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MINI-SYMPOSIUM: SEVERE ACUTE RESPIRATORY SYNDROME (SARS)

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Post-SARS infection control in the hospital and clinic

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Summary The recent severe acute respiratory syndrome (SARS) outbreak has almost mandated a re-evaluation of infection control practices in hospitals, clinics, schools and domestic environments, especially for patients with respiratory tract symptoms. Triage, early case detection followed by prompt isolation and quarantine are major preventive measures. Respiratory tract infections are the most common childhood illnesses and paediatric SARS poses special problems in diagnosis because of its non-specific presentation. The main lessons learnt from the outbreak were: (1) despite well established guidelines on infection control precautions, poor understanding of underlying principles and deficiencies in compliance are common among healthcare professionals, especially during emergencies; (2) even a slight lapse can be fatal; and (3) over-protection can be counterproductive. Hence it is important to: (1) be protected to protect others; (2) be vigilant and prepared for emerging infections; (3) be proficient and scrupulous in infection control measures; (4) be apposite and practical on personal protective equipments to ensure sustainability; and (5) be dutiful and prompt in informing of potential threats and work closely with others.

INTRODUCTION

SARS is a new devastating disease, the understanding of which is still evolving and includes its clinical syndromes, infectivity and transmissibility, optimal treatment and prognosis. Children are less commonly infected than adults, they have milder disease, are less infectious and present with non-specific clinical features. However, severe illness can develop in adolescents and young infants.[1,2] Detailed infection control guidances on SARS have been prepared by WHO, US Center for Disease Control, Health Canada, Health Protection Agency of UK, Ministry of Health Singapore, CDC of China, CDC of Taiwan and the Hospital Authority of Hong Kong. A comprehensive review and account of infection control measures will not be attempted. This article makes special reference to children, is based on personal experience and on local systems developed in Hong Kong. It may need modifying to suit local situations and will need to be updated as new knowledge arises.

INCUBATION PERIOD

The incubation as reported by most countries is said to be 4–6 days, with a mean of 4.6 days.[3] Analysis of cases in Hong Kong revealed that the incubation period lies from 4–10 days with a mean of 6.4 days.[4] The main mode of transmission differed in different countries. Using mathematical and statistical models it was estimated that 71.1% and 74.8% of SARS infections in Hong Kong and Singapore were attributable to super-spreading events.[5] It is not known whether the route of transmission affects the incubation period.

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SURVIVAL OF SARS-COV

SARS-coronavirus (CoV) can be found in respiratory secretions, saliva, tears, blood, urine and faeces of SARS patients. SARS-CoV is stable in the environment for up to 2 days at room temperature and longer at a lower temperature. Survival in a variety of stool suspensions varies depending on the pH, consistency of the stool and possibly other factors (up to 4 days in alkaline, diarrhoeal stool, 6 h in normal stool and 3 h in normal, acidic baby stool). The virus loses infectivity after exposure to different commonly used disinfectants (including alcohol and hypochlorite), and heating at 56 °C for 15 min.

VIRAL EXECRETION

Based on RT-PCR data, 36% of nasopharyngeal aspirate (NPA)/nasal throat swabs tested positive for virus on days 0–2, peaking at 61% positive on days 9–11, declining to 35% on days 15–17 and are 0% by day 23. However, 0–22% of stools tested positive for the virus on days 0–2, peaking at 100% on days 12–14 and falling to 50% by days 21–23. Detection of viral RNA has a much lower yield from serum, with only 19% testing positive on days 0–2, peaking at 39% on days 6–8 of illness and being undetectable by day 12. Viral excretion in NPA and stool peaked on days 12–14 but viral load in NPA specimen was at two orders of magnitude lower than viral excretion in stools. Hence, respiratory specimens including nasopharyngeal aspirates, throat swabs or sputum samples were the most useful clinical specimens in the first 5 days of illness, after this stools would be the best choice.[6]

Infectivity is greatest in the second week of the illness, including those with severe illnesses, but patients can be infective within the first 1–2 days. There is no reported instance of transmission before the onset of symptoms of the disease and transmission after the second week of illness is rare.

INTERESTING FACTS

The size of coronavirus is about 0.1 μm. Sneezing could have an ejection velocity of up to 30 metres per sec and cough 35 metres per sec. The number of droplets produced from coughing is about 40 000, talking produces 10 000 and singing 1000. Droplet size varies from 50 μm to 3 μm. Large droplets do not travel far and usually settle within 2 metres but droplets of 3 μm can stay in the air for 3 h. With forced ejection a good portion of these droplets can be evaporated rapidly, especially under low humidity and they may suspend in air longer. Using fluorescent-stained water, it was demonstrated that toilet seats had significant contamination by droplets after flushing and the aerosol effect can be up to the standing height of a child.[7]

Huge amounts of submicron (0.3–0.5 μm) aerosols can be generated from drainage flow, in the order of 60 000 per litre of air in the domestic sewage drainage system of high rises, suggesting that airborne transmission is possible from the empty U-traps and pipes leaking and containing infectious agents.[8]

MODE OF TRANSMISSION

The primary mode of transmission is by direct mucous membrane (eyes, nose and mouth) contact with infectious agents. The main routes are through contaminated hands or direct exposure to respiratory droplets – contact and droplet. The basic reproduction ratio of three is consistent with the main mode of transmission by droplets. However, airborne transmission of SARS can indeed occur in hospital and in community housing complexes.[9] Infected cases occurred primarily in persons in close contact with ill SARS patients in healthcare and household settings. Transmission to casual and social contacts has occasionally occurred, especially as a result of intense exposure to SARS patients eg. in lifts, in the workplace, on airlines or in taxis.

Transmission from children to adults is uncommon.[3,10] The attack rate for children was found to be lower than adults among quarantined close contacts in Beijing (5% in children <10 years of age, 11.4% in those between 30 and 39 years of age and 27.6% in those aged between 60 and 69 years)[11] There was no report of SARS transmission in schools both in Hong Kong and China where the outbreak was most extensive. A cluster of nine mild paediatric patients had been reported in a private boarding school for 820 students. All lived in the same building and ate daily meals together in the school canteen.[12] Congenital and perinatal infection have not been documented in the 12 pregnancies reported in Hong Kong,[13] nine in China[14] and one in the USA.[15]

In hospital settings, aerosolised respiratory secretions and direct contact with patients' secretion, excreta and fomites are other amplifying events. The role of faecal-oral transmission is unknown but is probably of some significance as profuse watery diarrhoea is common and large amounts of virus are found in stool. There have been no reports of food or waterborne transmission. The role of contaminated fomites in transmission is uncertain but must not be under estimated as the virus can survive for days at room temperature on most surfaces.

In one report of 193 emergency department workers exposed to SARS, nine (4.7%) were infected. Pneumonia developed in six, two had mild illness and one remained asymptomatic.[16] The emergency department is a high-risk area because of its nature of trauma, heavy workload, crowded environment and lack of isolation facilities. There were at least two outbreaks in community clinic settings in Hong Kong. In one, a nurse was first infected by a SARS patient attending the clinic and subsequently infected two other nurses, the doctor and his wife. In the second, a doctor was found to be infected on contact tracing of a household cluster of four SARS cases. On further case tracing two more of the doctor's patients were found to be infected.[17] Despite great concerns, compliance to infection control precautions by community general practitioners in Hong Kong lagged behind their hospital counterparts – 97.7% had not worn masks at all times, a third did not wash their hands after seeing/examining a patient and half did not wear gowns. Three-quarters did not wear goggles during patient encounters, just over half insisted patients wore masks during their consultation and over 10 doctors (12.4%) who were diagnosed with suspected or probable SARS had closed their clinics.[18] However, the sample size is small and may not be representative of community doctors in Hong Kong. Healthcare workers (HCWs) working in small clinics are of particular concern because of their small size and lack of adequate decontamination facilities and a good ventilation system. Ingenious designs have been developed by some to overcome this.

The rate of transmition of the disease to their household contacts were 26.1%, 9.8% and 0% in non-healthcare workers, healthcare workers infected before the use of protective equipments and healthcare workers infected after the use of protective equipments respectively, indicating that use of protective equipments, adhering to infection control precautions and early quarantine were effective in stopping transmission.[19] A similar study in Singapore also found that HCWs had a lower rate of household transmission but that their secondary household transmission rate was higher (6.2%).[20] Phasing of illnesses is probably the reason for a much higher transmission rate in healthcare facilities.

In a study of 1192 patients with probable SARS reported in Hong Kong, 26.6% were hospital workers, 16.1% were members of the same household as SARS patients, 14.3% were Amoy garden residents, 4.9% were in-patients and 9.9% were contacts of SARS patients who were not family members. Using multivariate analysis of 1: 2 matched case-controls of the remaining cases of undefined sources of infection, it was found that having visited mainland China, hospitals or the Amoy Gardens were significant risk factors. In addition, frequent mask use in public venues, frequent hand washing and disinfection of living quarters were significant protective factors.[21] A similar study conducted in Beijing on 94 unlinked probable SARS cases also showed that clinical SARS was associated with visits to fever clinics.[22] These indicate that household transmission is much less common and should allay public anxiety and panic.

INFECTION CONTROL PRECAUTIONS

The main infection control measures are droplet and contact precautions. Practices in paediatric and neonatal wards in Hong Kong that were utilised during the outbreak were well described.[23,24] It is important that strict hand hygiene and adequate decontamination be performed after each direct or potential exposure to patients and at any time that body parts are perceived to be contaminated by patients' bodily fluids. A shower after high-risk procedures and before leaving duty would have been most desirable. The employment of a 'policing nurse' had been found to be very effective in ensuring compliance to infection control precautions and procedures during the SARS epidemic.

MASKS

While N95 masks have higher filtration efficiency compared with surgical masks, they have lower breathability, higher thermal stress, more discomfort and cause more fatigue.[25] CDC recommended the use of N95 (95% filtration of 0.1 μm sodium chloride particles at a flow rate of 85 l/min),[26] the EU recommended the use of FFP2 or FFP3 masks (which had a filtering efficiency of 92% and 98% respectively, tested at 95 l/min with 0.1 μm sodium chloride particles) and Canada N100 respirators (filtering efficiency of 99.97% for mono-dispersed particles of size 0.12 μm).[27] A full face respirator with an ultra-low penetrating air filter has also been recommended for its higher efficiency, good fit and protection of the mucous membranes but the disadvantage is cost, cleaning, disinfection and maintenance.[28] N95 masks should be test-fitted and the same model used whenever possible. A check fit should be performed each time one puts on the respirator and before entering the patient's room.

In a study looking into factors affecting nosocomial infection in Hong Kong, it was found that all HCWs consistently used N95s or surgical masks and perceived that the inadequacy of personal protective equipment (PPE) supply, infection control training <2 h and inconsistent use of goggles, gowns, gloves and caps were significant independent risk factors for SARS infection.[29] The wearing of masks, gowns and goggles does pose considerable stress and fatigue to HCWs. Comfort and usability are other important issues to be considered. Masks can also affect visibility and patient rapport. The psychological impact of masking on children has not been studied. In low-risk times and areas, surgical masks would probably be sufficient.

It would be useful to have children wearing a surgical mask of appropriate size when they have respiratory symptoms, though the risk of transmission is considered to be lower than in adults. The associated discomfort may make it difficult to continue wearing the masks for a long period of time. With education, most children can be taught to put on a mask, at least when being examined or nursed and when outside the room.

EYE PROTECTION

Prescribed eye glass is not sufficient to protect against splashes. Face shields should be sufficient for most procedures unless excess splashes or direct coughing is expected, in these cases goggles should be worn. Full face masks and hoods are more cumbersome alternatives.

GOWNS – PERSONAL PROTECTIVE CLOTHING (PPC)

PPC are essential elements of infection control precautions, but which type of the available PPC provide better protection in terms of water repellency, water resistance, risk of environmental contamination, usability and comfort has not been determined. It is important to identify risk factors for non-compliance and design interventions and routines that are sustainable and practicable. In a study comparing different types of PPC available in Hong Kong, the use of a surgical gown in ordinary work procedures was recommended. When heavy splashes or droplets are expected, an additional plastic apron should be worn to protect the trunk.[30] It is important that PPC should be removed when soiled. Due care should be taken to avoid contamination of the environment and PPC should only be worn when needed and removed immediately on leaving isolation rooms.

REMOVAL OF PPC

Great care should be taken when removing PPC. Lack of appropriate PPC removal procedures can lead to lapses in infection control measures. This should be done outside the patient's area and with adequate spacing to avoid cross contamination and contamination of the environment. Mirrors would be helpful so that one can observe the whole procedure. One must avoid contamination of the nose, mouth and eyes while removing the cap, gown, gloves, mask and eye protectors. There are several sets of recommendations on the sequence of removing PPC. The one recommended by the National Institute for Infectious Diseases in Italy is probably the safest.[31] The essentials are that the procedures are clear, consistent and simple to follow.

The use of shoe covers is controversial and was not used in several hospitals in Hong Kong during the epidemics.

HIGH-RISK PROCEDURES

Stringent infection precautions, especially for high-risk procedures, appropriate triage and prompt isolation of potential SARS patients will contribute to the control of nosocomial spread and acquisition of HCW in hospital settings.[23,24,32] In a retrospective case control study of 91 intubations, risk factors for infection included difficult intubation (OR 8.8), extensive bagging (OR 25.9), intubation in a general ward environment (OR 8.2) and extensive droplet contamination.[33] Before performing high-risk procedures including CPR, intubation etc, one must ensure adequate protection in appropriate and properly equipped isolation facilities. Call for help if alone and choose the right technique before embarking on the procedure.[34] The analogy of putting on your own oxygen mask before attending to others while in air flight emergencies should be remembered.

Neubulisation, bronchoscopy induced sputum collection and face mask ventilation should be avoided as far a possible. If medically indicated, they should be undertaken in a negative pressure room with minimal but adequate staffing. All staff should be in PPC covering the torso, arms and hands as well as eyes, nose and mouth. N95s, N-99s or N-100s are adequate but full face masks are desirable. However, the use of powered air purifying respirators is not recommended because of risk to self and environmental contamination. The use of a face mask with a good fit and attached valved manifold may reduce the risk of transmission.[35]

No infection has been attributed to the taking of nasopharyngeal aspirate from SARS patients in Hong Kong. When performed it should be taken in a single room while wearing full PPC. A new upper respiratory tract irrigation method has been devised to replace nasopharyngeal aspirate testing, which should be safer.[36] The disadvantage of this method is that it cannot be used in young children.

TRIAGE AND EARLY DETECTION

Early recognition followed by prompt initiation of isolation and infection control precautions are the most important strategies for controlling SARS and other emerging infectious diseases. Clinical features alone cannot reliably distinguish SARS from other respiratory illnesses. Having an epidemiological linkage was the most consistent finding (95.5%) in children infected with SARS in Hong Kong.[37] Combining clinical findings and epidemiological linkage or clustering of cases and interpreting clinical findings with key epidemiological risk factors serves as a good framework for triage, especially for children. Precise and timely information about these epidemiological risks should be provided, coupled with proper training of frontline healthcare professionals on its interpretation.

FEVER AND RESPIRATORY SYMPTOMS ASSESSMENT ALGORITHM FOR CHILDREN (See Appendix)

A predictive model basing on a four-item clinical score of cough before or concomitant with fever, myalgia, diarrhoea and rhinorrhoea or sore throat had a 100% sensitivity and 75.9% specificity of early detection of probable

SARS. The addition of lymphopaenia and thrombocytopaenia increased the specificity to 86.2%.[38] In another model, a scoring system of attributing 11, 10, 3, 3 and 3 points to the presence of independent risk factors of epidemiological link, radiographic deterioration, myalgia, lymphopaenia and elevated ALT respectively, generated high- (11–30) and low- (0–10) risk scores for SARS. The sensitivity and specificity of this prediction rule in positively identifying a SARS patient were 97.7% and 81.3% respectively.[39] The prediction rule could be useful at the bedside. However, these studies were conducted in adult patients and would need to be validated in paediatric patients. Other clinical guidance has also been developed but again is probably only applicable to the adult population.[40] The case definition for clinical SARS used by Leung et al. in Hong Kong was: fever (rectal temperature of $\geq$38.5°C or oral temperature of $\geq$38°C); chest radiograph (CXR) findings of pulmonary infiltrates or acute respiratory distress syndrome; and suspected or probable contact with a person under investigation for SARS or exposure to a locality with suspected or documented community transmission of SARS through either travel or residence within 10 days of the onset of symptoms, as well as $\geq$1 of the following: chills, malaise, myalgia, muscle fatigue, cough, dyspnoea, tachypnoea, hypoxia, lymphopenia, decreasing lymphocyte count, or failure to respond, in terms of fever and general well-being, to antibiotics covering the usual pathogens of community-acquired pneumonia (e.g. a broad-spectrum lactam plus a macrolide) after 2 days of therapy. This case definition had a sensitivity and specificity of 97.8% and 92.7% respectively in identifying paediatric SARS during the SARS outbreak.[36]

While almost all reported patients with laboratory evidence of SARS have radiographic evidence of pneumonia at some point during their illness, paediatric SARS have non-specific radiographic features, making it difficult for radiological differentiation.[41] A private general clinic participating in the SARS-screening programme in Hong Kong during the SARS epidemic – by using telephone triage followed by chest radiograph of cases with 'flu-like' illness, the author successfully and safely screened 1161 attendees, X-rayed 151 patients and diagnosed one case of SARS. Therefore, a chest X-ray (CXR) would be a useful screening tool during outbreaks.[42] A SARS and avian influenza algorithm for early recognition and investigation of potential paediatric cases, modified from the UK Health Protection Agency's algorithm, is suggested in the Appendix.[40]

FACILITIES DESIGN AND VENTILATION

Negative pressure rooms are recommended for the isolation of patients with SARS. However, it should be noted that negative pressure rooms only prevent the virus from travelling outside the room and may not reduce viral load or environmental contamination inside the room. Several designs such as low level suction and laminar flow have tried to reduce the viral load inside the room but the effectiveness is unproven.[43] Various devices such as portable/mobile local exhaust ventilation devices, tents and personal isolation systems have been designed and tested but the usability, risk of contamination of staff and effectiveness are still under study.[44,45] A rethink on the best design for effective infection control which also improves clinical and psychological care of patients is very much needed. No matter how good the design this cannot replace preparedness, a good clinical routine and appropriate personal protection.

Elaborate ventilation designs and negative pressure systems would be difficult in most clinical settings. Exhaust fans and mobile local exhaust ventilation devices with HEPA filters have been used in hospitals and clinics in Hong Kong. Their efficacy has not been tested.

ADDITIONAL BARRIER PRECAUTIONS AND ENVIRONMENTAL HYGIENE

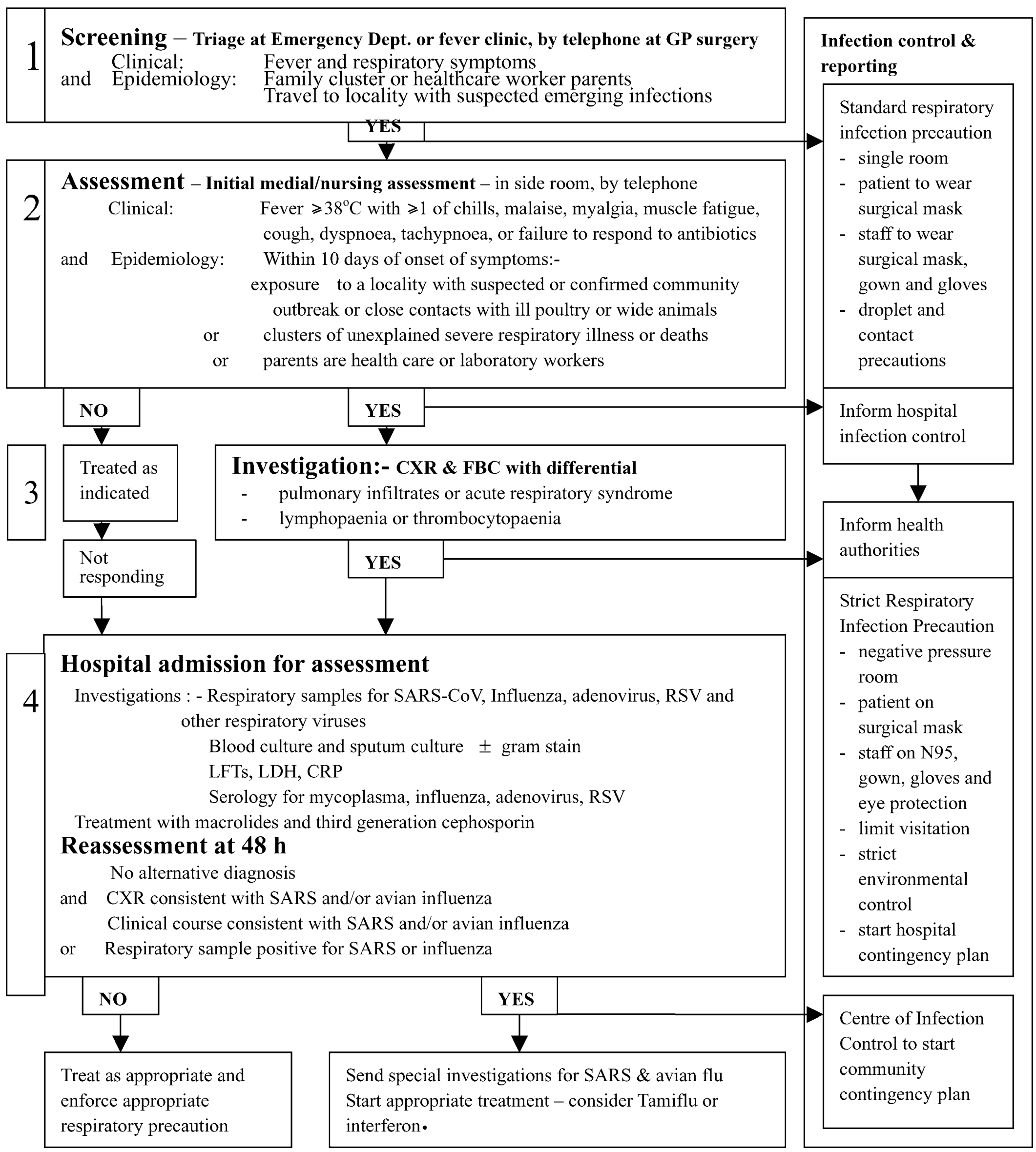
Several ingenious barrier precaution designs have been made by local medical practitioners: a torch mounted to a face shield for throat examination; cling film wrapping of telephones, keyboards and medical instrument to facilitate cleaning; and home-made air powered helmet hoods or tents for high-risk patients. These have not been tested and cannot replace hand hygiene, appropriate PPC and regular decontamination.

CONCLUSION

While having adequate infection control equipment and facilities are important, overcrowding or inadequate bed/clinic spacing or triage rooms and insufficient manpower are two major risk factors for hospital cross infection. Having clear clinical guidelines and timely information are essential but it is it even more important that everyone has adequate information and proper training, practice and enforcement on infections and infection control starting in schools and in the community. Panic and fear can be more harmful than the disease itself. SARS and avian flu have taught us that infections are not just a problem for healthcare professionals, they involve everyone of all ages within communities throughout the world.

APPENDIX A

SARS and avian influenza algorithm - recognition and investigation of potential paediatric cases.



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