Chapter 12
Imaging and Clinical Management of Paediatric SARS

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Introduction

Although SARS has wreaked havoc in South East Asia and other parts of the world, it appears to be a disease that predominantly affects adults. Less than 10% of the infected population in Hong Kong were children (http://www.info.gov.hk/). Among these infected children, only 5% required care in the intensive care unit (ICU) and less than 1% required mechanical ventilation based on the local experience from Hong Kong hospitals. In contrast to its adult counterpart:
- Clinical course of affected children was usually milder
- Duration for resolution was shorter
- Potential of children to infect others was lower

This chapter will discuss the clinical features, radiological presentation, management and outcome of children suffering from SARS based on our institutional experience.

Clinical presentation

Most children with SARS have either been in close contact with infected adults, as a household contact or in a health-care setting. These are believed to be the important routes of transmission that put children at a particular risk. Surprisingly, in Hong Kong there has been no major spread of the disease among classmates in schools. This may partly be explained by the early strict hygiene precautions undertaken by schools following a large-scale educational program conducted by the local government.

There are two distinct patterns of clinical presentation among children in different age groups:
- Teenage patients presented with symptoms of malaise, myalgia, chills and rigor similar to presenting symptoms in adults
- Younger children presented mainly with cough and runny nose, and none had chills, rigors, or myalgia

The clinical course is much milder and shorter among younger patients except infants. The average hospital stay is two to four weeks in all these children.

The incidence of clinical presentation of children with suspected SARS is shown in (Figure 1).

Problems with WHO definition

- Although we follow WHO case definition for SARS in the diagnosis of paediatric patients who suffer from the disease, we find “Severe Acute Respiratory Syndrome” a
misnomer for children since the clinical features in majority of them are neither ‘severe’ nor ‘respiratory’ in nature.

The distinction between suspected case and probable case based on radiographic changes alone is also not very helpful in the clinical management. WHO defines SARS as either suspected or probable. The case definition of suspected SARS is (i) fever and (ii) respiratory symptoms including cough and difficulty breathing and (iii) close contact with SARS patients or history of travel to an epidemic area. Probable SARS is a suspected case with radiographic evidence of pneumonia or respiratory distress syndrome. Thus, probable SARS is a suspected SARS with chest radiographic changes. Aetiological diagnosis is not required in these clinical definitions. However, it is neither practical not to have chest radiographs performed on a child suspected as having SARS nor sensible to label a child as having suspected SARS in the absence of chest radiographic change. Therefore, in our experience it is not logical to differentiate suspected SARS from probable SARS based on radiographic changes alone. Furthermore, any child residing in an endemic area who has a ‘cold’ with fever and cough would be diagnosed as suspected SARS by WHO definition! WHO has since revised the definition of a probable case to include a suspected case of SARS that is positive for SARS coronavirus.

**Key Points**

1. Contacts at home and in health care setting are important routes of transmission of SARS to children.
2. Young children have a milder form of disease with a less-aggressive clinical course than adults.
3. Teenagers may mimic the disease pattern of adult and can have a longer and more severe form of the disease.
Plain radiography

A chest radiograph is the primary initial imaging modality for SARS, as in the majority of acute chest infections in children. It provides supportive information on the diagnosis of SARS in addition to the WHO definition of surveillance case. Most children have radiographic abnormalities on presentation to the hospital. However, the radiographic appearance itself are non-specific. Based on our institutional experience:

- The primary radiographic finding in paediatric patients with SARS is air-space opacification, which can be unilateral focal (62%) or unilateral multiple/bilateral (38%) (Figure 2).
- Children with younger age, and those with mild symptoms usually present with unilateral focal consolidation (Figure 3), while multi-focal and bilateral involvement (Figure 4) occurs in a few teenage patients who present with a more severe disease and require supportive oxygen therapy as well as a longer hospital stay.
- There is a higher prevalence of consolidation in the lower lung zone (63%) compared with the upper lung zone (31%) while only 6% involve the mid zone (Figure 5).

Although a coronavirus has been implicated as the causative agent of SARS, the radiological presentation of SARS in children is different from most common radiological appearance of viral disease of the lower respiratory tract in children.

![Figure 2](Pattern of air space opacification on chest radiograph in SARS children.)

![Figure 3](Zonal distribution of air space opacification on chest radiograph in SARS children.)
In viral infection such as respiratory syncytial viral infection of children, the most common radiologic findings on chest radiographs are:

- Peribronchial shadowing, bronchial wall thickening and perihilar linearity
- Air trapping and atelectasis are often seen
- Coalescent air space consolidation is less common.

Localized air space consolidation with lobar or segmental distribution is a more classical radiographic presentation of bacterial pneumonia though there is significant overlap of radiologic appearance between viral and bacterial infection.

The primary radiologic feature of SARS therefore resembles that of bacterial pneumonia with air-space consolidation; however, there is a striking absence of pleural effusion, which is commonly encountered in bacterial chest infection. Cavitation that occurs in pneumococcal and anaerobe pneumonia, is also not a feature of SARS. Unlike tuberculosis, another common disease in children transmitted via contact, lymphadenopathy is not a feature of SARS.
In our patients with SARS, the air space opacification usually became worse on day 5 to day 7 after the onset of the fever. Unlike adults who usually progressed to multiple areas of involvement, majority of our children only showed increase in extent of air space opacification in the same lung zone where consolidation was first identified (Figure 6). Progression to multi-focal bilateral lung infiltrates was only observed in a few teenage patients who run a more aggressive course of the disease (Figure 7). The mean duration of time required for complete resolution of the consolidation on radiograph was 16 days (range 8-30 days) from our institutional experience. No definite scarring, volume loss, bronchial thickening or bronchiectasis is identified in the follow up radiographs of our paediatric patients who have recovered from the illness (Figure 8). Again this is in contrary to the initial report from adults that pulmonary complications in the form of pulmonary fibrosis and bronchiectasis may be as high as 20% 16,17.

![Figure 6](image)

**Figure 6**
Chest radiographs (a) on admission, (b) four days later of a 15-year-old boy, who presented with fever, rough and myalgia. There is a small focal area of air space opacification with air bronchogram in the right upper zone (arrows in a), which enlarges and becomes more apparent on the subsequent radiograph (b).
Figure 7
Chest radiographs (a) on day 3 and (b) day 10 after the onset of fever in a 15-year-old girl presenting with sore throat, myalgia and dyspnoea. Initial radiograph (a) shows unilateral focal air space opacification in the left lower zone (arrows) which progresses to coalescent air space consolidation of bilateral lower zones (b) [Courtesy, Dr CW Leung and Dr M C Chiu, Princess Margaret Hospital, Hong Kong].

Figure 8
Chest radiograph of the same patient in figure 3, one month after the acute infection, shows complete resolution of radiologic abnormality. No evidence or residual parenchymal density, bronchiectasis or volume loss.
### Key Points

**Comparison of radiographic features in children and adults**

<table>
<thead>
<tr>
<th>Children</th>
<th>Adults</th>
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<tbody>
<tr>
<td>- The most common radiologic finding is air-space consolidation</td>
<td>- Similar to children</td>
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<tr>
<td>- Younger children and those with mild symptoms usually present with unilateral focal consolidation</td>
<td>- Most adults also present with initial unilateral focal consolidation but with rapid progression</td>
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<td>- Teenage patients with a more severe disease present with multi-focal and bilateral involvement</td>
<td>- Progression with extensive bilateral involvement is common</td>
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<tr>
<td>- Majority show focal progression of air space opacification without bilateral lung involvement</td>
<td>- Similar to children</td>
</tr>
<tr>
<td>- Lymphadenopathy, pleural effusion and cavitation are not seen</td>
<td>- Radiological abnormality becomes worse on day 7</td>
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<tr>
<td>- Radiological abnormality becomes worse on day 5 to 7</td>
<td>- It takes a longer time for resolution and many have long-term residual changes</td>
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<td>- Complete resolution is achieved around 2 weeks</td>
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### High resolution computed tomography

Chest computed tomography (CT) is usually not required for the initial diagnosis of paediatric SARS because majority of the patients show radiographic abnormality at presentation. CT however plays a role in the detection and exclusion of SARS in highly suspected cases with clinical symptoms and contact history but negative radiographic findings. The recognition and treatment of paediatric SARS are particularly important not only because of the impact on the personal health of infected children, but also because children with primary infection may become the reservoir from which future cases will emerge. We therefore advocate the use of HRCT in making prompt diagnosis in highly suspected cases with a non-contributory
CXR. Not uncommonly, the number of areas of abnormality detected on CT is much higher than the number detected on chest radiograph. The fast scan times of modern CT scanners permits performing HRCT in children without the need for sedation. The radiation dose in children is reduced using a lower mA technique (50-80mA) without compromising the diagnostic value of the scan (Figure 9).

Similar to the findings of plain radiography, most patients present with milder form of the disease and show focal segmental air space disease on HRCT (Figure 10). Ground-glass opacification and consolidation are the two predominant features on HRCT (Figure 11). The former refers to hazy increased attenuation of the lung with preservation of the bronchial and vascular markings, caused by partial filling of the air spaces or partial collapse of alveoli. The latter refers to a homogeneous increase in pulmonary parenchymal attenuation that obscures the margins of vessels and airway walls. It is common to find a combination of both findings in SARS. In patients with multi-focal disease, a mosaic pattern of lung attenuation with ground-glass and air-space infiltrates is observed simulating the appearance of bronchiolitis obliterans organizing pneumonia (BOOP). Again the above radiological appearances are non-specific. Both ground-glass opacity and consolidation attenuation are common findings in children suffering from pneumonia of any etiology (Figure 11). Pulmonary nodules, septal thickening, pleural effusion and lymphadenopathy are not features of SARS.

**Figure 9**
High resolution CT of a 4-month-old baby, who presented with fever and history of contact with SARS infected adults. Using only 50mA and non-breath hold technique, there is satisfactory image quality with identification of air space consolidation and air-bronchogram in the superior segment of left lower lobe (arrows).

**Figure 10**
High resolution CT of a 15-year-old boy presenting with fever, rough and myalgia. There is a large area of mixed ground-glass opacification and air space consolidation in the right upper lobe.
There is no specific preference of distribution of the disease in children. We have observed an approximately equal involvement of subpleural and peribronchial regions in children presenting with either segmental or multi-focal disease (Figure 12) whereas peripheral distribution is a predominant feature in the adult cases 20.

HRCT was performed for children with prolonged course of the disease. In the limited follow up of our initial children who have recovered from SARS:

- Despite no significant change on radiograph, HRCT shows evidence of partial resolution of the air-space consolidation (Figure 13) and therefore provides more accurate assessment of the response to the treatment.
- Radiologic findings on HRCT show no evidence of bronchial dilatation, fibrous scarring, air trapping or emphysematous changes.

Figure 11
High resolution CT of a 14-year-old girl, who presented with persistent fever for one week with chills and rigors, runny nose and myalgia. There is mixed air space consolidation and ground glass opacity in the left lower lobe.

Figure 12
High resolution CT of an 8-year-old boy, who presented with day 5 fever with chills and rigor. There are multi-focal areas of consolidation in the central region of left upper lobe (a) and the peripheral region of right upper lobe (b). [Courtesy, Dr PS Kan, Alice Ho Miu Ling Nethersole Hospital, Hong Kong]
Figure 13

a and b: chest radiographs of a 14-year-old girl presenting with prolonged course of symptoms. There is no significant change in the extent of ground-glass opacification in the left lower zone on admission (a) and 10 days later (b). HRCT however, shows evidence of partial resolution of the ground-glass opacification in the left lower lobe 10 days after the onset of fever (d) as compared with the initial study (c).
**Key Points**

1. High-resolution CT is recommended to aid diagnosis in children with strong clinical suspicion of SARS but non-contributory radiographic findings.
2. A low mA technique (50-80mA) is recommended for HRCT in paediatric patients to reduce the radiation dose.

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<tr>
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<tr>
<td>- Ground-glass opacification and consolidation are the two predominant features</td>
<td>- Same as children</td>
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<tr>
<td>- Pulmonary nodules, septal thickening, pleural effusion and lymphadenopathy are not seen.</td>
<td>- Interlobular septal and intralobular interstitial thickening is sometimes seen giving rise to crazy-paving pattern. Pleural effusion and lymphadenopathy are not seen.</td>
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<tr>
<td>- Equal involvement of subpleural and peribronchial regions</td>
<td>- Lesions are predominantly peripheral and subpleural in location</td>
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<tr>
<td>- Bronchial dilatation, fibrous scarring, air trapping or emphysematous changes not seen in the follow-up HRCT of recovered children</td>
<td>- Parenchymal bands, bronchovascular distortion, irregular interface and traction bronchiectasis are seen in some adult patients on follow up</td>
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Management and outcome

The first 10 children reported in our initial cohort received a treatment regimen similar to the regimen of adult SARS in Hong Kong \(^1\). Currently, intravenous cefotaxime (25-50 mg/kg/dose, every 6 or 8 hours), oral clarithromycin (15 mg/kg/day, to a maximum dose of 250 mg twice daily) and oral ribavirin (40 mg/kg/day, in 2 or 3 divided doses) are started if a clinical diagnosis of SARS is suspected on admission. Oral prednisolone (0.5 – 2 mg/kg/day) is added if there is no decrease in fever or improvement in the general well-being of the patient within 48 hours. If the child is admitted with moderately severe symptoms of high swinging fever and marked malaise, intravenous ribavirin (40-60 mg/kg/day, in 3 divided doses) and intravenous hydrocortisone (2 mg/kg/dose, every 6 hours) in addition to antibacterial therapy are administered immediately after admission. For patients with persistent fever and progressive clinical or radiological deterioration, pulse intravenous methylprednisolone (10 to 20 mg/kg/dose) is administered. The decision to give further pulsed treatment is based on clinical response. Antibacterial agents are discontinued five days after defervesence. Ribavirin is administered for one to two weeks, and corticosteroid is tapered over the course of two to four weeks.

The management regimen is likely to undergo revisions as more is known about SARS. There have been concerns with regard to the use of corticosteroids in the treatment of SARS. The indication for corticosteroid use in severe infectious diseases is the need to decrease inflammation caused by excessive cytokine response by the host. Because all patients with SARS have pneumonia, one might assume that ribavirin treatment would be more effective if administered by small particle aerosol generator (SPAG) as this method has been recommended previously for the treatment of respiratory syncytial viral infections in children. However, this method of administration is not considered because the first major outbreak of SARS appeared to have been accentuated by the use of a nebulizer on a general ward \(^2\).

The overall prognosis in children with SARS appears to be good. However, a small number of children have required care in the intensive care unit and mechanical ventilation. In accordance to our institutional policy, all patients with probable or suspected SARS are hospitalized for 21 days.
Key Points
Current medical treatment for paediatric patients with SARS at our institution

Suspected paediatric SARS

Mild symptoms
- i. Cefotaxime i.v.
- ii. Clarithromycin p.o.
- iii. Ribavarin p.o.

No improvement
- + Prednisolone p.o.

Moderately severe symptoms + high swinging fever
- i. Ribavirin i.v.
- ii. Hydrocortisone i.v. / prednisolone p.o.
- iii. Cefotaxime i.v.
- iv. Clarithromycin p.o.

Persistent fever, clinical deterioration
- + Pulse Methylprednisolone i.v.

No improvement
- + Pulse Methylprednisolone i.v.
Infection control

**Risk stratification and guidelines for paediatric patients**

All children with fever and pneumonic changes on chest radiograph are admitted to the ultra-high risk (UHR) wards, either UHR-S area (with SARS contact) or UHR-I area (without SARS contact). This policy is adopted to separate patients with probable or suspected SARS from those who are admitted for afebrile illness to prevent the possibility of cross infection. Patients with respiratory failure are admitted to the intensive care unit based on the prevailing selection criteria. During their hospitalization, all children are required to wear surgical masks at all times.

Upon discharge from hospital, parents of the children are given an information sheet detailing the precautions to be taken at home. In particular, they are reminded that their body secretions and excretions might still contain the pathogen. These children should limit interaction outside the home (i.e. not go to school or other public areas) for at least 10 days following discharge.

**SARS precautions in paediatric wards**

The precaution measures taken by health care workers are the same as in the adult wards. Below are the highlights of some important issues:

- Designated places and instructions are available for putting on and removing personal protective equipment
- Routine thorough cleansing of the ward is carried out at least three times per day using hypochlorite solution.
- There is a strict control on patient visits to reduce the risk of cross-infection. Visitors are not allowed in UHR-S area, and only one parent is allowed to visit each patient for at most two hours everyday.
- Visitors must follow the dress codes appropriate to the risk stratification of the areas.
- “Police nurses” are present at the entrance to ensure that the above steps are strictly followed

**Conclusion**

Based on our institutional experience in imaging children with SARS, we advocate chest radiography to be the initial imaging modality for all patients suspected of SARS. High resolution CT is reserved for those cases with high index of suspicion but negative radiographic findings. High resolution CT is also useful in monitoring the treatment response in children with unexpectedly long course of the disease.
Like any other chest infection of children, SARS may give rise to long term complications though significant chest radiographic changes are not evident in the initial cohort of our patients. We speculate that those children without obvious extensive BOOP pattern would do well since children have a lot of pulmonary reserve. The impact of SARS on a growing child may become clearer with long-term follow up of this group of patients in the future.
References


20. Wong KT, Antonio GE. Hui DSC et al. Thin-section CT of severe acute respiratory syndrome: evaluation of 73 patients exposed to or with the disease. http://radiology.rsajnl.org/cgi/content/full/2283030541v1