SARS and the city—emerging health concerns in the built environment

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ABSTRACT
Severe acute respiratory syndrome (SARS) outbreak in Singapore lasted 11 weeks with 238 cases developing onset of illness between 25 February and 11 May 2003. Local transmission began when a returning traveller was admitted on 1 March to Tan Tock Seng Hospital for atypical pneumonia. Because existing control practices were inadequate against the virus, infection spread rapidly to involve healthcare workers, other patients, visitors and close family contacts. With little known about SARS infection and super-spreading events at that time, prevention and control relied on empirical epidemiology to detect early and isolate all cases, and contain the spread by ring fencing those exposed. Three lines of defence were drawn: at the air, sea and land checkpoints; in the healthcare institutions; and in the community setting. A contact tracing centre was established to undertake steps for the comprehensive identification and quarantine of close contacts of SARS cases to prevent spread to the community. The biggest test occurred when SARS was identified in an infected vegetable hawker at a crowded wholesale market. Immediate closure of the market and contact tracing of all persons who had been to the market between 5 and 19 April 2003 limited spread of the infection to no more than 12 persons. Our experience underscored the importance of maintaining a high level of vigilance and also of preparedness to respond to challenges with extraordinary measures. As new diseases emerge, public health authorities have to rethink the value of quarantine as well as look for new tools for disease detection and control to reduce opportunities for spread from potential reservoirs of infection.

INDEX TERMS
SARS; Disease control; Health concern; Built environment

INTRODUCTION

Severe acute respiratory syndrome (SARS) is caused by a novel coronavirus that is transmitted primarily from person to person through close personal contact and droplets from the mouth or nose of a symptomatic person during talking, coughing or sneezing. Infection may also occur from indirect contact with contaminated fomites (e.g. table surfaces, doorknobs, lift buttons) as the virus is believed to survive for days in the environment. Additional evidence from limited instances suggests that the virus may be transmitted by small particle aerosols.

In late February 2003, the SARS outbreak moved from southern China across several cities and threatened to establish itself endemically in Singapore (Hsu *et al.*, 2003; Leo *et al.*, 2003). The index cases in Singapore were three travellers to Hong Kong who contracted the disease from a Guangdong professor staying at their hotel on the same floor. The returning travellers were hospitalized in the first week of March 2003 for atypical pneumonia. Because existing control practices were inadequate against the virus, infection spread rapidly from the first case who was admitted to Tan Tock Seng Hospital

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on 1 March 2003 to involve healthcare workers, other patients, visitors and close family contacts.

A total of 238 SARS cases developed onset of illness between 25 February and 11 May 2003. They comprised seven imported cases, 21 introduced cases (secondary to imported infections) and 210 indigenous cases (secondary to introduced infections). One hallmark of the outbreak was the phenomenon of super-spreading events, triggered by individuals who, for as yet unexplained reasons, were highly efficient in amplifying the virus and spreading it to many people. A total of 121 of the cases were directly linked to contact with five cases in super-spreading events. The cause of these events was unclear but contributing factors include clinical severity of the disease, presence of co-morbid conditions that masked the telltale symptoms of SARS and failure to isolate the cases early.

Concerns about community-acquired infections were compounded in the tropical city state by Singapore being one of the most densely populated countries in the world with more than 4.1 million people living in slightly more than 700 square kilometres (Lee and Yeo, 2003). The urban conurbation is characterized by high-rise high-density apartment blocks in which the bulk of the people (more than 90%) reside in close proximity. In offices, shopping complexes, work environments, institutions of higher learning, some crèches and schools, air-conditioning would operate with very high re-circulation rates, keeping ventilation to a minimum to conserve the use of energy for de-humidification and cooling, creating indoor environments with moderate to high human originated bio-effluent levels (Tham *et al.*, 2000; Sekhar *et al.*, 2003). The high participation rate of the community in crèches, markets and eating places also amplified the risks of spread through intimate human contact and required firm control measures.

Measures to control the situation in Singapore focused on three fronts where defences had to be strengthened: at the border checkpoints; in the healthcare institutions; and in the community setting. This preliminary report describes the prevention and control measures taken to contain the spread of the disease during the outbreak period and outlines some of the issues involved in the public health management of SARS.

BORDER CHECKPOINTS

The air, sea and land checkpoints formed the first line of defence against imported infections. Temperature checks using thermal imaging scanners were conducted on all incoming passengers at Changi airport. Persons picked up by the scanners had their temperatures re-checked by nurses and were referred for examination by doctors at the airport if found to be febrile. Suspect cases were sent to Tan Tock Seng Hospital for further assessment and admission for isolation. At the seaports, incoming passengers and crew underwent similar screening using thermal imaging scanners. At the land checkpoints, temperature checks were made on all incoming bus, train and walk-in passengers and about 15% of those coming via other vehicles. For ease of tracing, all visitors were also required to complete a Health Declaration Card. The declaration covered symptoms of SARS, contact and travel history as well as personal particulars and address in Singapore. In case travellers from SARS-affected areas were incubating the disease, they were given a Health Alert Notice explaining the disease and how they could get medical help if symptoms appeared.

To prevent the export of SARS cases, mandatory screening of all outgoing travellers from Singapore through temperature checks were conducted at Changi airport and the seaports, and all bus travellers at land checkpoints using thermal imaging scanners.

Outgoing travellers from the airport and seaports were also asked to declare symptoms of SARS and contact history with SARS patients.

Through the World Health Organization, Singapore informed other countries whenever there were possible contacts of SARS cases who travelled out of the island. Singapore also initiated a multilateral agreement between the 10 ASEAN countries, China, Japan and Korea on information exchange in relation to travellers. In view of the high volume of people movement to and from Malaysia daily, a special bilateral arrangement was set up between the two governments for information exchange and ease of operations when persons with fever were detected at the land checkpoints.

HEALTHCARE INSTITUTIONS

The healthcare institutions were all potential amplifiers of the disease and constituted the main battleground in the fight to prevent further spread of infection. The Ministry of Health implemented very stringent measures to prevent and contain SARS outbreaks in hospitals, national centres, nursing homes, medical, dental and traditional Chinese medicine clinics.

Healthcare workers were required to wear N95 masks, gloves and gowns and practice frequent handwashing after every patient contact. Goggles were also required in isolation facilities, Emergency Departments and Intensive Care Units. When performing high risk procedures such as bronchial aspiration and intubation, positive airway pressure respirator hoods were used. All healthcare institutions were required to monitor their staff closely through twice or thrice-daily temperature monitoring and strict instructions were given to disallow any staff who had fever or was unwell to work.

To prevent cross-infections between hospitals, no inter-hospital transfers of patients were allowed. Doctors and other healthcare workers in the private hospitals were required to register to work in one hospital only. The hospitals also restricted the number of visitors per patient to just one per patient and strictly enforced the visiting hours. This measure was even stepped up one notch during 29 April–31 May 2003, when no visitors were allowed in all public sector hospitals with the exception of paediatric and obstetric (delivery) cases, who were allowed just one visitor each day. All visitors had to be registered so that they could be traced quickly if necessary.

The Ministry carried out regular audits to ensure compliance with the hygiene, sanitation and infection control practices. The measures were deemed to be effective and sufficient when no more healthcare workers contracted SARS after 13 April 2003.

THE COMMUNITY SETTING

The most important challenge in the fight against SARS was to safeguard public health against spread of any infection in the community. Through various mass media channels, the public were educated to exercise social responsibility if they had fever by seeking proper medical attention instead of going to work or school. Fever checks became the norm and daily temperature taking was instituted in all national schools and public institutions. Private sector workplaces were also encouraged to conduct temperature taking of their employees. In addition, organizers of mass events such as concerts, social functions and recreational activities were encouraged to screen participants for fever prior to admission.

The Emergency Department of Tan Tock Seng Hospital was set up to receive all symptomatic suspects for SARS screening. To ferry these persons to the hospital, the Ministry of Health commissioned a dedicated ambulance service. This provided confidence to the public that the public transport system was not compromised and

remained safe. Further, to prevent the services at the SARS-designated hospital from being overloaded, fever centres with the necessary laboratory and radiological facilities to screen patients who presented with fever were set up in four government polyclinics located across the island.

Besides the early detection of cases in the community, the strategy to ring fence the disease also required rapid and thorough contact tracing and quarantine of all close contacts exposed to a SARS case. These measures are described below.

CONTACT TRACING

When the Singapore health authority mounted resources to institute contact tracing, it established a centre to undertake comprehensive procedures for the identification of all close contacts of probable/suspect SARS cases and observation cases in whom SARS could not be ruled out. The components of contact tracing included: obtaining all patient movements during the symptomatic stage; identifying the persons exposed to these movements; and instituting follow-up on all the close contacts over a 10-day period.

A Trigger Board chaired by the Director of Medical Services decided on the classification and priority of each notified case. The triggers to activate contact tracing covered a broad spectrum of possibilities and relied on a high index of suspicion by physicians. These triggers included: all probable and suspect SARS; atypical pneumonias pending confirmation; fevers >38°C with travel history to SARS-affected area; any cluster of fever cases in a healthcare or stepdown facility; unexplained fevers; death due to pneumonia without identifiable cause; and postmortem findings of respiratory distress syndrome.

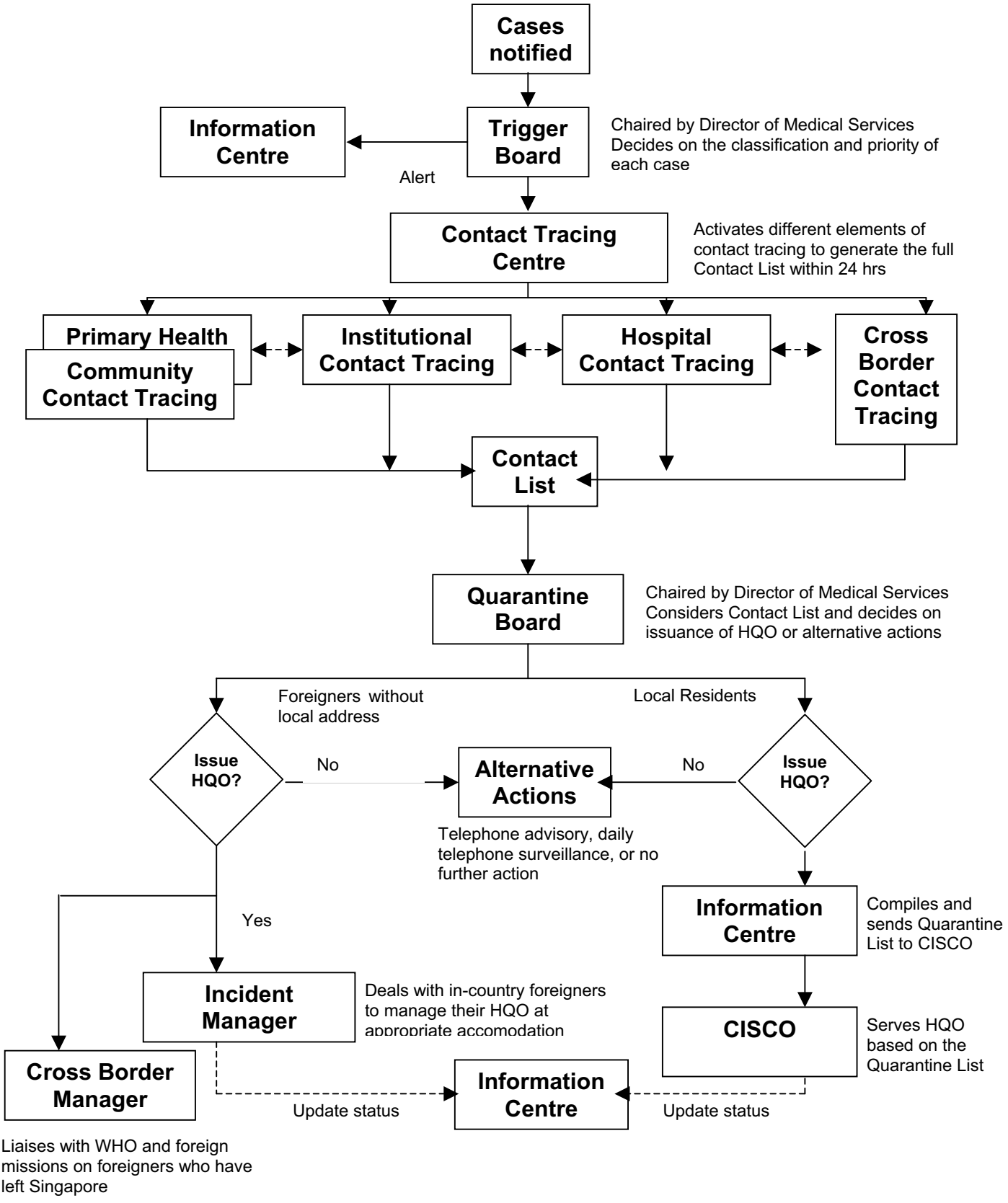
As challenges to contact tracing emerged involving aircraft flights, cruise vessels, hospitals (including a mental hospital), large educational institutions, hostels, factories, markets, food centres, places of worship and public buildings, our experience underscored the importance of maintaining a high level of vigilance and the preparedness to act and adjust strategies. Based on the lessons learned, policies were periodically modified to reduce the numbers that truly warranted monitoring without compromising public health (Olsen *et al.*, 2003).

The management work flow for contact tracing is shown in Figure 1. The contacts involved immediate family members and persons who worked full-time in the household; healthcare workers, patients and visitors exposed in primary health and hospital facilities; and other contacts with more than passing exposure in specific locations. Inherent in the contact tracing operation was the assurance of quarantine, with health checks and careful follow-up of all identified close contacts.

HOME QUARANTINE

The decision to quarantine rested with the Director of Medical Services, assisted by a Quarantine Board that provided advice based on clinical and epidemiological findings. Home quarantine was deemed the most logistically feasible means of quarantine for large numbers of contacts. When MOH invoked the Infectious Diseases Act on 24 March 2003 to impose the home quarantine order (HQO) on persons who had been exposed to SARS and were potentially infectious, it became clear that the existing legislation was inadequate in several areas. On 28 April 2003, the Infectious Diseases Act was amended in Parliament to strengthen the legal provisions for quarantine.

Figure 1 Management work flow for contact tracing.



HQO = Home Quarantine Order
CISCO = a security enforcement agency

Enforcement and surveillance measures were conducted by CISCO police auxiliaries. Singaporeans served with the HQO could choose to be quarantined at home or at a designated quarantine centre as 'temporary home'. Travellers to Singapore served with the HQO could choose to leave Singapore within 24 h so long as they were afebrile, or to remain in Singapore at a designated quarantine centre. The measures came across to the public as hard but necessary. Later, the approach was softened by home visits by Health Promotion Board nurses. During these visits, the nurse would provide health education and a home quarantine kit that included an oral thermometer and a mask.

Persons who were quarantined were given instructions to monitor their temperatures twice daily and to call for the dedicated ambulance service if they were unwell. Quarantined persons were checked daily by telephone to make sure that they were well and did not break quarantine (they had to activate and appear before an electronic picture camera each time they were called). Strict implementation of the quarantine measures gave assurance to the public that safeguards were in place for them to go out and continue with their normal lives.

CASE STUDY AT PASIR PANJANG

The biggest test for disease control occurred when SARS threatened to move into the community from an infected vegetable hawker who worked at the Pasir Panjang Wholesale Market (PPWM). Despite his onset of fever on 5 April 2003, he had worked for a few days in the first week of April before succumbing to the disease. On the evening of 19 April 2003, three more cases associated with PPWM were identified.

The three new cases linked to PPWM had worked in separate areas and it could not be established how the infection spread. The PPWM complex housed some 800 tenanted stalls in 26 blocks which operated round the clock daily, and also included an eating house and a supermarket. Investigation into the movement of each SARS victim showed no direct contact with one another. However, PPWM was designed for easy mingling and efficiency in movement, which could also make for efficient transmission of the virus.

To break the chain of transmission, the market was immediately closed and contact tracing mounted for all persons who had been to the market between 5 and 19 April 2003. Nearly a hundred officers from the Community Centres were mobilized with the assistance of the People's Association that evening to join in the massive exercise. At the same time, an appeal was made through the media for any ill persons who were at the market during the period to seek medical attention at Tan Tock Seng Hospital as they might have come into contact with the three SARS cases.

Over the next 72 h, a total of 1917 persons who frequented the market were identified and comprised 964 tenants and stall holders, 616 employees and workers, 337 regular customers. As a precautionary measure, they were placed under home quarantine by CISCO and monitored for fever until 4 May 2003. When the entire episode unfolded, the PPWM cluster accounted for 12 SARS cases involving three vegetable sellers, two cab drivers and seven family contacts.

The speed of actions in the contact tracing and home quarantine enforcement to prevent community spread of SARS was necessary but caused confusion on the ground. Many stall holders complained of conflicting instructions from different officials and tried hard to skirt the quarantine. CISCO also had problems mustering enough manpower that could communicate in dialect. In addition, the quick removal of tenants from PPWM resulted in some pets and animals serving 'quarantine' in the

stalls. Subsequently, owners, through the use of proxies, were allowed to remove these animals.

The PPWM operations were complex and involved at least eight government agencies, viz. the Housing and Development Board, Agri-Food and Veterinary Authority, Ministry of Health, Ministry of Manpower, Singapore Police Force and National Environment Agency, and a host of secondary agents to safeguard public health, look after foreign workers, and manage the cordon and cleansing operations.

EFFECTIVENESS OF CONTROL MEASURES

It took 11 weeks before the SARS outbreak was finally contained. The last case had onset of illness on 11 May 2003. By then, the outbreak had involved a total of 238 SARS cases, of whom 33(13.9%) died. Nonetheless, disease control efforts had been successful in preventing community-acquired infections.

A single infectious case of SARS is estimated to infect about three secondary cases in a population that has not yet instituted control measures (Lipsitch *et al.*, 2003). Casting the net wide increased the sensitivity of surveillance and ensured that community exposure to potential reservoirs of infection was limited. As a result, 199 (83.6%) of the cases did not transmit the infection to others, contributing to the low number of new cases generated by each case. The period between onset of illness and isolation in hospital was also shortened from over 3 days in the early phase of the outbreak to 1.3 days, reducing by more than half the amount of time infected persons could expose others to the virus. By reducing opportunities for the virus to spread, the outbreak was characterized by nosocomial (hospital-acquired) and intra-household infection.

On 31 May 2003, the World Health Organization took Singapore off the list of countries with local SARS transmission (WHO, 2003).

CONCLUSION

The global infectious diseases situation is changing rapidly today. Our experience highlighted the importance of maintaining a high level of vigilance and also of preparedness to respond to challenges with extraordinary measures. A key lesson was the need to cast the surveillance and control net as wide as possible to reduce opportunities for the virus to spread from potential reservoirs of infection and to shorten the period between onset of symptoms and isolation in hospital. High occupant densities in the built environment can lead to greater transmission potential. As new diseases emerge, we have to rethink the value of quarantine as an old but nonetheless useful tool for disease control.

New tools for disease detection and control are needed to reduce opportunities for spread of infection. A greater understanding of the virus, its survivability under different environmental conditions, and its aerodynamic behaviour that determine airborne transportation and deposition characteristics are key elements in the development and implementation of effective and efficient technologies for its control. The design, operation and maintenance of engineering systems to treat bio-effluent, particularly in hospitals, require understanding of the dispersion of droplets in coughing and sneezing, the environmental factors aggravating super-spreading events, the effect of disinfection, localized extraction and other removal or immunization technologies. The roles of building services engineers, architects and indoor environment experts in the control of respiratory infectious diseases such as SARS have now been challenged beyond their conventional boundaries of professionalism and expertise. Inter-disciplinary collaboration between the medical and public health

community would identify new research directions related to respiratory infectious disease control relevant to building design.

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