidence for COVID-19)

Features: when the radiological picture Does not fit into definite, probable, or non COVID-19. Or manifests above patterns but the clinical context is wrong or suggest an alternative diagnosis e.g an interstitial lung disease in a connective tissue disease. See figure 6

Clinical and other laboratory correlations are also needed in such cases.

Non-COVID-19 (70% confidence for alternative)

Features: Lobar pneumonia, cavitating infections, tree in bud/centrilobular nodularity, lymphadenopathy, effusions, established pulmonary fibrosis.

Such findings usually refer to a diagnosis other than COVID-19; however, we should not ignore the concomitant occurrence of COV-

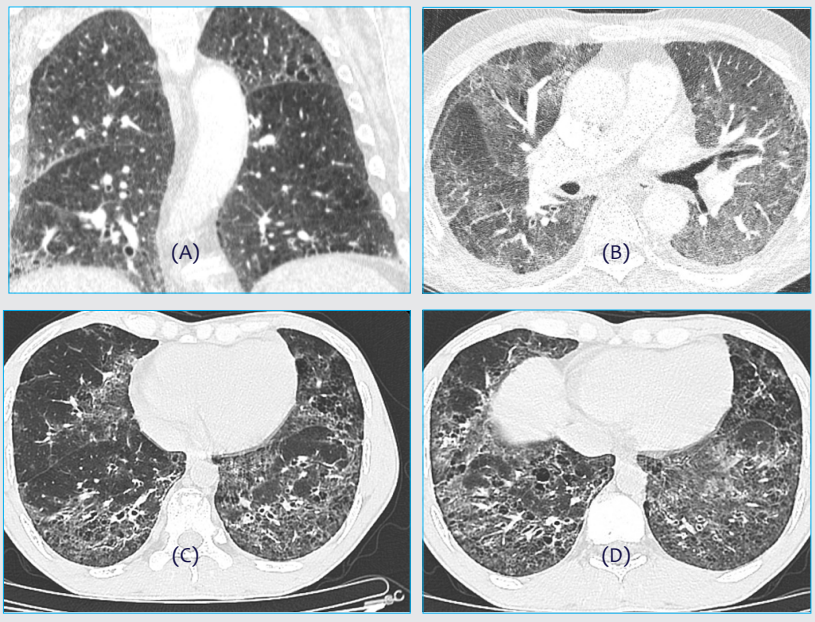


Figure 6 | CT chest of patients with indeterminate pattern of COVID-19: (A) and (B); coronal and axial images show diffuse ground glass opacity (GGO) in a patient with combined pulmonary fibrosis and emphysema.
(C) and (D) axial images of a patient with systemic lupus erythematosus (SLE) show complex patterns, a GGO admixed with fibrotic lung changes and honeycomb appearance.

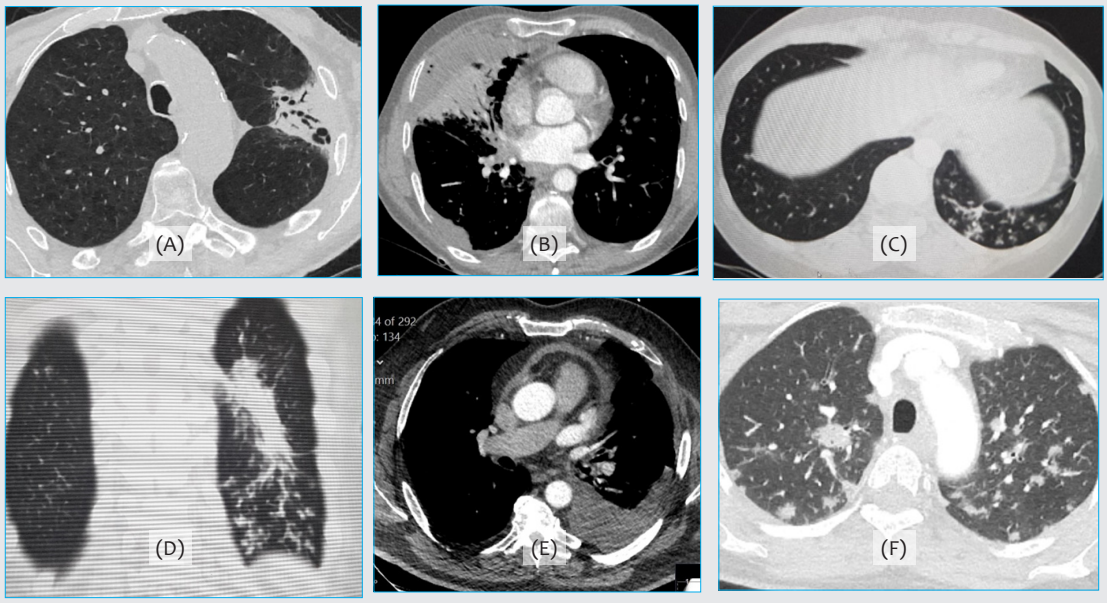


Figure 7 | CT pictures of different patients represent example of non COVID-19. (A) and (B) show a consolidation lesions with obvious air bronchogram suggestive of lobar pneumonia. (C) and (D) show centrilobular nodules in the left lower lobe with tree in bud appearance suggestive of infectious bronchiolitis. (E) shows left pleural effusion and (F) shows multiple and bilateral nodules.

ID-19 with other pathologies like heart failure or preexisting diffuse lung diseases which make the patient vulnerable to contract COVID-19 or have a severe form of it. Examples for non COVID-19 pattern **See figure 7**.

Complications of COVID-19 reported on chest imaging:

1. Pulmonary embolism and thrombosis in COVID-19 the European Society of Radiology and the European Society of Thoracic imaging suggested that contrast-enhanced CT should be performed to rule out pulmonary embolism if supplementary oxygen is needed in COVID-19 pneumonia patients with limited disease extension.[11] In a study in France about 50 % of Hospitalized patients who had respiratory deterioration with more need for oxygenation were found by CTPA to have pulmonary embolism.[12] **See figure 8**
2. Superadded bacterial infection represented by the development of pleural effusion and / or empyema. In a study, ventilator-associated pneumonia occurred in 10 of 32 patients (31%) with COVID-19 requiring invasive mechanical ventilation.[13] **Figure 9**
3. Rapid progression to acute respiratory dis-

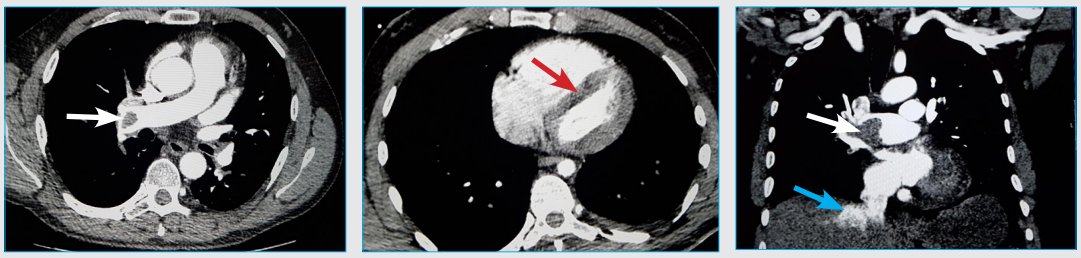


Figure 8 | CT pulmonary angio mediastinal window of a patient with COVID-19 and significant O2 desaturation. (A) and (B) are axial sections while (c) is a coronal section. A & C show a filling defect (white arrows) in the right main pulmonary artery with early visualization of the inferior vena cava (blue arrow) due to reflux indicating high right ventricular pressure. The interventricular septum is pushed to the left ventricle in (B) (red arrow) due to increase right ventricular pressure.

Figure 9 | Axial section of a CT chest of a patient with COVID-19 shows left pleural effusion with patchy opacities more on the right lower lobe due to superadded bacterial infection (proved by bacteriological examination).

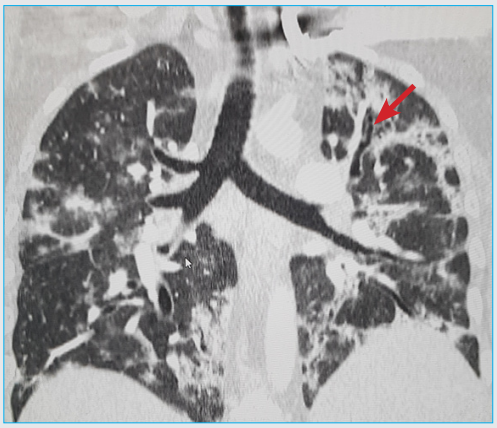
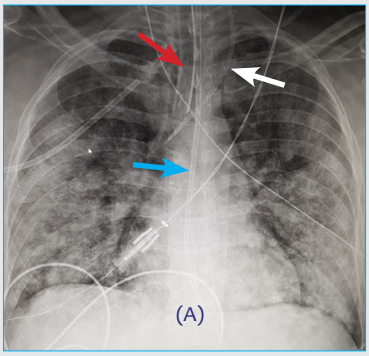


Figure 11 | Coronal section of a chest CT scan of evolving fibrosis in a patient with COVID-19 pneumonia (after 5 weeks of admission) shows linear and irregular diffuse opacities with reverse halo sign suggestive of organizing pneumonia pattern. Areas of reticulation and traction bronchiectasis are seen in left upper lobe (arrow).

Figure 10 | Severe COVID-19 patient admitted to ICU because of respiratory failure. (A) AP chest X-rays shows bilateral diffuse alveolar shadowings with good position of central venous line (white arrow), ET tube (red arrow) and NG tube(blue arrow). (B) Coronal CT image of the chest shows diffuse bilateral coalescent opacities and consolidation in the background of GGO.



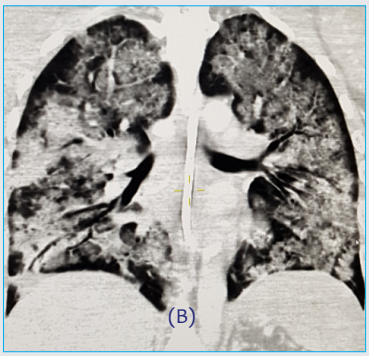
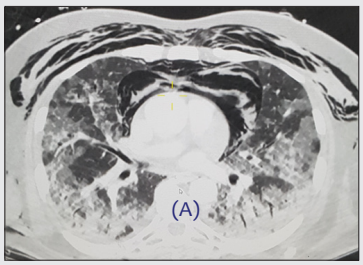
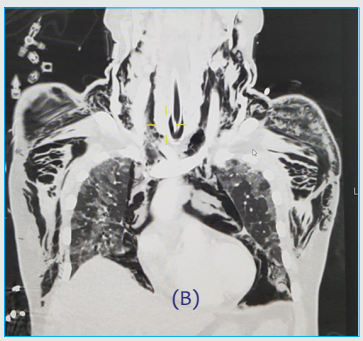


Figure 12 | **(A) axial section and (B) coronal section of a CT scan of the chest of a patient with COVID-19 show huge surgical emphysema and pneumomediasinum extended to the neck on a background of GGO with some consolidation and air trapping. A complication of invasive ventilation.**





tress syndrome (ARDS). ARDS is a recognised complication of COVID-19 and it may occur rapidly over few hours to few days and usually carries a bad prognosis. **See figure 10**

4. Interstitial fibrosis can evolve in patient with COVID-19 pneumonia or a sequelae of ARDS, Some have reported lung fibrosis as a complication of severe COVID-19 as early as 2 weeks.[14] Currently, there is no evidence that indicates the scarring in the lungs experienced by COVID-19 patients is progressive.[15] **See figure 11**
5. Surgical and mediastinal emphysema. It is usually iatrogenic and seen in ICU patient due to intubation or as a complication of artificial ventilation. This is not uncommon complication in ICU. In a study conducted in a tertiary centre in the UK, five patients developed pneumomediastinum within 7 days. Two of them had passed away.[16] **See figure 12**

CONCLUSION

The radiological findings in COVID-19 may be nonspecific and have similarities with other infectious and noninfectious diseases, so radiological features should be correlated with the clinical findings and laboratory tests . Peripheral, bilateral, and multiple lower lobe predominant GGO is the classic features of COVID-19. While bronchocentric and peripheral consolidations with scarce GGO are features of probable infection.

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Abbreviations list: Acute respiratory distress syndrome (**ARDS**), British Society of Thoracic Imaging (**BSTI**), C Reactive protein (**CRP**), Computerized tomography (**CT**), CT pulmonary angiography (**CTPA**), Erythrocyte sedimentation rate (**ESR**), ground glass opacities (**GGO**), Intensive care unit (**ICU**), Interleukin 6 (**IL6**), Reverse transcriptase-polymerase chain reaction (**RT-PCR**), Severe acute respiratory syndrome coronavirus 2 (**SARS-CoV-2**), United Kingdom (**UK**), World Health Organization (**WHO**).

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