Chapter 5

The Role of Chest Radiographs in the Diagnosis of SARS

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Introduction
At the onset of the SARS crisis, the majority of patients presented with respiratory symptoms. As the epidemic progressed, either due to a different mode of transmission or a mutation of the virus, some SARS patients presented with minor or no respiratory symptoms but diarrhea\(^1\). Understandably, this created a problem with case definition and diagnosis, and the lack of a reliable and rapid biochemical test for SARS placed more emphasis on chest imaging findings for diagnosis of the disease.
The wide availability, speed and inexpensive nature of the chest radiograph (CXR) has made it the first line imaging investigation when faced with a respiratory complaint. It is only fitting that the initial imaging investigation of SARS also starts here. This chapter presents the radiographic features of SARS and the differential diagnosis.

Key Point
- SARS patient may not present with respiratory symptoms

Pathological considerations
Viral infection of the respiratory tract may involve the upper system\(^2\), from the common cold (rhinoviruses and coronaviruses), larynx (respiratory syncitial virus), trachea and bronchi (herpes simplex type 1), to the lung parenchyma (influenza). The initial phase in viral lung parenchymal involvement is a pneumonitis. A local inflammatory response is directed towards the offending virus, an inflammatory cocktail of cells and fluid accumulate in the alveolar interstitium of the lung parenchyma. In bacterial infections this exudate spills over into the air-space and results in the classic consolidation. This flooding of the alveolar space occasionally occurs in viral pulmonary infections.
Coronavirus infection of the respiratory tract is not new. It is previously well known for causing upper respiratory tract infections, such as coryza and pharyngitis.
There has been scanty documentation of lung involvement\(^3\) and none on the imaging appearance of it. This has changed with SARS, and imaging appearances (on CXR and HRCT) of SARS pneumonia are well documented.
Similarities between other viral infection and SARS include:

(i) mild or patchy consolidation may occur in both instances, the consolidation may initially be focal and may progress to a multi-focal involvement in later stages.

(ii) In severe, later stages of a viral infection of the lung, changes of Adult Respiratory Distress Syndrome (ARDS) may occur in the lung. This is also seen in patients with SARS and has been confirmed by post-mortem in patients who have succumbed to the disease.

Thus two broad categories of lung pathology may occur in SARS and be seen on presentation. An earlier focal or multi-focal pneumonitis and a later extensive consolidation resembling ARDS. Many variations will exist between these two extremes, at presentation and during the course of the patient’s illness. The imaging of SARS reflects this spectrum of pathology.

**Key Points**

Two types of pathology:

(a) focal or multi-focal pneumonitis (early stage disease)

(b) confluent consolidation sometimes resembling ARDS.

**Role of the Chest Radiograph in the Diagnosis of SARS**

This is the first line imaging tool for all respiratory complaints and remains so for SARS. In routine clinical practice, when confronted with a very sick patient with respiratory symptoms, the immediate role of the chest radiograph is to establish the presence of intra-thoracic disease and to exclude a surgically correctable cause such as a pneumothorax, large pleural effusion/empyema.

When a patient presents with less severe symptoms but has respiratory problems and is febrile, a chest radiograph is performed as a routine workup in most centers. Differentiation of SARS from other causes of respiratory distress requires knowledge of the radiographic appearance of SARS and the radiographic appearances of other pulmonary diseases, particularly other pneumonias, which often overlap among themselves (see chapter 3). The lack of a reliable, rapid and widely available test, at the time of writing this chapter, has further compounded the issue.
Several investigators (6, 7, and 8) have reported that the CXR is abnormal in approximately 80% of the initial radiograph of SARS patients. However, one must view this figure in the correct perspective. These CXRs were performed during the course of an epidemic, in patients with significant clinical signs and symptoms and a history of contact. This is probably the reason for the high sensitivity of CXRs in identifying SARS. At the end of the epidemic, when the number of patients were few, signs and symptoms variable and the history of contact difficult to verify, the accuracy of the CXR is likely to be lower. In the authors’ experience, under these circumstances, the initial CXR is often normal even in later confirmed cases of SARS. The diagnosis is made a couple of days later when laboratory results are available. It is during this time when the risk of transmission of infection is the medical staff and community is the highest, particularly if the patients are housed in the general wards and not in separate isolation rooms.

Protocol for Diagnostic Imaging

It is therefore imperative that the protocol for diagnostic imaging be reviewed in its proper perspective:

(i) during the initial outbreak
(ii) as the situation stands now at the end of the epidemic

i) During the initial outbreak/epidemic it was essential to make a prompt diagnosis as: a) it allowed for more timely medical treatment which would affect prognosis; b) it allowed prompt isolation of infected patients to protect other in-patients, health-care workers, and the community.

The protocol used at our institution at the time was:

• Patient suspicious of SARS satisfying WHO criteria, underwent a frontal chest radiograph. If this showed pneumonic changes, the patient was treated as a SARS patient i.e. admitted to SARS isolation ward and treated.
• Patient suspicious of SARS satisfying WHO criteria, had a frontal chest radiograph. If this was normal, a High Resolution Computed Tomography (HRCT) scan was performed.
• Patients with respiratory symptoms, low suspicion for SARS and not fulfilling WHO criteria had a frontal chest radiograph. If this was negative, the patient is considered as not having SARS and treated in a non-SARS ward.
Thus a HRCT was performed only in patients with a strong clinical suspicion and a negative chest radiograph.

ii) By the end of the epidemic, the situation was remarkably different. The patients who were ultimately diagnosed to have SARS were often the frail elderly from old age/convalescent homes. They presented with variable symptoms, often, non-respiratory in nature. The CXR in these patients was often normal at presentation and became positive a few days later (around the same time as the laboratory results return). Therefore the early use of a CXR was probably not beneficial and may provide a false sense of security. The authors believe that in this category of patients the threshold for doing a HRCT should be low as it may detect lung abnormalities early in the course of the disease. The HRCT is obviously interpreted based on clinical findings and hopefully as the radiologists and clinicians acquire more experience with SARS, one may be able to make an early diagnosis. This is probably a stop gap measure as eventually accurate laboratory tests will become available and one may not need to resort to imaging for diagnosis.

For SARS patients, the initial radiographic appearance will also act as a baseline for the progression of disease. It is useful as a guide for tailoring treatment and may potentially have some value in terms of an outcome predictor.

**Key Points**

**Roles of CXR in Diagnosis of SARS:**
- Confirm presence of lung disease
- Limit differential diagnosis
- Act as baseline for disease progression monitoring
- ? outcome predictor

**Digital Radiography and PACS**

Digital Radiography and PACS deserve special mention for their contribution in a crisis like SARS. With a wide dynamic range and the power of post-processing, digital radiography minimizes the number of repeat chest radiographs.
Not only does this decrease the radiation dose to the patient (which is substantial due to the long hospital stay and frequent radiographs), it also reduces exposure of radiographers to the infected patients and areas. On the other hand, a PACS system protects the radiologists and clerical staff in that it stops film and envelop transaction between the isolation wards or clinics and the radiology department. PACS also allows instantaneous reporting of the radiograph and remote consultation with clinicians without needing the radiologist to be at the ward or clinic. Reporting images while wearing full protection clothing is uncomfortable (hot and sweaty), inefficient (thick gloves and muffled voice) and probably less accurate (looking through the visor or face shield). One can only speculate the psychological effects on the radiologist and his reading accuracy when one has to report films in an ultra-high risk environment. With either piece of equipment, the window levels could be adjusted so that progress changes can be more easily evaluated.

### Key Points

**Digital Radiography for SARS:**
- minimized repeat radiographs
- less time with infected patients
- less radiation for patients
- uniform images for progress review

**PACS for SARS:**
- no physical transfer of film or envelops
- almost instantaneous reports
- tele-consultation of images

### Chest Radiograph appearances

The presenting chest radiograph of patients suspected of SARS, using WHO criteria was abnormal in 78.3% in a study by Wong et al. 6 and 80% in a study by Tsang et al. 7. Hon et al found similarly high sensitivity of 90% in children. 8

The most representative radiographic abnormality seen in SARS patient is airspace opacification.
This opacification may be of ground glass opacity (Figure 1) suggesting an alveolitis or less commonly consolidation with air-bronchograms (Figure 2). The two types may represent different stages of the disease or different degrees of host reaction 7. The opacities have ill-defined margins and no evidence of cavitation or calcification.

**Figure 1**
40 year old female, chest radiograph on day 4 since the onset of fever and respiratory symptoms. There is an area of ground glass opacification in the right lower zone peripherally. Vascular markings are not obscured. No air-bronchograms present. There is no lymphadenopathy or pleural effusion.

**Figure 2**
26 year old female, chest radiograph on day 5 since the onset of symptoms. There is an area of consolidation in the anterior segment of the right upper lobe. Vascular markings are obscured and air-bronchograms are present. There is no lymphadenopathy or pleural effusion.

There is no reticular or nodular pattern and there was no hilar or mediastinal enlargement or pleural effusion 6,7,10. There is no evidence of significant volume loss or increase. Two radiographic patterns of distribution of the lesions are seen in SARS at presentation: (a) uni-focal, peripheral airspace opacification (Figures 1 and 2) and (b) lobar or extensive involvement, sometimes bilateral and occasionally resembling ARDS 6 (Figure 3). The two patterns represent the extremes of a spectrum of appearances and may reflect either the stage of the disease or the extent of host reaction to the infection.
The majority of the opacities are found in the lower to mid zones of the lungs. In one study of 108 patients, the lower or the mid zones (64.8% lower, 52.8% mid) were involved (Figures 4, 5).

**Figure 3**
44 year old male, chest radiograph on day 5 since the onset of symptoms. There are bilateral widespread areas of mixed ground glass and consolidative opacification. There is no cardiomegaly, lymphadenopathy or pleural effusion.

**Figure 4**
Location of Opacities on Presenting Radiograph (N=108)

<table>
<thead>
<tr>
<th>Zone</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower</td>
<td>12%</td>
</tr>
<tr>
<td>Mid</td>
<td>39%</td>
</tr>
<tr>
<td>Total</td>
<td>76%</td>
</tr>
</tbody>
</table>

**Figure 5**
25 year old male, chest radiograph on day 7 since the onset of symptoms. There is area of consolidation in the periphery, between the mid and lower zones on the right. There is no lymphadenopathy or pleural effusion.
Only 16.7% of patients had upper zone involvement. The disease appears to start in one lung, unilateral involvement was seen in 82% of patients. The right lung was slightly more commonly involved than the left (75.9% right, 62.0% on the left). A solitary lesion (seen in 54.6% of patients) was slightly more common than multi-focal involvement (45.4%) (Figures 6, 7). In the majority of patients, the lesions involved the peripheral or subpleural lung parenchymal (88%) and only a small proportion of lesions (12%) did not involve the peripheral lung (Figure 8).

**Figure 6**
Number of lesions.

**Figure 7**
25 year old female, chest radiograph on day 5 since the onset of symptoms. There are two area of opacification, in the right upper zone and the right lower zone. There is no lymphadenopathy or pleural effusion.

**Figure 8**
Location of lesions.
Key Points

Air-space opacification:
- ground glass density or consolidation
- no volume loss or increase
- no cavitation or calcification

Two types of distribution:
(a) focal (slightly more common) or multi-focal
(b) extensive lobar, sometimes bilateral resembling ARDS

Location
- Unilateral involvement much more common
- right slightly more left
- lower or mid zone predominance
- peripheral/subpleural involvement in the majority of lesions

Differential Diagnosis

Although the imaging appearances of various pneumonias have been discussed in a separate chapter, the following paragraphs re-emphasize a few salient features.

The differential diagnosis for focal or limited multi-focal peripheral hazy opacification are: other forms of atypical pneumonia, bronchopneumonia, Bronchiolitis Obliterans Organizing Pneumonia (BOOP), Chronic Eosinophilic Pneumonia and Acute Extrinsic Allergic Alveolitis. When the radiographic features are combined with clinical information, these differential diagnoses (except for other forms of atypical pneumonia) are virtually ruled out. The radiographic features of the more common types of atypical pneumonia (Chlamydia, Mycoplasma, and Influenza) share many features with SARS.

Influenza pneumonia also demonstrates airspace opacification that involves the lower zones and may be either patchy or homogeneous, unilateral or bilateral. Extensive bilateral involvement resembling pulmonary oedema may also occur. Pleural effusion is rare.

Mycoplasma pneumonia may present with either airspace or reticular opacification and involves the lower zones predominantly.
It may produce a segmental involvement. Hilar lymphadenopathy may occur especially in children. Pleural effusions occur in 20% of patients. Chlamydial pneumonia similarly shows either airspace or reticular opacification, may be uni-focal or multi-focal, unilateral or bilateral. Pleural effusions may occur. In summary, the radiographic features of SARS overlap with those of the different causes of atypical pneumonia and are thus non-specific.

The differential diagnosis for lobar or bilateral confluent consolidation, sometimes resembling ARDS, are other causes of ARDS, which include sepsis, shock, inhalational injury, aspiration, narcotics, pancreatitis etc. Again, the features seen in SARS are indistinguishable from these other causes radiologically but the clinical history should be helpful in ruling out other causes.

**Key Points**

**Differential Diagnosis:**
- Atypical pneumonia
- Bronchopneumonia
- Bronchiolitis Obliterans Organizing Pneumonia
- Chronic Eosinophilic Pneumonia
- Acute Extrinsic Allergic Alveolitis
- Adult Respiratory Distress Syndrome

*Clinical history rules out most of the differential diagnoses.*

**General Features of Atypical pneumonia (non-specific):**
- Influenza, Mycoplasma, Chlamydia
- Lower lobe predominance
- Airspace opacification
- Rarely pleural effusion

**Blind Spots for Chest Radiographs**

The blind spots for radiographic abnormalities in the detection of SARS are those inherent in using a single frontal chest radiograph. Lesions that were detected by HRCT on SARS patients with normal initial chest radiographs reveal that the hidden lesions were behind...
dense breast shadows, retrocardiac, paraspinal regions, posterior costophrenic angles \(^{5,6,9,10}\). If HRCT is not a feasible option, a lateral chest radiograph may be helpful.

**Key Points**

**Blind Spots:**
- Behind breast shadows
- Retrocardiac
- Paraspinal
- Posterior costophrenic angles

**Conclusion**

The radiographic appearance of SARS on presentation are airspace opacification of the lung periphery and the lower zone, and absence of cavitation, hilar lymphadenopathy or pleural effusion. The roles of the chest radiograph in SARS are to rule out a surgical cause in an acutely unwell patient, to confirm presence of lung disease in suspected cases, to limit the differential diagnosis and to act as a baseline for disease progression monitoring. The limitations of the chest radiograph in diagnosing SARS lies in both the non-specific appearance of the lesions and the poor ability to detect small lesions in “blind spots”. The former can be partly resolved with the help of the clinical history and the latter by the use of HRCT.
References