Review Article

Role of Chest Radiograph (CXR) in COVID-19 Diagnosis and Management

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Coronavirus disease- 2019 (COVID -19) is a highly contagious disease and has been declared as a pandemic by the World Health Organization. COVID-19 presents with lower respiratory tract infection-related symptoms and many patients might be asymptomatic carriers. Reverse transcriptase-polymerase chain reaction (RT-PCR) test used for diagnosis is not robust and has limited availability. Chest radiograph (CXR) is an easily available test and universally used for assessment of patients with respiratory symptoms. In this review, we discuss the various imaging appearances of COVID-19 on a CXR. We also look at the role of CXR in the diagnosis/screening of COVID-19, the utility of artificial intelligence and highlight various guidelines on imaging in COVID-19. Practical aspects relating to infection control and quality control are also discussed.

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Key words **: COVID-19, CXR, Imaging, Chest radiograph, Novel Corona Virus.**

First cases of pneumonia with unknown cause were reported to the World Health Organisation (WHO) on 31st December 2019 from Wuhan city. By 7th January, 2020, a novel coronavirus was identified as the cause for this and termed '2019-nCoV'. Subsequently, the virus was officially named as Severe Acute Respiratory Syndrome coronavirus 2 (SARS CoV-2)and the illness caused is termed COVID-19 (Corona Virus Disease 2019) by the WHO. On 30th January, COVID-19 was declared as a public health emergency of international concern and by 11th March, 2020 declared it as a global pandemic[1,2].

Since its discovery, COVID-19 has rapidly spread across the globe claiming many lives. At the time of writing, there are more than 40 lakhs of proven cases worldwide with a mortality of nearly 2.8 lakh[3]. In India, the disease has affected nearly seventy thousand subjects with more than two thousand deaths[4]. With lockdown restrictions being eased, it is likely that the numbers will see a further rise in the coming weeks to months.

COVID-19 has similar clinical profile as Severe Acute Respiratory Syndrome (SARS) and Middle Eastern Respiratory Syndrome (MERS) and mainly presents as lower respiratory tract infection[5,6]. COVID-19 diagnosis is reliant on identifying the virus in the respiratory samples using real-time reverse transcriptase-polymerase chain reaction (RT-PCR). There is limited availability of the test in different parts of the country and the turn around time for reports is also variable. The RT-PCR testing has also been reported to have variable sensitivity ranging from 37% to 71%[7-9]. All these factors make imaging critical in the assessment of suspected patients.

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Editor's Comment :

- **Coronavirus Disease 2019 (COVID-19) is an infection caused by SARS CoV-2**
- **Easy accessibility and low cost are the most important advantages of chest X ray in our country**
- **Poor sensitivity and specificity are limitations of Chest X ray**
- **Bilateral involvement, peripheral and lower lobe involvement increases the probability of COVID-19.**
- **It is helpful for triage.**

CXR's are widely available and cost-effective imaging modality in the initial assessment of thoracic abnormalities. Frontline clinicians must be aware of the CXR findings in patients with COVID-19 and also its limitations. In this review, we demonstrate the typical and atypical presentations of COVID-19 on CXR. We also discuss the role of CXR in management of COVID, national and international guidelines on CXR imaging and certain practical aspects related to quality and infection control.

CXR findings in COVID-19 :

Most common findings seen on imaging of COVID-19 patients are ground-glass opacity and consolidation with a preferential involvement of lower lobes and bilateral disease[5-7,10-13].

Ground Glass Opacities (GGO):

On CXR, GGO appears as an area of hazy increased

lung opacity within which margins of pulmonary vessels may be difficult to see[14]. These are much better seen on Computed Tomography (CT) and are less opaque compared to consolidation (Fig 1). When associated with reticular opacities, the detection becomes easier. Hazy opacities on CXR can also be diffuse making its identification challenging[10] (Fig 2). In patients with proven COVID-19, GGO was seen in 20-33% of patients at presentation[11-13,15]. Normal lung parenchyma may mimic areas of GGO in poorly taken films and/or due to overlying soft tissues such as prominent breast tissue[13].

Consolidation :

Consolidation is seen as an area of homogeneous opacification in the lung parenchyma with obscuration of the vessel and airway walls[14]. In COVID-19 and other viral pneumonias, there is multi-lobar and often bilateral involvement (Fig 3). This is in contrast to the typical unilateral lobar distribution of bacterial pneumonia[16]. One of the early studies from China had reported the presence of consolidation in all CXR's at presentation[17]. On studies published subsequently, consolidation was found in varying frequency, ranging from 5-80%[11-13 15].

Distribution :

Classical distribution seen in most of the patients is that of bilateral involvement with lower lobe predominance. Peripheral distribution was more common than central involvement[12,13,17] (Fig 4). In a more recent study by Weinstock *et al*[15], lower lobe predominance and peripheral distribution was seen in about 35% of patients but bilateral involvement was only seen in 21% of cases. Diffuse distribution of lung opacities can also be seen as the disease progresses. The appearances are similar to Acute Respiratory Disease Syndrome (ARDS) patterns[10] (Fig 5).

Atypical Findings :

Interstitial pattern of distribution has been reported apart from GGO and consolidation[15]. Pleural involvement is an atypical finding with pneumothorax and pleural effusions reported in some selective cases especially during disease progression/prolonged admission. Assisted ventilation related pathologies such as pneumo-mediastinum have also been reported[18,19] (Fig 6). Nodular lesions have also been described and more easily recognized on CT[13] (Fig 7).

Learning Points :

- ***Ground glass opacification and consolidation are the most common findings on CXR of patients with COVID-19.***
- ***Bilateral involvement with lower lobe predominance and peripheral distribution is most likely.***

Fig 1 — CXR (A) and CT (B) images of a 45-year-old male who presented with fever and cough. He had hypoxia and leukopenia on examination and his nasal swab was positive for SARS COV-2. CXR shows bilateral blurred opacities with unclear vascular margins (white arrow) with corresponding ground glass changes in the CT (black arrows). Images reproduced with permission from Covid-19 Database of the SocietaItaliana di Radiologia Medica e Interventistica.

Fig 2 — CXR (A) and CT (B& C) images of a 50-year-old man with 6 days history of fever and dry cough. RT-PCR test was positive. CXR shows bilateral diffuse opacities, with a more opaque patch in the right lower zone (white arrow). The corresponding CT shows the true extent of the disease (black arrows). Images reproduced with permission from Covid-19 Database of the Fleischner Society.

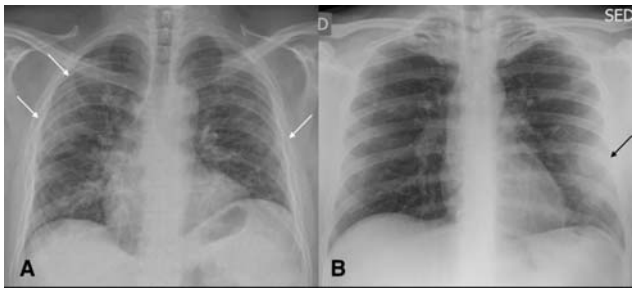

Fig 3 — CXR images from two different patients with COVID-19 showing peripheral areas of consolidation bilaterally in A and unilaterally in B (arrows). Images reproduced with permission from Covid-19 Database of the Societa Italiana di Radiologia Medica e Interventistica.

- ***Pleural involvement at the time of presentation is not common.***

Role of CXR in COVID-19

CXR in Diagnosis and Screening for COVID-19:

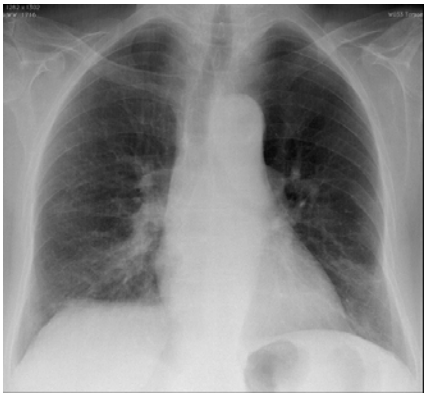

Fig 4 — CXR of a 71-year-old man with 4 days history of shortness of breath. Classical features of hazy opacities are seen in the lower lobes bilaterally in a peripheral distribution. Image reproduced with permission from Covid-19 Database of the Fleischner Society.

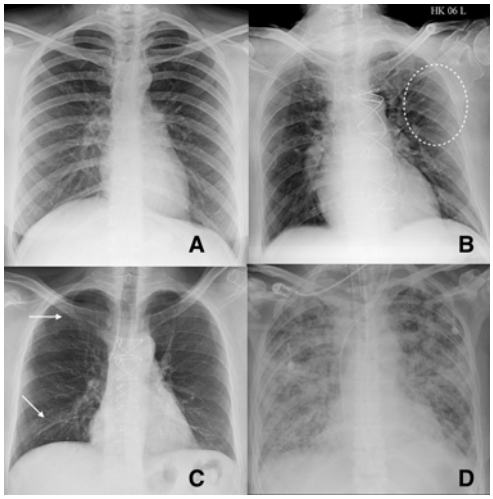

Fig 5 — CXR's of different patients with proven COVID-19 demonstrating varied appearances at the time of presentation. A- No abnormalities could be seen on CXR and the corresponding CT (not shown) was also near normal. B- Ill-defined hazy peripheral opacities seen in the left upper zone. C- Multifocal opacities were seen in the right lung on CXR at presentation. D- CXR showing extensive parenchymal infiltrates in a patient who came to the hospital in very bad respiratory distress and was found to have COVID-19 on testing.

Two of the very early reports from China and Hongkong had shown high sensitivity of CXR abnormalities in patients testing positive for COVID-19[11,17]. Wong *et al*[12], showed a sensitivity of 69% of CXR compared to 91% of RT-PCR with CXR abnormalities preceding positive RT-PCR testing in 9% of patients. With these results, it was proposed to consider CXR as a screening tool especially due to limited availability and sensitivity of RT-PCR testing[12]. The same performance of the CXR, however, could not be replicated as the disease spread wider and more continents were involved. A recent study from New York City looked at 636 patients (confirmed and

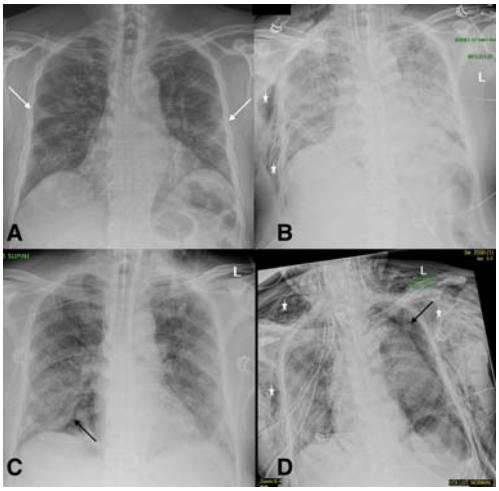

Fig 6 — Serial CXR's of a patient with COVID-19 showing development of atypical findings during the admission. The admission radiograph (A) demonstrates multifocal peripheral opacities (white arrow), followed by the development of right pneumothorax (black arrow) on day 7 (B) of admission with improvement in parenchymal changes subsequently on day 15 of admission (C). He developed extensive left pneumothorax (black arrow) and surgical emphysema (star)(D)of the chest wall later in the course. Images courtesy of Dr Amrita Bajaj, Glenfield Hospital, Leicester.

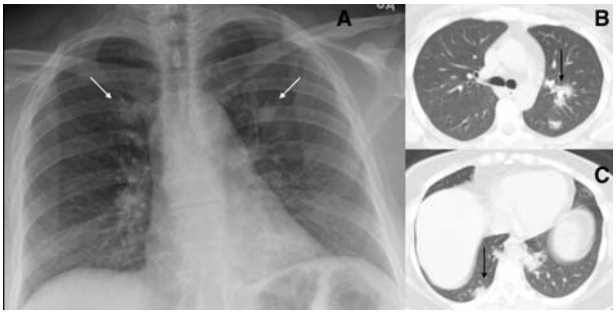

Fig 7 — Atypical presentation of COVID-19 in the form of nodules (arrows) seen on the CXR (A) and the corresponding CT (B). Image reproduced with permission from Covid-19 Database of the Fleischner Society.

symptomatic COVID-19) presenting to urgent care. They found a normal CXR in 58.3% patients and up to 89% of patients had normal to near normal CXR[15]. A similar finding was also seen in a study published from Korea[15]. The described CXR findings are not specific for COVID-19 and may also be seen in other viral pneumonias such as SARS and MERS. Many GGO and consolidative changes visible on CT may not be seen on CXR making it a less sensitive technique[11].

Learning Points :

- ***CXR can be normal or near-normal in a large number of patients with COVID-19 and hence will not be a reliable test for diagnosis or screening.***

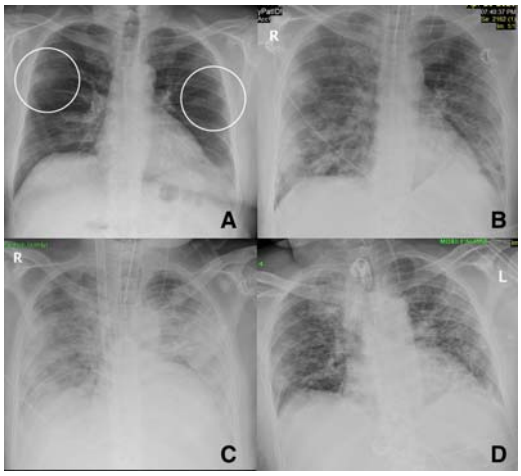

Fig 8 — Serial CXR examinations in a patient showing disease progression. Presentation (A) film had bilateral peripheral hazy opacities that increased on day 7 (B) and became confluent. Further worsening of parenchymal changes on day 11 with the patient requiring extracorporeal membrane oxygenation (ECMO) support (C) with improvement in clinical condition and persistent parenchymal fibrotic infiltrates on day 23 of admission (D). Images courtesy of Dr Amrita Bajaj, Glenfield Hospital, Leicester.

- ***CXR abnormality can precede RT-PCR positivity. Patients with abnormal CXR and high suspicion for COVID-19 should undergo repeat RT-PCR testing.***

CXR in assessing severity of COVID-19:

Imaging can play a vital role in assessing the severity of COVID-19 patients. To assess the extent of disease involvement, a simplistic radiographic scoring system was used by Wong *et al*[12]. Each lung was graded from 0-4 based on the extent of involvement (0- no involvement, 1- up to 25%, 2- 25-50%, 3- 50-75% and 4 >75% involvement). The scores of each lung were added to get a final score. The severity score of CXR varied over the time and peak severity was seen at 10-12 days from symptom onset (Fig 8). As the disease progresses the GGO are replaced by areas of consolidation that either resolves or worsens to give ARDS picture[11] (Fig 9). Various CT severity scores have shown good correlation with clinical severity of disease[20 21]. The degree of lung inflation at the initial CT can also predict adverse outcomes in patients with COVID-19[22].

Learning Points :

- ***CXR findings are at its worst at 10-12 days from symptom onset.***
- ***Simple CXR severity scoring can be used to assess the progression of disease.***

CXR for Disease progression/ Discharge decision :

Can CXR be used to decide when to discharge the patient? No, there is no clear evidence to support this. In the study by Wong et al, there was no statistical difference between the time taken for radiographic and virologic recovery[12]. About 42% of patients had shown recovery in CT findings before RT-PCR test getting negative while the remainder either showed worsening of findings or showed improvement after RT-PCR became negative[7].

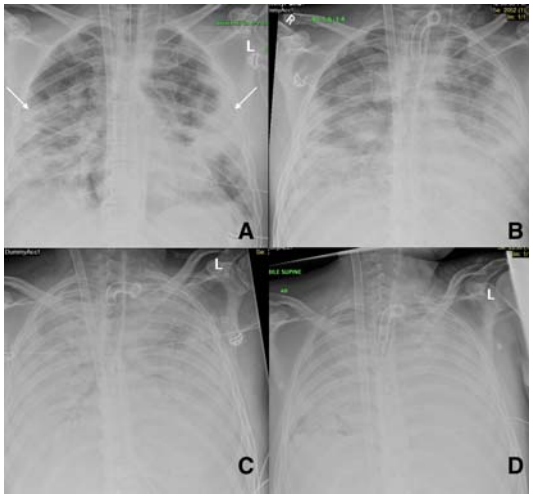

Fig 9 — Serial CXR examinations in a patient who succumbed to the infection. This patient came in with severe respiratory distress and was put on ventilator support early in his admission. ECMO therapy was also started (A) with bilateral parenchymal consolidation. Patient kept deteriorating on ECMO (Day 13- B, Day 18 C and Day 27- D) and succumbed to the disease. Images courtesy of Dr Amrita Bajaj, Glenfield Hospital, Leicester.

Learning Points :

- ***CXR resolution cannot be used to decide the time to discharge.***

Guidelines on Use of CXR in COVID-19 :

Multiple national and international societies have proposed guidelines on the use of different imaging modalities in the diagnosis and management of COVID-19[6,23-25]. Some of these have also taken into account resource constraints in their guidelines[9]. None of the recommendations support the use of CXR for the diagnosis or screening of the patients. Imaging is recommended in patients with proven COVID-19 and worsening clinical features or patients with moderate to severe disease at presentation. Routine serial follow-up CXR is not recommended. In areas where RT-PCR testing is not available, imaging (either CXR/CT) can be utilized in medical triage of patients with suspected COVID-19 with moderate to severe features and high pre-test probability[9]. Most of the guidelines also recommend the use of dedicated portable/mobile equipment for performance of CXR. Specific reporting guidelines have also been proposed to

encourage structured reporting of findings, which will help in the assessment of disease severity and also in research studies.

Learning Points :

- ***CXR imaging should not be used for screening purposes.***
- ***CXR should be used in patients with COVID-19 and worsening clinical condition.***
- ***In areas with lack of RT-PCR testing, imaging can be utilized for medical triage of patients with moderate to severe features and high pre-test probability of COVID-19.***

Machine Learning/Artificial Intelligence in CXR :

There have been significant advances in the field of machine learning/artificial intelligence (ML/AI) in the field of imaging. Many commercially available products have been utilized in the interpretation of CXR and are effective, especially for tuberculosis (TB)[26]. Interpretation of CXR can be subjective, especially when there are subtle abnormalities. There are also resource constraints in the developing world with regards to the availability of radiologists around the clock[27]. ML/AI based CXR reporting may provide a viable solution which can interpret CXR accurately, quickly and round the clock. One of the ML/AI models achieved similar accuracy of 6 independent radiologists in detected COVID-19 related changes on a CXR with a sensitivity of 85%[28]. Many other products are available commercially and some of them are indigenously built in India.

Learning Points :

- ***Artificial Intelligence-based CXR interpretation can help in early and accurate detection of COVID-19.***

Practical Aspects :

Infection Control :

The SARS CoV-2 is a highly contagious virus and transmission via droplets and contaminated surfaces in radiology departments is known[29]. This was one of the reasons for not utilizing imaging in screening/diagnosis of COVID-19 patients. Patient care should not be compromised while maintaining staff safety[5]. Every imaging department should have a thorough standard operating procedure (SOP). Continued education and regular training should be provided to the staff regarding social distancing, hand hygiene and use of personal protective equipment (PPE). Wherever possible, portable radiographic equipment should be used to limit disease transmission. If possible, radiographic equipment should be dedicated to isolation units/wards and should be stationed within the ward[29]. Spontaneously breathing patients should wear a mask. When imaging proven patients or patients with suspected COVID-19, radiology technologists should use PPE according to their institution policy. A facemask, face shield, gloves, head-cover and a disposable isolation gown are standard recommendations[5] [29]. Equipment should be thoroughly cleaned, with water and manufacturer-approved detergent, after each patient. Fumigation and ultraviolet rays are also other ways of cleaning the equipment post use.

Learning Points :

- ***Dedicated portable equipment should be utilized whenever possible.***
- ***All radiology technologists, while performing CXR examination, should use appropriate PPE.***
- ***Equipment should be sanitized between two examinations.***

Quality Control :

CXR abnormalities may be subtle and not easily recognizable. It is important to get the best quality images with appropriate exposure parameters and good inspiration. Computed Radiography (CR) is superior to conventional radiography in image quality and reducespatient's radiation exposure[30]. Digital Radiography (DR) systems are faster and allow immediate visualization of the image at the bedside. This has a great advantage in the isolation wards as the equipment does not have to leave the ward and the images can be directly loaded into the hospital PACS (picture archiving and communication system) wirelessly. Physicians can also see the CXR images straightaway in their mobile phones/computers as per the institutional setup.

Learning Points :

- ***CXR should be of high quality to detect subtle findings.***
- ***DR (digital radiography) technology is faster and better compared to conventional radiography.***

Conclusion :

CXR is aneasily available and cost-effective imaging modality in the assessment of chest pathologies. COVID-19 predominantly presents with lower respiratory tract infection-related symptoms. CXR is not sensitive in diagnosis/screening for COVID-19 and can be normal at the time of presentation. In areas with limited access to RT-PCR testing, CXR/CT imaging can be utilized for medical triage of patients with moderate to severe features and

high pre-test probability of COVID-19. CXR can be utilized in assessing disease severity and monitoring its progress. Ground glass opacity and/or consolidation in a peripheral distribution with lower lobe/bilateral involvement are commonly seen. Portable bedside examination is recommended to restrict disease spread. Robust infection control and quality control policies should be set up and followed to ensure staff and patient safety.

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