Chapter 7

The Role of High-Resolution Computed Tomography (HRCT) in Diagnosis of SARS

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Introduction

Plain radiography and high-resolution computed tomography (HRCT) are the cornerstones for imaging the lungs. HRCT is capable of imaging the lung with excellent spatial resolution, providing anatomic detail similar to that available from gross pathologic specimens or lung slices. It is especially good for the early detection and characterization of localized or diffuse lung parenchymal abnormalities. However, HRCT involves a high radiation dose, is not readily available and therefore may not be suitable as the first line of investigation for suspected SARS patients or in a screening role in endemic / pandemic situation. In such a situation, HRCT should be reserved for selected group of patients with good clinical indication and non-diagnostic chest radiograph. The indications should be more relaxed with sporadic cases. The diagnostic protocol for imaging and the use of CXR and HRCT has been discussed previously.

Apart from diagnosis, HRCT also plays an important role to monitor progress and response to treatment and for follow-up. These will be dealt with separately in later chapters. This chapter aims to give the reader an insight about the role of HRCT in diagnosis of SARS and to describe various radiologic appearances on HRCT.

Key Points

Introduction

- currently there is no simple diagnostic test that can reliably diagnose SARS
- HRCT provides excellent spatial resolution and anatomic detail of the lungs
- Due to radiation hazard it cannot be used as first line investigation or screening tool in an epidemic
- Indications for scanning may be more relaxed in sporadic cases

Scanning Technique

The imaging technique for suspected SARS patients is similar to that of other pulmonary diseases.

As there was no literature on the imaging features of SARS to consult in the initial phase of
the outbreak, Wong et al performed both conventional CT (without iv contrast) and high-resolution CT for delineation of lung parenchymal, mediastinal and pleural abnormalities. As experience about this disease increased with time and with an initial observations of absence of lymphadenopathy and pleural abnormality, HRCT alone was performed for suspected SARS patient.

The examination is done with the patient in supine position at full inspiration. Scanning parameters are standardized at: 1mm collimation, 6mm inter-slice gap, 120 kV, 140mA, scan time of 1 second for each axial slice. The scanning procedure of the entire thorax takes about approximately 1 minute. For patients in respiratory distress, scanning in shallow breathing is performed.

Images are viewed at lung window settings (window level: -700 HU; window width: 1500 HU) after image reconstruction using a high-spatial frequency algorithm.

Close monitoring of vital signs including SaO2, pulse and blood pressure should not be neglected especially for critically ill patients. Meticulous attention should be placed on infection control measures in the CT suite. The measures are designed to protect

1. staff working in the CT suite
2. other patients who would be examined using the same scanners

The infection control measures are discussed in detail in a separate chapter towards the end of this book.

**Key Points**

**HRCT Imaging Technique**

- patient in supine position, full inspiration
- 1mm collimation, 6mm inter-slice gap
- 120kV, 140mA, scan time of 1 second
  * close patient monitoring during scanning
  * infection control guidelines strictly followed
Indication

Whether during the early phase of an epidemic or later when dealing with sporadic cases, HRCT has a higher sensitivity in detecting lung abnormalities than CXR in diagnosing SARS. As discussed earlier, this sensitivity difference should be larger in sporadic cases than earlier in an epidemic.

In the initial phase of the epidemic, the majority (78%) of patients with SARS had abnormal chest radiograph on clinical presentation 7. In the presence of relevant clinical context and laboratory findings, the presence of air-space opacification on chest radiograph helped to confirm the diagnosis of SARS. In the remaining 22% of patients, the initial chest radiograph at presentation was negative 7. In those patients with strong clinical suspicion (including positive contact history, high fever, lymphopenia, thrombocytopenia, elevated LDH level etc) and negative chest radiograph, HRCT played an important role in detection of early lung parenchymal changes to support the clinical diagnosis.

For patients with strong clinical suspicion and chest radiograph finding of air-space opacification, HRCT is usually not necessary as the diagnosis is already supported by the CXR findings. HRCT does not add further information in terms of diagnosis, though in some patients additional lung parenchymal involvement can be demonstrated apart from those revealed by CXR.

The importance of good clinical assessment for the level of suspicion cannot be over emphasized. In a study by Wong et all 8, all (17 out of 17) patients with high clinical index of suspicion and negative chest radiograph had lung parenchymal changes detectable on HRCT whereas all 34 patients with minor symptoms or low level of clinical suspicion had normal HRCT. Therefore in our institution, HRCT was performed only in patients with high clinical index of suspicion and a negative initial chest radiograph (Figure 1,2). HRCT was also used in suspected cases with subtle or equivocal findings on chest radiograph (Figure 3).

However, one must note that in the absence of an epidemic setting, the algorithm for the use of HRCT should be revisited. In such circumstances, the patients are usually frail and old with no obvious history of contact with SARS patients. Many of these patients have pre-existing disease and CXR alone may not be very useful. Therefore the threshold for indication for HRCT may be lowered.
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Figure 1
Imaging protocol for suspected SARS patients in our institution.

Figure 2
HRCT of a 50-year-old female SARS patient shows small patch of ground-glass opacification in antero-lateral basal segment of left lower lobe. Subtle areas of ground-glass opacification are present in the rest of both lower lobes (arrows). Note CXR on the same day is clear.

Figure 3
43-year-old female SARS patient (a) Postero-anterior chest radiograph shows a small area of increased opacity in left lower zone (arrow). The finding is equivocal, especially in female patient with dense breast shadows. (b) HRCT shows small area of ground-glass opacification in posterior basal segment of left lower lobe corresponding to the CXR change.
Key Points

Indication for HRCT in patients with suspected SARS
- high clinical index of suspicion with negative CXR
- high clinical index of suspicion with equivocal CXR findings (especially in females with dense breasts)

HRCT not recommended for:
- all patients with low clinical index of suspicion
- high clinical index of suspicion with definite CXR changes

N.B. indications more relaxed at a late stage of the epidemic / with sporadic cases.

Imaging Features on HRCT

The radiological features of SARS on HRCT are variable, depending on the stage of the disease at presentation. For patients presenting during the early phase of the disease, the HRCT abnormalities are less extensive than those with late presentation. It is important to recognize that there is no single radiological sign to definitely diagnose SARS without knowing the patients’ clinical information.

Appearances

In the authors’ experience, the most common appearances of lesions in patients with SARS are:

1. ground-glass opacification, which is defined as increased lung parenchymal attenuation without obscuring the underlying vascular architecture. This appearance accounts for 68% of all 149 lesions seen on our initial series of 40 patients with SARS (Figure 4,5).
2. Consolidation, defined as opacification where the underlying vasculature is obscured, is seen in 32%, half of these are admixed with areas of ground-glass opacification (Figure 6,7,8).
3. Within areas of ground-glass opacification, there are associated abnormalities including thickened intralobular interstitium (32%) and interlobular septa (24%) (Figure 9). A ‘crazy-paving’ appearance is noted if these interstitial changes are marked (Figure 10).
4. Bronchial dilatation is present in 7% of lesions and affects the segmental bronchi supplying the area of parenchymal opacification.

5. There is no peri-bronchovascular interstitial thickening, mass or nodule, emphysema, cavitation or pleural effusion encountered in our series.

Figure 4
HRCT of a 51-year-old female with SARS shows focal area of ground-glass opacification involving posterior and lateral basal segment of left lower lobe (arrow).

Figure 5
HRCT of a 29-year-old male with SARS shows multiple peripheral subpleural ground-glass opacifications in both lower lobes.

Figure 6
HRCT of a 50-year-old male with SARS shows more extensive consolidation and ground-glass opacification in both lower lobes.

Figure 7
HRCT of a 61-year-old male with SARS shows mixed consolidation (arrow) and ground-glass opacification in right middle lobe.
**Figure 8**
HRCT of a 52-year-old patient with SARS shows pure consolidation in right middle lobe.

**Figure 9**
HRCT of a 33-year-old patient with SARS shows interlobular septal thickening (arrowheads) within the ground-glass opacity in left lower lobe.

**Figure 10**
HRCT of a 25-year-old female with SARS shows markedly thickened intralobular interstitium and interlobular septa within ground-glass opacity with ‘crazy-paving’ appearance.


**Location**

1. The lesions tend to be peripheral (72%) or both central and peripheral (20%) while pure central location is uncommon (8%)\(^8\).
2. Although all segments of the lung can be involved, there is a slight predominance of lower lobe involvement.
3. Bilateral involvement occurs in about half of patients which is more common in the advanced cases (61% vs 18%).

**Key Points**

**HRCT features of SARS**

- ground-glass opacification +/- consolidation
- thickened intralobular interstitium and interlobular septa
- peripheral / subpleural in location
- unilateral / bilateral (depends on stage of disease at presentation)
* cavitation, lymphadenopathy, pleural effusion are not imaging features

HRCT is especially useful for detection of lung parenchymal changes of SARS in certain radiographic blind-spots which are not easily assessed by plain radiograph. These include retrocardiac area, paraspinal region, retrodiaphragmatic area over posterior costophrenic sulcus\(^10\) (Figure 11, 12, 13). Early disease with small areas of ground-glass opacification is also commonly missed on plain radiograph but are readily demonstrated by HRCT.

**Figure 11**

HRCT of a 30-year-old female with SARS shows focal consolidation / ground-glass opacification in paraspinal area of left upper lobe (arrow). This is a common radiographic blind spots on CXR.

**Figure 12**

HRCT of a 28-year-old male with SARS shows focal consolidation in left retrocardiac area (arrow). The corresponding CXR on the same date is normal.
Figure 13
HRCT of a 33-year-old male with SARS shows area of ground-glass opacification in right posterior costophrenic sulcus which is not detectable on CXR.

Key Points
Blind spots on CXR best assessed by HRCT
- retrocardiac area
- paraspinal area
- posterior costophrenic sulcus

Differential Diagnosis
It should be stated from the beginning that none of the CT features of SARS are themselves specific or diagnostic. The differential diagnosis in terms of the CT findings include atypical pneumonia caused by other infective agents, bronchiolitis obliterans organizing pneumonia (BOOP) and chronic eosinophilic pneumonia (CEP).

Atypical pneumonia is most commonly caused by mycoplasma, chlamydia, legionella and virus (such as influenza virus). Centrilobular opacities, acinar shadows, air-space consolidation and ground-glass opacity with a lobular distribution are the most common HRCT features of atypical pneumonia \(^\text{11}\). However, in our experience, these are not consistent findings in patients with SARS.

Mycoplasma pneumonia is a common cause of community acquired pneumonia, accounting for up to 30% of all pneumonias in the general population \(^\text{11,12}\). The most commonly described HRCT findings in patients with serologically proven mycoplasma pneumonia are \(^\text{13}\):
• Areas of ground-glass opacification (85%) and air-space consolidation (78%).
• Lobular distribution of consolidation (59%)
• Nodules in 89% patients, predominantly centrilobular in distribution
• Thickening of the bronchovascular bundles in 82% of patients.

Influenza virus types A and B cause most cases of viral pneumonia in immunocompetent adults. Common HRCT findings include 14 (Figure 14):
1. poorly defined centrilobular nodules,
2. ground-glass attenuation with a lobular distribution,
3. segmental consolidation, or
4. diffuse ground-glass attenuation with thickened interlobular septa.

The radiologic findings reflect the variable extents of the histopathologic features: diffuse alveolar damage (intra-alveolar edema, fibrin, and variable cellular infiltrates with a hyaline membrane), intra-alveolar hemorrhage, and interstitial (intrapulmonary or airway) inflammatory cell infiltration.

Bronchiolitis obliterans organizing pneumonia (BOOP) is a disease of unknown cause characterized by presence of granulation tissue polyps within lumina of bronchioles and alveolar ducts and patchy areas of organizing pneumonia. Typical HRCT features include 15,16,17 (Figure 15):
1. patchy consolidation or ground-glass opacification in subpleural and/or peribronchial distribution;
2. small ill-defined nodules that may be peribronchial or peribronchiolar;
3. large nodules or mass;
4. bronchial wall thickening or dilatation in abnormal lung regions.
5. crazy-paving, with superimposition of ground-glass opacification and interlobular septal thickening may also seen in patients with BOOP.
6. lower lung zones are involved more commonly than upper lung zones.

Chronic eosinophilic pneumonia is an idiopathic condition characterized by extensive filling of alveoli by mixed inflammatory infiltrates consisting primarily of eosinophils. Common HRCT findings 18,19 include (Figure 16):
1. consolidation in lung periphery and patchy in distribution;
2. patchy or peripheral ground-glass opacification, sometimes associated with crazy-paving;
3. linear or band-like opacities;
4. an upper lobe predominance of abnormalities.

Since there is much overlap in radiological appearances of SARS and these pulmonary disorders, clinical information is indispensable for accurate diagnosis. In patients with clinical presentation of high fever, chills and rigor with recent contact history and laboratory findings of lymphopenia and thrombocytopenia, the presence of lung parenchymal abnormality strongly supports the diagnosis of SARS.

Figure 14
HRCT of a 17-year-old patient with influenza pneumonia shows multiple small acinar / centrilobular nodules (arrowheads) and consolidation (arrow) in right upper lobe. Occasional ‘tree in bud’ appearances are present.

Figure 15
HRCT of a 44-year-old female with BOOP shows multiple peripheral subpleural consolidation (black arrows), peribronchial consolidation (white arrow) and thickened bronchovascular interstitium (arrowheads).

Figure 16
Spiral CT of a 28-year-old female with CEP with multiple peripheral consolidations in both lungs.
**Key Points**

Differential diagnosis of HRCT findings
- other atypical pneumonias (including mycoplasma and viral pneumonia)
- bronchiolitis obliterans organizing pneumonia (BOOP)
- chronic eosinophilic pneumonia (CEP)

**Diagnostic Pitfalls**

With use of modern CT scanners and meticulous imaging techniques, HRCT helps in the diagnosis of early cases of SARS. However, several confusing artifacts may be seen on HRCT which may pose diagnostic difficulty, especially for the inexperienced. Familiarity with their appearances should eliminate potential misdiagnosis.

Atelectasis is commonly seen in dependent lung in both normal and abnormal subjects, resulting in a so-called dependent density (Figure 17). This normal finding can closely mimic the appearances of consolidation or early lung fibrosis. It can be easily distinguished from true pathology by obtaining scans in both supine and prone positions. In our experience, it was seldom required given the specific appearances of this artifact.

**Figure 17**
Dependent densities (arrows) mimicking consolidation. The characteristic distribution in dependent positions and symmetrical in nature help differentiate from genuine pulmonary lesion.

**Figure 18**
Pulsation artifacts from adjacent cardiac motion (arrow) may mimic ground-glass opacification. Note the presence of ground-glass opacification / consolidation in periphery of right lower lobe.
Motion artifact due to respiratory movement is especially important to note in patients with respiratory distress. Pulsation artifact from adjacent heart and major thoracic vessels are also commonly encountered (Figure 18). These could potentially create areas of increased attenuation mimicking lung parenchymal abnormalities.

**Conclusion**

High resolution computed tomography is a useful imaging tool for early diagnosis of patients with SARS. It is especially useful for patients with high clinical suspicion and negative chest radiograph at initial presentation. In our experience, patchy ground-glass opacification with or without consolidation in a peripheral distribution were the most typical appearances of SARS on HRCT.
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