Original Article

Epidemiology and Control of SARS in Singapore

Kee-Tai Goh,[1] *MSc (PH), MD, FAMS*, Jeffery Cutter,[2] *MMed (PH), MSc (Epidemiol), FAMS*, Bee-Hoon Heng,[3] *MBBS, MMed (PH), FAMS*, Stefan Ma,[4] *PhD*, Benjamin KW Koh,[5] *MBBS, MPH*, Cynthia Kwok,[2] *MBBS, MMed (PH)*, Cheong-Mui Toh,[6] *MBBS, MMed (PH), FAMS*, Suok-Kai Chew,[4] *MSc (PH), MSc (Epidemiol), FAMS*

Abstract

Severe acute respiratory syndrome (SARS) was imported into Singapore in late February 2003 by a local resident who returned from a holiday in Hong Kong and started an outbreak in the hospital where she was admitted on 1 March 2003. The disease subsequently spread to 4 other healthcare institutions and a vegetable wholesale centre. During the period between March and May 2003, 238 probable SARS cases, including 8 imported cases and 33 deaths, were reported. Transmission within the healthcare and household settings accounted for more than 90% of the cases. Factors contributing to the spread of infection included the failure to recognise the high infectivity of this novel infection, resulting in a delay in isolating initial cases and contacts and the implementation of personal protective measures in healthcare institutions; and the super-spreading events by 5 index cases, including 3 with co-morbid conditions presenting with atypical clinical manifestations of SARS. Key public health measures were directed at prevention and control within the community and hospitals, and the prevention of imported and exported cases. An isolated laboratory-acquired case of SARS was reported on 8 September 2003. Based on the lessons learnt, Singapore has further strengthened its operational readiness and laboratory safety to respond to SARS, avian flu and other emerging diseases.

Ann Acad Med Singapore 2006;35:301-16

Key words: Cross infection, Preparedness plan

Introduction

Since the 1990s, a number of infectious diseases have emerged in Singapore, despite its high standard of environmental hygiene, comprehensive childhood immunisation programme and strict control of imported food and livestock. These emerging diseases include Bengal cholera caused by a new cholera biotype, *Vibrio cholerae* O139,[1] multi-drug-resistant salmonellosis caused by *Salmonella enterica* subsp. *enterica* serotype Typhimurium DT 104 L,[2] norovirus gastroenteritis,[3] Nipah virus disease,[4] meningococcal disease caused by an uncommon serogroup of *Neisseria meningitidis*, W 135[5] and hand, foot and mouth disease caused by enterovirus 71.[6] One major contributing factor in this emergence is the increasing travel and trade within and beyond the region.[7] A high degree of vigilance is maintained over the emerging disease situation in the region and beyond through linkages with international health agencies and regional health authorities.

Severe acute respiratory syndrome (SARS), a novel infection caused by the SARS coronavirus (SARS-CoV),[8] was introduced into Singapore without the knowledge of the health authorities until 5 days after the index case was hospitalised. The index case, A, was a 22-year-old female local resident who reported ill with fever and dry cough on her way home from a "free-and-easy" holiday in Hong Kong on 25 February 2003. She was admitted to Ward 5A,

[1] Communicable Diseases
[2] Communicable Diseases (Policy)
[4] Epidemiology and Disease Control Division
[5] International Strategy
[6] Biomedical Research Regulation, Health Regulation Division
Ministry of Health, Singapore
[3] Health Services and Outcomes Research
Clinical Project Management and Planning Division, National Healthcare Group, Singapore
Address for Reprints: Clinical Assoc Prof Goh Kee Tai, Senior Consultant, Office of the Director of Medical Services, Ministry of Health, College of Medicine Building, 16 College Road, Singapore 169854.
Email: goh_kee_tai@moh.gov.sg

Tan Tock Seng Hospital (TTSH), on 1 March and diagnosed to have atypical pneumonia.[9] Another 2 Singaporeans who had been in Hong Kong at the same time (20 to 25 February) and had been staying in the same hotel (Hotel Metropole) were also hospitalised for atypical pneumonia on 2 March and 3 March, one at TTSH and another at Singapore General Hospital (SGH). The hotel was subsequently found to be the focus of transmission for the global spread of SARS.[10] When the Ministry of Health (MOH) was notified of these cases on 6 March 2003, the hospitals were directed to isolate the patients as a precautionary measure as the World Health Organization (WHO) had reported a hospital outbreak in Hanoi, where several healthcare workers (HCWs) had developed an unusual illness after treating an American-Chinese patient with severe atypical pneumonia.

Materials and Methods

Following the WHO's global alert on 12 March 2003 on the hospital outbreaks of atypical pneumonia in Hong Kong, Hanoi and Guangdong, all healthcare institutions were advised to be vigilant and reminded to notify the MOH of every patient that fulfilled the WHO's case definition of a suspected or probable case of SARS.[11] Epidemiological information obtained for each case included age, gender, ethnicity, nationality, occupation, date of contact with a probable case and onset of illness, travel and movement history, and possible sources of infection in the 10 days prior to onset of illness. The healthcare institutions were also directed to notify contacts of suspected and probable cases.

The clinical and epidemiological features of each suspected or probable case notified to the MOH was reviewed daily by an expert group of senior infectious disease physicians, epidemiologists and virologists chaired by the Director of Medical Services (DMS). The cases included atypical pneumonia under investigation, death due to pneumonia of unknown aetiology or acute respiratory distress syndrome, travellers who developed fever (>38°C) of unknown origin for >72 hours after returning from SARS-affected countries, and febrile patients and HCWs in a fever cluster in a healthcare setting. Contact tracing, initiated within 24 hours of notification of the case, was carried out by trained medical and health officers in hospitals, nursing homes and other healthcare institutions, and in the community, including residential homes, places of work or school, hostels, food centres, markets, places of worship and factories. Following the spread of infection to a wholesale market in April, 200 staff from the People's Association were mobilised and trained on the spot to trace the large number of contacts. On 23 April, 250 army personnel were deployed to the MOH for 2 months to strengthen its operational capability, especially the development of the IT system to support epidemiological investigations, contact tracing and quarantine operations. Contacts included HCWs who had not worn personal protective gear while attending to an undiagnosed case of SARS, family members, visitors to healthcare institutions, school teachers, classmates, workplace colleagues, and commuters in close proximity to a SARS case in the public transport system (taxi, bus, train, ship, aeroplane). These contacts were assessed on their risk of exposure to SARS. Those who were febrile were immediately transported by a delegated ambulance service to TTSH, the designated SARS hospital. Contacts who were apparently well were quarantined for 10 days either at home or at a specific quarantine centre, where their temperatures were monitored twice daily for early signs of SARS. Any person who developed a fever (>38°C) during the quarantine period was isolated at TTSH for further investigations. As a precautionary measure, contacts assessed to have a low risk of exposure (e.g., inpatients with no chronic co-morbid conditions discharged from TTSH) were not quarantined but put on daily telephone surveillance for SARS symptoms for 21 days by a team of 100 health staff.

Attempts were made to epidemiologically link the reported probable cases with one another by person, place and time. The chain of transmission chart was constructed based on the initial WHO case definition for a probable case.

When laboratory tests for SARS-CoV became available, the WHO case definition for SARS was revised on 1 May 2003.[12] Locally validated assays for SARS-CoV by reverse-transcriptase polymerase chain reaction (RT-PCR) (available on the first week of April) and serology (available on the first week of May) were used for all suspected and probable cases as well as for cases under observation in whom SARS could not be excluded. Samples collected from suspect cases and cases under observation were subsequently tested during the post-outbreak period.

Results

Epidemiological Features

A total of 206 probable SARS cases, including 8 imported cases, with onset of illness between 25 February and 11 May 2003, were reported. Of these, 58 cases were detected among 12,194 persons who had previously been on home quarantine (7863) or under telephone surveillance (4331). Of 600 clinically suspected cases admitted to TTSH who had had laboratory tests conducted during the post-outbreak period, an additional 32 probable cases were picked up, giving the final figure of 238 probable cases, including 33 deaths. None of the 700 cases admitted for observation tested positive.

The demographic characteristics of the reported cases and deaths are shown in Table 1. The majority (79.4%)

Table 1. Demographic Characteristics of 238 Cases of SARS, including 33 Deaths, in Singapore, March to May 2003

Characteristics	Gender		Total	%
	Male	Female		
Age group (y)				
0-4	2 (0)	3 (0)	5 (0)	2.1
5-14	0 (0)	5 (0)	5 (0)	2.1
15-24	8 (1)	29 (0)	37(1)	15.5
25-34	13 (2)	53 (2)	66 (4)	27.7
35-44	21 (4)	24 (1)	45 (5)	18.9
45-54	11 (2)	22 (5)	33 (7)	13.9
55-64	11 (4)	14 (2)	25 (6)	10.5
65+	11 (6)	11 (4)	22 (10)	9.2
Nationality				
Singaporean	123 (17)	66 (14)	189 (31)	79.4
Filipino	17 (1)	5 (0)	22 (1)	9.2
Chinese	7 (0)	3 (0)	10 (0)	4.2
Indonesian	6 (0)	1 (0)	7 (0)	2.9
Malaysian	6 (0)	1 (0)	7 (0)	2.9
Indian	4 (1)	1 (0)	5 (1)	2.1
Sri Lankan	4 (0)	0 (0)	4 (0)	1.7
	0 (0)	1 (0)	1 (0)	0.4
Ethnic group (Singaporean)				
Chinese	85 (15)	53 (9)	138 (24)	73.0
Malay	21 (0)	4 (3)	25 (3)	13.2
Indian	14 (2)	8 (2)	22 (4)	11.6
Other	3 (0)	1 (0)	4 (0)	2.1
Occupational group				
HCW	13 (3)	84 (2)	97 (5)	40.8
Non-HCW*	64 (16)	77 (12)	141 (28)	59.2
Source of infection				
Imported	1 (0)	7 (1)	8 (1)	3.4
Healthcare institution	50 (16)	125 (8)	175 (24)	73.5
Household	17 (1)	24 (5)	41 (6)	17.2
Community/Workplace†	6 (2)	2 (0)	8 (2)	3.4
Undefined	3 (0)	3 (0)	6 (0)	2.5
Total	77 (19)	161 (14)	238 (33)	100

HCW: health care worker

* Family members, friends or visitors (37.4%), inpatients (13%), others (8.8%)

† Wholesale market (3), taxi (3) and aeroplane (1)

Death cases indicated in brackets

were Singaporeans, and 67.6% were females. About half (46.6%) of the cases were in the 25 years to 44 years age group. The ethnic distribution among the Singaporean cases was proportionate to that of the population of Singapore. HCWs constituted 40.8%; family members, friends, social contacts and visitors, 37.4%; and inpatients, 13%. Transmission within healthcare and household settings accounted for over 90% of the cases. The case-fatality rate (CFR) increased with age from 2.7% in the 15 years to 24 years age group to 45.5% in those 65 years and above. The overall CFR was 13.9%.

The median incubation period was determined based on the records of 50 SARS cases who had a single and specific close contact history, prior to onset of illness, with a person who had been diagnosed with probable SARS. Of these, 15 were hospital visitors, 20 HCWs and 15 family and social contacts. The median age was 42 years (range, 22 to 84) and 56% were females. The mean (SD) and median incubation periods were estimated to be 5.1 (2.2) days and 5 days, respectively. The 95th percentile incubation period was 9 days. All were within the 10-day period between exposure and onset of illness.[13]

Chain of Transmission

Outbreak at TTSH: Before the index case A was isolated on 6 March 2003 and subsequently diagnosed to have probable SARS on 15 March, she had already infected 22 persons, comprising 10 HCWs, 2 inpatients, 7 visitors and 3 family members. One of the infected HCWs (index case B), with onset of symptoms on 7 March and provisionally diagnosed to have dengue fever, was later admitted on 10 March to Ward 8A. At the ward, she in turn infected 21 persons, including an inpatient with ischaemic heart disease and diabetes mellitus, before she was isolated on 13 March. The inpatient (index case C) had been admitted on 10 March with fever, community-acquired pneumonia and gram-negative bacteraemia. When she developed heart failure on 12 March, she was transferred to Ward 6A (coronary care unit) and mechanically ventilated. However, she was only isolated on 20 March, when SARS was suspected. By that time, 21 HCWs and 5 family members had become infected. A total of 109 cases were epidemiologically linked to the index case A before intra-hospital transmission was interrupted by the date of onset of the last case on 12 April. The cases epidemiologically linked to these 3 index cases are shown in Figures 1, 2 and 3, respectively. Despite the institution of very rigorous infection control measures at TTSH, the disease spread to 4 other healthcare institutions and a vegetable wholesale market.[14]

Outbreak at SGH: The index case D was a 60-year-old ex-patient of TTSH, with multiple medical problems, including ischaemic heart disease and diabetes mellitus with kidney damage. He was admitted on 5 March to Ward 5A (the same ward as index case A), TTSH, and discharged on 20 March with no clinical manifestations of SARS. He was readmitted to an open ward (Ward 57), SGH, on 24 March for steroid-induced gastrointestinal bleeding and a diabetic foot ulcer.[15,16] Although he had had a low-grade

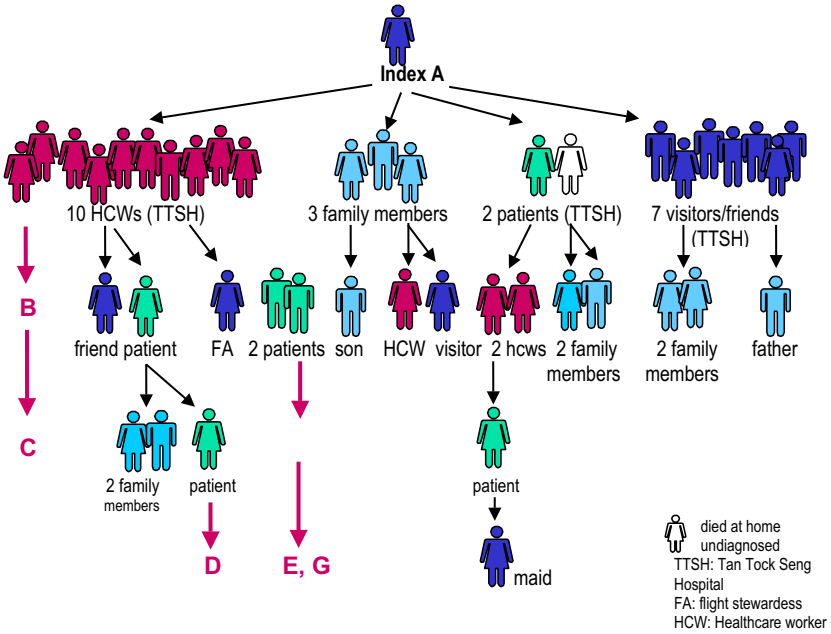


Fig. 1. Chain of transmission of index case A (imported case), Tan Tock Seng Hospital (TTSH).

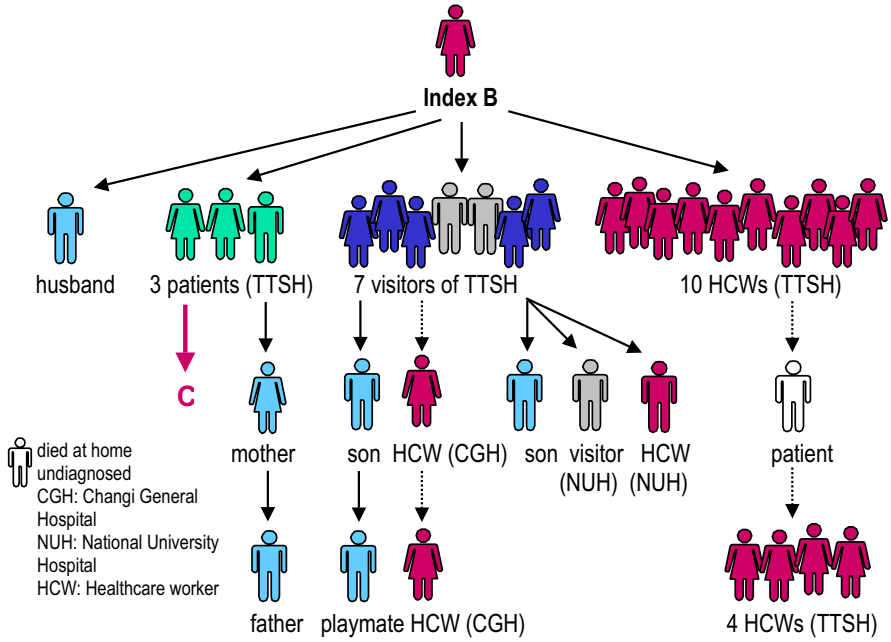


Fig. 2. Chain of transmission of index case B (healthcare worker), Tan Tock Seng Hospital (TTSH).

fever since 26 March, after admission to SGH, 4 consecutive chest x-rays were normal. His blood culture grew *E. coli*.[17] He was transferred to another open ward (Ward 58) from 29 March to 2 April. On 4 April, a cluster of 13 febrile HCWs from the 2 wards where he was admitted was identified. It was only on 5 April when chest x-ray showed evidence of pneumonia that he was clinically diagnosed as a probable SARS case. A total of 40 cases were directly linked to him with the date of onset of the last probable case on 17 April (Fig. 4). All the exposed HCWs and inpatients were transferred to TTSH, where 8 subsequently developed probable SARS.

Outbreak at National University Hospital (NUH): The index case E at NUH was a 63-year-old man with a history of hypertension, ischaemic heart disease and chronic atrial fibrillation. He was infected when he visited his brother, the index case D at SGH, on 31 March. He developed a fever on 5 April, was seen at the A&E department, NUH, on 8 April and was admitted 4 hours later to an open ward for cardiac failure.[18,19] When his condition deteriorated rapidly

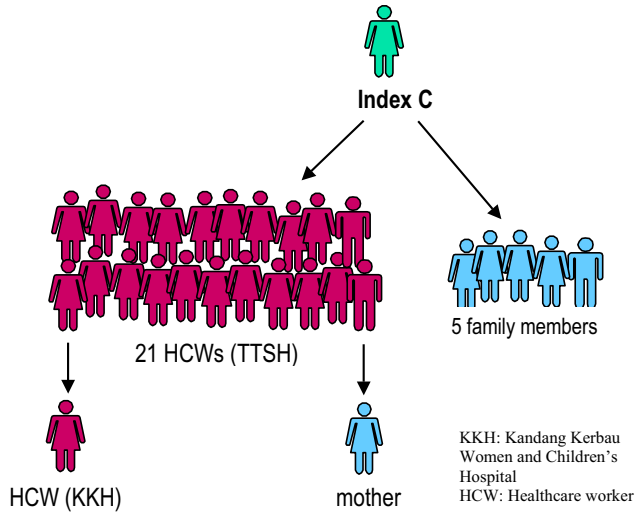


Fig. 3. Chain of transmission of index case C (inpatient), Tan Tock Seng Hospital (TTSH).

in the next 8 hours, he was isolated in the intensive care unit (ICU). As soon as SARS was suspected, the patient was immediately transferred to TTSH, where he died on 12 April. A total of 15 SARS cases at NUH were epidemiologically linked to him, with the date of onset of the last case being 25 April (Fig. 5).

Outbreak at Orange Valley Nursing Home/Changi General Hospital: A 90-year-old woman (index case F) with pneumonia and urinary tract infection, who had been warded next to a SARS patient in Ward 7D in TTSH from 16 to17 March, was discharged to a private nursing home (Orange Valley Nursing Home) and then admitted to Changi General Hospital (CGH) on 25 March when she subsequently fell ill again with breathing difficulty.[20] This led to a small cluster of 7 cases linked to the nursing home and CGH (Fig. 6). The dates of onset of the last case at the nursing home and CGH were 2 April and 4 April, respectively.

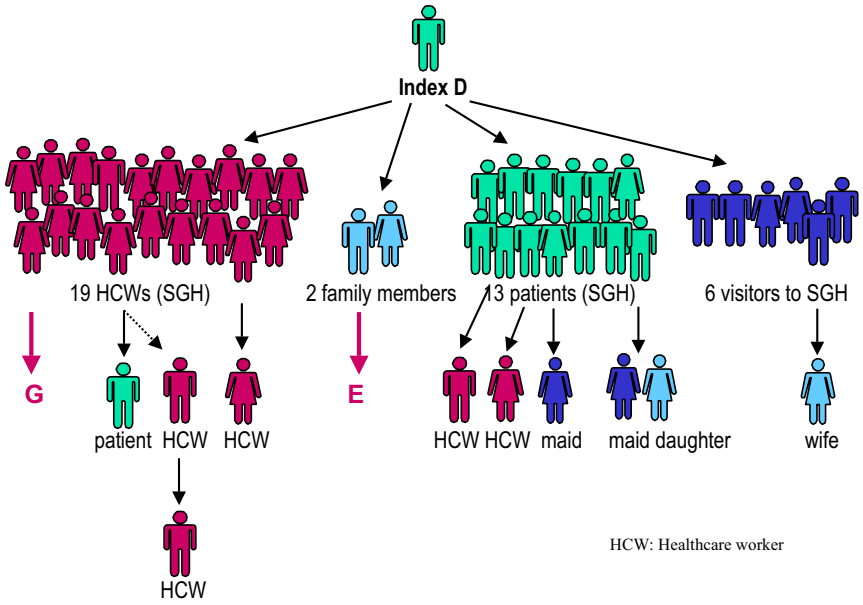


Fig. 4. Chain of transmission of index case D, Singapore General Hospital (SGH).

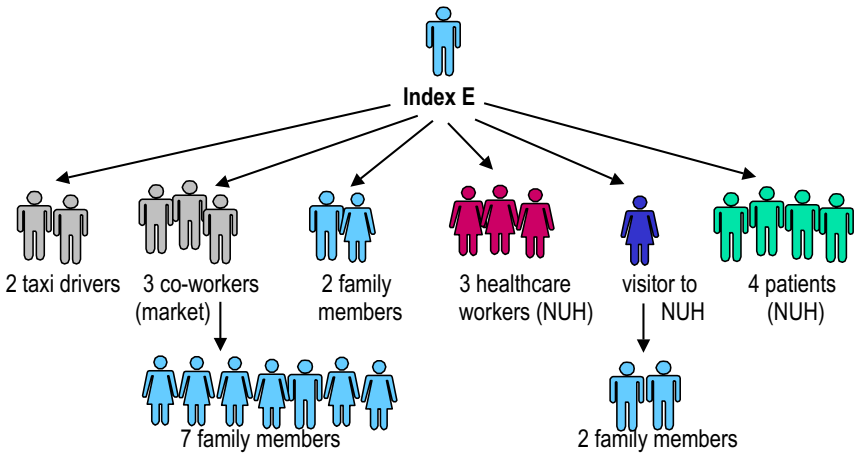


Fig. 5. Chain of transmission of index case E, National University Hospital (NUH)/Pasir Panjang vegetable wholesale centre.

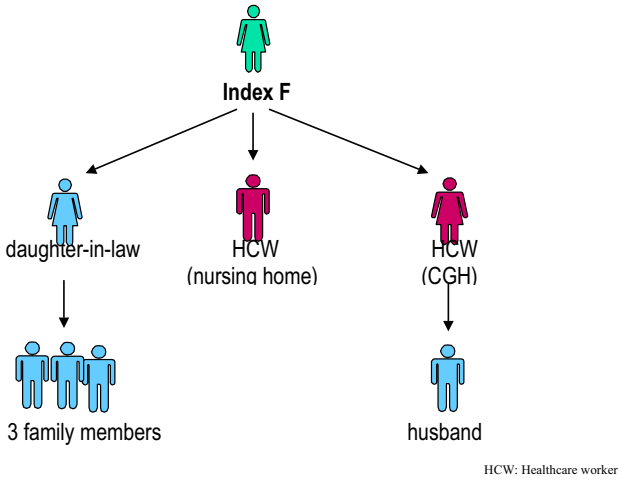


Fig. 6. Chain of transmission of index case F, Orange Valley Nursing Home/ Changi General Hospital (CGH).

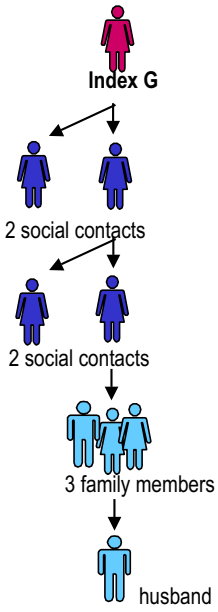


Fig. 7. Chain of transmission of index case G (healthcare worker), Singapore General Hospital (SGH).

Community outbreaks: The index case E at NUH worked as a vegetable seller at the Pasir Panjang wholesale market. He had worked there for a few hours each day on 5 April, 7 April and 8 April. It was only on 19 April that another 2 SARS cases (a taxi driver who transported him to work and another worker at the market) were epidemiologically linked to the market. He started a cluster of 12 cases, including 8 in a family linked to this centre (Fig. 6). Another cluster of 8 cases in the community was started by a febrile HCW (index case G) at SGH who had been given

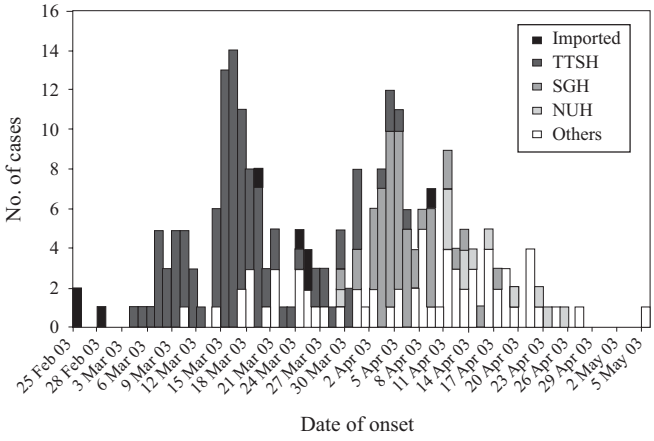
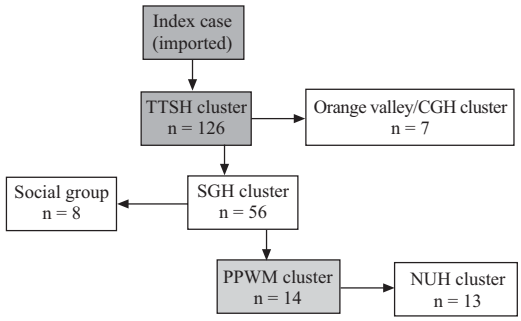


Fig. 8. Epidemic curve of 238 reported cases of SARS, March-May 2003



CGH: Changi General Hospital
NUH: National University Hospital
PPWM: Pasir Panjang Wholesale Market
TTSH: Tan Tock Seng Hospital

Fig. 9. Chain of transmission of 238 probable cases of SARS from an imported case to 3 hospitals, 1 nursing home, 1 social group and 1 wholesale market in Singapore, March-May 2003.*
*6 unclassified and 7 imported cases not shown

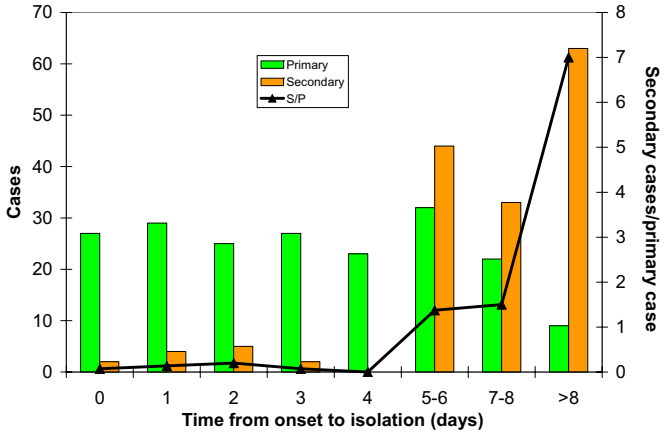


Fig. 10. Number of primary cases (green) by time from symptom onset to isolation, number of secondary cases infected by such cases (orange) and mean number of secondary cases per primary case
(Figure reproduced with permission from Science 2003;300:1966-70).

medical leave to stay at home. Transmission occurred through social contact in a Chinese card game (Fig. 7).

There were 2 local cases whose sources of infection could not be determined despite intensive epidemiological investigations. Three of the 32 probable cases retrospectively diagnosed to have SARS could not be linked to any of the clusters. The epidemic curve of the SARS outbreak and the chain of transmission are shown in Figures 8 and 9, respectively.

The last probable SARS patient with onset of illness on 5 May was isolated at TTSH on 11 May. Singapore was removed from the WHO's list of areas with local SARS transmission on 31 May. However, intensive case findings continued, particularly for patients with chronic medical conditions and with atypical clinical manifestations. They were subjected to repeated SARS-CoV testings prior to discharge from hospital. In view of the improved global and local situation, SARS prevention and control measures were progressively stepped down from mid-July 2003 (Appendix). Unfortunately, a probable case of SARS was diagnosed by SGH on 8 September 2003.

A Laboratory-acquired Case

The patient was a 27-year-old Chinese Singaporean in the third year of a doctoral programme in microbiology at the National University of Singapore (NUS). He had been working on the West Nile virus at a microbiology laboratory at NUS. He had also done some work at the Environmental Health Institute (EHI) laboratory of the National Environment Agency. He had last visited the EHI laboratory on 23 August. He had no history of travel to previously SARS-affected areas and no known contact with SARS patients.

His date of onset of illness was 26 August. When he was admitted to SGH on 3 September, he complained of fever, muscle aches and joint pains, but he did not have any significant respiratory symptoms. He developed a dry cough after admission, but his fever resolved 2 days later. Three serial chest X-rays done at SGH were all normal. On 8 September, his stool and sputum specimens tested positive for SARS-CoV by RT-PCR. Three serial serological tests done on 3 September, 4 September and 8 September showed a rising titre of SARS-CoV antibodies. He was immediately transferred to the Communicable Disease Centre, TTSH, for further management.

A repeat of his PCR tests in 2 other laboratories in Singapore on 9 September were confirmed positive. His blood samples also tested positive for antibodies to SARS-CoV in another laboratory in Singapore. The results from the Centers for Disease Control, Atlanta, corroborated with Singapore's PCR and serological results. Subsequent investigations of the chest on 13 September showed that he had radiological evidence of pneumonic changes in his left lung. Tests for a whole range of other pathogens, including 2 human coronaviruses (OC 43, 229 E), were negative. The patient was discharged on 16 September and placed on a 14-day home quarantine.

Investigations by an 11-member review panel, comprising local and international experts, showed that the patient had worked in the EHI laboratory 3.5 days before his onset of illness. Although the patient reported only working on the West Nile virus, the laboratory was doing live SARS-CoV work around that time. Poor record-keeping made it difficult to ascertain if there had been live SARS-CoV in the laboratory on the day of his visit, but it had been present 2 days before. Testing of the frozen specimen that the patient had worked with on 23 August was positive by RT-PCR for the SARS-CoV and West Nile virus, suggesting contamination. As the laboratory had only worked on one strain of the SARS-CoV, the laboratory strain and the patient strain were sequenced for comparison. Approximately 91% of the genome was sequenced from the patient's strain and it was found to be most closely related to the sequence of the laboratory strain. Minor differences were likely to be the results of the natural mutations of the virus.[21]

Prevention and Control

Prevention and control measures were initiated by the MOH SARS Task Force, which was formed on 15 March 2003 and chaired by the DMS. Its members included the chief executive officers of all hospitals, chairmen of medical boards, infectious disease physicians, epidemiologists and virologists. Strategies to contain the rapid nosocomial transmission were discussed, formulated and effectively implemented across all healthcare institutions through the Infectious Diseases Act and Private Hospitals and Medical Clinics Act. The Ministerial Committee on SARS (chaired by the Minister for Home Affairs) was established on 7 April to provide political guidance and quick strategic decisions to minimise the socioeconomic impact of SARS. The Executive Group, comprising permanent secretaries of the relevant ministries, was responsible for the overall coordination and implementation of multi-agency issues outside the healthcare setting, while an Inter-Ministry SARS Operations Committee ensured that cross-ministry operational issues on SARS were well coordinated. A Ministerial SARS Combat Unit was also appointed on 20 April; 3 of its members were medical doctors. It worked closely with the public and private hospitals and other healthcare institutions to prevent and control SARS transmission in these facilities. Key measures implemented in Singapore were directed at the prevention and control of SARS in the community, healthcare institutions and the borders.

Community

In the prevention and control of SARS within the community in Singapore, the key strategy was to detect persons with suspected or probable SARS as early as possible and isolate them in TTSH. At the same time, the Infectious Diseases Act was reviewed and amended to ensure that all necessary public health measures could be taken to control the outbreak; e.g., handling and disposal of bodies due to SARS within 24 hours of death. Early identification of SARS cases was done through several ways, including active contact tracing for all contacts within 24 hours of notification of a case, mandatory home quarantine enforced through the use of electronic cameras, and intensive education of healthcare professionals and the public. The effectiveness of these strategies was reflected in the fact that in the week of 3 to 9 March, the average interval between the onset of symptoms and isolation in hospital was 6.8 days. The interval was reduced to 2.9 days for the week of 31 March to 6 April and 1.3 days for the week of 21 to 27 April.

The Pasir Panjang wholesale market was closed for 15 days from 19 April, and a total of 2007 workers and regular visitors to the market from 5 to 19 April were put on mandatory home quarantine. Teams of nurses visited all those under quarantine to check their temperatures and to ensure that they were well. The infection did not spread to other wet markets. To allay the concern of parents, all preschools, primary and secondary schools were closed for 2 to 3 weeks at the end of March to early and mid-April 2003.

Healthcare Institutions

The MOH implemented very stringent infection control procedures to prevent and contain outbreaks in hospitals, nursing homes and other healthcare institutions. At the first point of contact with healthcare facilities [accident and emergency (A&E) departments, specialists outpatient clinics], triage was carried out to separate out febrile patients. To widen the surveillance net, the WHO's definition for suspected and probable SARS was expanded to include any HCW with fever and/or respiratory symptoms (particularly in a cluster of 3 or more febrile cases), inpatients (>16 years old) with atypical pneumonia under investigation, sudden unexplained deaths with respiratory symptoms, and inpatients with fever (>38°C) of more than 72 hours and with relevant travel history but without known causes. Case finding was further intensified with the introduction of thrice-daily temperature surveillance of all HCWs in every institution and active surveillance for clusters of febrile patients, especially among the immunocompromised, who tend to have atypical clinical presentations, and staff from the same work area. Sick leave of HCWs was centrally monitored. Audits were periodically conducted to ensure that the directives and guidelines issued by the MOH were strictly enforced.

Three separate hospital containment strategies were implemented. In the case of TTSH, it was designated as a SARS hospital and non-SARS patients were diverted to other hospitals.[14] As for SGH, the strategy was ring fencing and transfer of the exposed group (patients and HCWs) to the designated SARS hospital.[16] In the case of NUH, the strategy was management of the exposed cohort in situ. These containment strategies were supported by strict enforcement of the proper use of personal protective equipment (PPE) (test-fitted N95 mask, gowns, gloves and goggles/protective eye gear if managing suspicious cases, and powered air purified respirator for high-risk procedures such as intubation), control of visitors, restriction of movements of HCWs (including confining their practice to one institution) and patients (readmission to the same hospital within 21 days after discharge), and close monitoring of discharged patients from SARS-affected wards. In view of the risk posed by atypical SARS cases, all inpatients with chronic medical conditions at TTSH and SGH were placed on home quarantine for 10 days upon discharge.

Intra-hospital transmission of SARS was successfully contained and the risk of HCWs transmitting the infection to their family and the community was minimised. The last date on which an HCW was infected with the SARS-CoV was 13 April 2003.

Border Checkpoints

In addition to issuing a health alert advising travellers to avoid SARS-affected countries, unless absolutely necessary, on 14 March the MOH took various measures to minimise the risk of imported cases. These measures were implemented in phases. On 30 March, health alert notices were issued at the airport to inbound air passengers from SARS-affected countries to highlight the signs and symptoms of SARS and the need to seek immediate attention if fever developed. Health screening of all incoming air and sea passengers and crew from affected areas was carried out through temperature checks using thermal imaging scanners.[22] Travellers picked up by the scanners had their temperature re-checked by nurses who would refer them for further examination by doctors at the air and sea terminals if they were confirmed to have a fever. Those who were suspected of having SARS were referred to TTSH for further assessment and admission for isolation and treatment if necessary. Incoming bus passengers at the land checkpoints were also screened with the thermal scanners. Screening was progressively extended to travellers coming in via other vehicles at the land checkpoints. All visitors to Singapore through air, sea and land checkpoints were required to complete a SARS health declaration card to

facilitate contact tracing. However, not a single case of SARS was detected through these measures.[23]

Very stringent steps were taken to minimise the possibility of exporting cases to other countries. These measures included the rapid containment of outbreaks in Singapore, and mandatory temperature screening of all outgoing travellers from Singapore. In addition, special bilateral arrangements on the exchange of information necessary to conduct contact tracing and quarantine was set up with Malaysia and Indonesia. Singapore also initiated a similar multi-lateral agreement among the 10 member countries of ASEAN, plus China, Japan and the Republic of Korea (ASEAN+3), in view of the possible spread of infection by travellers.

None of the hundreds of suspected cases among travellers who had visited Singapore were known to have acquired the infection in the country after the implementation of the border health checks. There was a Singaporean infectious disease physician who had treated index case A from 1 to 8 March 2003 and subsequently travelled to New York for a conference. He sought treatment in a private clinic there when he developed a fever, and his chest X-ray showed evidence of pneumonia. When the MOH was informed by TTSH on 15 March that the physician was on a flight back to Singapore via Frankfurt, the German health authorities were immediately alerted through the WHO.

Based on the recommendations of the review panel appointed by the MOH to investigate the laboratory-acquired case of SARS, steps have been taken to implement the biosafety requirements and practices at the laboratories, including training, adoption of national standards, audit and accreditation for biosafety.

Discussion

The outbreak of SARS was unprecedented in causing massive socioeconomic disruptions. It exposed the weaknesses of the epidemiological surveillance and healthcare system for emerging diseases which are spread from person to person by the respiratory route. The outbreak evolved very rapidly and unexpectedly. In the early phase of the outbreak, the aetiological agent and its infectiousness were unknown, there were no diagnostic tests for this novel disease, and not much was known of the spectrum of clinical manifestations.[24] Containment measures implemented were mainly empirical, based on the limited clinical and epidemiological information available. The public health system was not geared for such an epidemic and there were no established operational procedures to deal with such a problem in the healthcare facilities. There was insufficient experienced staff to undertake epidemiological investigation and contact tracing. PPE was in short supply and stringent infection control measures, including the restriction of visitors and the movement of patients and HCWs, were not enforced in the clinical areas of all healthcare institutions, except in TTSH, until 8 April. Mathematical modelling showed that the earlier the patient was isolated, the fewer the number of secondary cases generated (Fig. 10).[25]

Several factors had contributed to the rapid transmission of SARS within hospitals and across healthcare institutions. Delay in recognition and isolation of the index cases in TTSH, SGH and NUH was responsible for the intra-hospital transmission. When the index case in TTSH was admitted on 1 March, it was thought to be a case of avian influenza, which is not known to be transmitted from person to person. (The WHO had on 19 February issued an alert of an outbreak in Hong Kong.) Moreover, none of the members of a Singapore-based medical evacuation company deployed to transfer an American-Chinese with pneumonia from Hanoi to Hong Kong on 5 March developed clinical illness. By the time the term SARS was coined by the WHO on 15 March, and the MOH SARS Task Force was formed, 13 cases (including 7 HCWs) had been reported and the index case A had already spread the infection to more than 69 hospital contacts (who were in the incubation period at that time). Patients with co-morbidity presenting with atypical clinical manifestations were transferred from one ward to another, and by the time SARS was suspected and the patient isolated, transmission to their close contacts had already occurred. The index case of SGH was an ex-patient of TTSH with multiple medical conditions. SARS was only suspected when a cluster of fever cases was detected among HCWs who had had contact with the patient. The index case at NUH did not give a contact history when seen at the A&E department.[26] Super-spreading events by 5 patients, including the 3 index cases at TTSH, SGH and NUH, accounted for more than half the cases. Fortunately, 80% of the cases did not transmit the infection to their contacts.[27] The laboratory-acquired case of SARS was due to inappropriate laboratory standards, non-compliance in laboratory procedures and an accidental cross-contamination.

The rapid containment of the outbreak was due to the strong political leadership, effective command, control and coordination at all levels, prompt and coordinated inter-agency response, high level of professionalism and dedication of HCWs, and strong community support.[28,29] Collaboration with international agencies such as the WHO and the US Centers for Disease Control and Prevention, whose experts worked hand-in-hand with the Singaporean counterparts right from the beginning of the outbreak, also contributed to this success.

Based on the lessons learnt, Singapore has further strengthened its operational readiness and laboratory safety

to respond to SARS. A number of measures have been put in place. A contact tracing centre has been established to undertake community contact tracing as well as coordinate and assist in the contact tracing efforts undertaken by the hospitals and government agencies. All matters related to the conduct of quarantine operations, e.g., issuing and enforcement of home quarantine orders (HQOs), phone surveillance, ambulance services, allowances, and alternative housing facilities for those on HQOs will be centrally managed. A new SARS IT infrastructure has been developed and consolidated to support the surveillance and management of SARS. It provides the MOH and other agencies with the ability to access integrated information of all SARS cases in Singapore in a timely fashion. For medical surveillance, there is the Infectious Disease Alert and Clinical Database System, which integrates critical clinical, laboratory and contact tracing information on SARS. In addition, the Health Check System enables healthcare professionals in hospitals and clinics to identify patients who may have been exposed to SARS. For contact tracing and quarantine operations, the Contact Tracing System is in place to capture SARS cases, contact history and HQO status. This will facilitate speedier generation of the HQO reports, contact listings, and listings for external agencies automatically. An e-Quarantine Management System (eQMS) has also been developed for better management in the processing and enforcement of HQOs by a Singapore security agency.

The MOH was reorganised with the incorporation of an Operations Group, which serves as the main operational linkage between the MOH and all healthcare providers. It is responsible for the prevention and control of outbreaks of major infectious diseases, including bioterrorism events; planning for crisis management and the coordination of health services and operations during peacetime; and command and control of all medical resources during a crisis. A three-pronged strategy comprising the establishment of the disease outbreak and response system, the strengthening of the public health system, and the development of national biosafety standards was formulated. The surveillance and analysis capacity has been enhanced, a command and communication network has been put in place, contingency plans for all healthcare institutions and agencies have been developed and coordinated, preparedness exercises and audits are periodically conducted, and emergency procurement and stockpiling of critical medical supplies such as PPE for up to 6 months have been established. Professional manpower has been reviewed and additional isolation facilities in all hospitals, including Communicable Disease Centre 2, with 39 isolation and 18 intensive care beds, have been built. A national centre for infectious diseases and emergency preparedness is being reviewed. Legislative framework for biosafety, including the licensing of BSL-3 laboratories, has been finalised.

A 3-level SARS response framework which corresponds to the existing level of local transmission of SARS and severity of threat to public health has been formalised and serves as a platform for coordinating the response measures for the various agencies. There are 3 colour-coded alert statuses, which have also been adopted by the hospitals – yellow (no or sporadic imported cases but with no local transmission); orange (local transmission confined to close contacts in healthcare settings or households); and red (outbreak in the community where local transmissions are no longer confined to close contacts in healthcare settings or households).

At SARS alert level yellow, the main focus is to prevent imported cases and detect SARS cases early. Active surveillance and enhanced protection at high-risk areas in the healthcare settings underpin the prevention strategy. At the borders, temperature screening of inbound visitors will be instituted at all entry points. Within the healthcare settings, active surveillance for atypical pneumonia as well as fever clusters will be carried out. For prevention, HCWs in high-risk areas such as A&E departments, isolation facilities, ICUs and triaging areas will be required to don full PPE. Workflow changes to separate febrile and non-febrile patients at hospitals and healthcare institutions will be enforced. To reduce the prevalence of acute respiratory viral infections due to influenza, HCWs and those travelling to temperate countries were encouraged to receive influenza vaccination. Mandatory influenza vaccination is also given to long-staying patients in nursing homes.

Moving up to alert level orange, the focus is to contain. Additional measures will be introduced with the aim of containing the spread of SARS in Singapore as well as to prevent the export of cases. Infection control measures in healthcare institutions will be enhanced to break the chain of transmission. This will include the restriction of hospital visitation and the movement of HCWs and patients between healthcare institutions. Contact tracing and quarantine efforts will be stepped up. Community surveillance through daily temperature taking at workplaces and schools will also be instituted. Outbound screening and "not-to-depart" measures will be implemented at the border checkpoints to prevent the export of cases. Health declaration will also be implemented for inbound travellers.

At alert level red, the strategy is to suppress. More measures will be added with the aim of gaining control of community spread in Singapore and preventing the export of cases. These could include the selective closure of schools, foreign workers' dormitories, factories and places

of mass gathering and the suspension of selected public events. Contact tracing and quarantine measures will be strictly enforced.

The robustness of the system was demonstrated in the early detection, isolation and contact tracing of all contacts in the workplace, healthcare setting and the community when the laboratory-acquired SARS case was diagnosed in September 2003.

Singapore is now better prepared to respond to the re-emergence of SARS and other emerging infectious diseases spread by the respiratory route. An avian influenza/influenza pandemic preparedness plan was developed from the SARS response framework to prevent and control this impending health emergency.

REFERENCES

1. Tay L, Goh KT, Lim YS. Vibrio cholerae 0139 'Bengal' in Singapore. J Trop Med Hyg 1994;97:317-20.
2. Ling ML, Goh KT, Wang GCY, Neo KS, Chua LT. An outbreak of multidrug-resistant *Salmonella enterica* subsp. *enterica* serotype Typhimurium, DT 104 L linked to dried anchovy in Singapore. Epidemiol Infect 2002;128:1-5.
3. Ng TL, Chan PP, Phua TH, Loh JP, Yip R, Wong C, et al. Oyster-associated outbreak of Norovirus gastroenteritis in Singapore. J Infect 2005;51:413-8.
4. Chan KP, Rollin PE, Ksiazek TG, Leo YS, Goh KT, Paton NI, et al. Survey of Nipah virus infection among various risk groups in Singapore. Epidemiol Infect 2002;128:93-8.
5. Wilder-Smith A, Goh KT, Barkham T, Paton NI. Hajj-associated outbreak strain of *Neisseria meningitidis* serogroup W 135: estimates of the attack rate in a defined population and the risk of invasive disease developing in carriers. Clin Infect Dis 2003;36:679-83.
6. Chan KP, Goh KT, Chong CY, Teo ES, Lau G, Ling AE. Epidemic hand, foot and mouth disease caused by human enterovirus 71, Singapore. Emerg Infect Dis 2003;9:78-85.
7. Wong SY, Goh KT. Emerging infections: why we must be concerned. Ann Acad Med Singapore 1997;26:535-7.
8. Ksiazek TG, Erdman D, Goldsmith CS, Zaki SR, Peret T, Emery S, et al. A novel coronavirus associated with severe acute respiratory syndrome. N Engl J Med 2003;348:1953-66.
9. Hsu LY, Lee CC, Green JA, Ang B, Paton NT, Lee L, et al. Severe acute respiratory syndrome (SARS) in Singapore: clinical features of index patient and initial contacts. Emerg Infect Dis 2003;9:713-7.
10. Centers for Disease Control and Prevention. Update: outbreak of severe acute respiratory syndrome – worldwide, 2003. MMWR Morb Mortal Wkly Rec 2003;52:269-72.
11. World Health Organization. Case definition for surveillance of severe acute respiratory syndrome (SARS). Available at: http://www.who.int/crs/sars/casedefinition/en/. Accessed 2 February 2006.
12. World Health Organization. Case definition for surveillance of severe acute respiratory syndrome (SARS) (Revised 1 May 2003). Available at: http://www.who.int/crs/sars/casedefinition/en/. Accessed 2 February 2006.
13. Kuk AYC, Ma S. The estimation of SARS incubation distribution from serial interval data using a convolution likelihood. Stat Med 2005;24:2525-37.
14. Gopalakrishna G, Choo P, Leo YS, Tay BK, Lim YT, Khan AS, et al. SARS transmission and hospital containment. Emerg Infect Dis 2004;10:395-400.
15. Ong YY. SARS – lessons from two Singapore General Hospital cases. Singapore Med J 2003;44:420-2.
16. Chow KY, Lee CE, Ling ML, Heng DM, Yap SG. Outbreak of severe acute respiratory syndrome in a tertiary hospital in Singapore, linked to an index patient with atypical presentation: epidemiological study. BMJ 2004;328:195-8.
17. Tan TT, Tan BH, Kurup A, Oon LL, Heng D, Thoe SY, et al. Atypical SARS and *Escherichia coli* bacteremia. Emerg Infect Dis 2004;10:349-52.
18. Ooi SS, Tambyah PA. Transmission of severe acute respiratory syndrome in an emergency department. Am J Med 2004;116:486-9.
19. Fisher DA, Chew MH, Lim YT, Tambyah PA. Preventing local transmission of SARS: lessons from Singapore. Med J Aust 2003;178:555-8.
20. Tee AK, Oh HM, Lien CT, Narendran K, Heng BH, Ling AE. Atypical SARS in geriatric patient. Emerg Infect Dis 2004;10:261-4.
21. Lim PL, Kurup A, Gopalakrishna G, Chan KP, Wong CW, Ng LC, et al. Laboratory-acquired severe acute respiratory syndrome. N Engl J Med 2004;350:1740-5.
22. Wilder-Smith A, Paton NI, Goh KT. Experience of severe acute respiratory syndrome in Singapore: importation of cases, and defense strategies at the airport. J Travel Med 2003;10:259-62.
23. Bell DM. Public interventions and SARS spread, 2003. Emerg Infect Dis 2004;10:1900-6.
24. Tan CC. SARS in Singapore: looking back, looking forward. Ann Acad Med Singapore 2003;32(Suppl):S4-S5.
25. Lipsitch M, Cohen T, Cooper B, Robin JM, Ma S, James L, et al. Transmission dynamics and control of severe acute respiratory syndrome. Science 2003;300:1966-70.
26. Singh K, Hsu LY, Villacian JS, Habib A, Fisher D, Tambyah PA. Severe acute respiratory syndrome: lessons from Singapore. Emerg Infect Dis 2003;9:1294-8.
27. Centers for Disease Control and Prevention. Severe acute respiratory syndrome: Singapore, 2003. MMWR Morb Mort Wkly Rec 2003;52:405-11.
28. Chua MH. A Defining Moment: How Singapore Beat SARS. Singapore: Institute of Policy Studies, 2004.
29. Menon KU, Goh KT. Transparency and trust: risk communications and the Singapore experience in managing SARS. J Communications Management 2005;9:375-83.

Appendix

Chronology on the Spread of SARS and Key Actions Taken in Singapore, 20 February to 18 August 2003

Date	Key events/actions taken
20-25 February 2003	Two pairs of Singaporeans travelled to Hong Kong for a "free-and-easy" holiday
1-3 March	Three of the 4 returning tourists developed respiratory illness and admitted to 2 hospitals in Singapore – Tan Tock Seng Hospital (TTSH) and Singapore General Hospital (SGH).
6 March	The Ministry of Health (MOH) was informed by the World Health Organization (WHO) that several healthcare workers (HCWs) caring for an American-Chinese who was sick with pneumonia in Hanoi had developed a similar respiratory illness. The MOH alerted the hospitals to isolate the 3 patients and take strict infection control precautions. Contact tracing was started.
13 March	The WHO issued a global alert on cases of atypical pneumonia in hospitals in Hong Kong and Vietnam (12 March in Geneva). The MOH alerted all hospitals and doctors to look out for cases of pneumonia who had recently travelled to Hong Kong, Hanoi or Guangdong province. The MOH also advised travellers returning from these areas to seek medical attention if they developed flu-like symptoms.
14 March	Six more cases (including 2 HCWs) of atypical pneumonia reported. The MOH issued advice that travel to areas affected by outbreaks of atypical pneumonia should be avoided, unless absolutely necessary.
15 March	Seven more cases reported, bringing the total to 16. This included 7 HCWs who had attended to patients with atypical pneumonia. The WHO case definition for SARS distributed to all hospitals and doctors. Suspected cases were to be sent for screening at the Communicable Disease Centre (CDC), and MOH was to be notified. All hospitals, including accident and emergency (A&E) departments, were reminded to observe strict infection control procedures. SARS Task Force formed, chaired by the Director of Medical Services. The MOH was informed of a Singaporean doctor who was suspected to have SARS onboard SQ25 from New York – Frankfurt. The MOH contacted the WHO and the German health authorities. The doctor, his wife and mother-in-law were met by the German health authorities in Frankfurt, and admitted to a hospital in Frankfurt.
17 March	SARS made notifiable under the Infectious Diseases Act.
18 March	Total number of probable cases increased to 23. Four cases in critical condition. All hospitals instructed to have triage procedures at A&E departments to separate suspect cases from the main crowd for quick clinical assessment. Travel advisory on SARS given to all passengers for outbound and inbound flights for Hong Kong, Guangdong and Hanoi.
20 March	Total probable cases 34; 5 in critical condition. Hospitals informed of Hospital Infection Control Guidelines issued by the WHO and the US Centers for Disease Control & Prevention (US CDC).
21 March	Five new cases reported, bringing total number of probable cases to 39. The Ministry of Education (MOE) announced that children and teachers with travel history and fever were to be isolated immediately and to stay away from school for 10 days when schools resumed term break on 24 March (school holidays: 15 to 23 March).
22 March	Total number of probable cases 44. The MOH decided to centralise all suspected and probable SARS cases, including paediatric cases, at TTSH, with added infection control protection measures for staff. All hospitals instructed that strict infection control procedures must be followed at all times in high-risk areas i.e., A&E departments and intensive care units (ICUs). All hospital patients with fever and/or pneumonia should be regarded as suspected cases and isolated, and visitors disallowed. All hospitals instructed that every sick HCW should be seen at their staff clinics. Medical certificates issued by private clinics not allowed. All HCWs who had contact with cases instructed to monitor their temperatures twice daily. An MOH hotline established for hospitals to check contacts of SARS patients.
23 March	Seven more cases; total probable cases 51. Close contacts of SARS cases issued with Home Quarantine Orders (HQOs) under the Infectious Diseases Act.
25 March	First death from SARS.
26 March	Decision taken to close all childcare centres, pre-schools, primary and secondary schools, junior colleges (JCs), centralised institutes and madrasahs from 27 March 2003 to 6 April 2003.

Date	Key events/actions taken
28 March	Fourth imported case reported – a 28-year-old woman who had travelled to Beijing. The MOH started contact tracing of 49 fellow passengers on flight.
	The Inter-Ministry Working Group formed to look into further measures to contain SARS.
30 March	The Civil Aviation Authority of Singapore (CAAS) directed all airlines at Changi Airport to ask departing passengers the 3 WHO-recommended questions on symptoms of SARS and contact history before departure. Health alert notice given to inbound passengers from affected areas.
	Fifth imported case reported – a 17-year-old boy who had travelled with his family to Guangdong through Hong Kong.
31 March	Case of death in National University Hospital (NUH) reported. Had been admitted to NUH for pneumonia on 24 March but not diagnosed as SARS as no contact history or travel to affected areas. History of recent visit to TTSH only obtained on 30 March.
	For all inbound flights from affected areas, nurses stationed to check passengers who appeared unwell and those with fever sent to TTSH for assessment.
1 April	Sixth imported case – a 56-year-old Chinese national from Fujian province who came to visit her daughter in Singapore.
	A doctor in NUH who had attended to the case who had died on 31 March was diagnosed with SARS.
2 April	All incoming sea passengers from affected countries were given a health alert notice and checked by nurses. Ngee Ann Polytechnic closed for 3 days following the detection of a suspected case among the students.
4 April	Infection control guidelines for HCWs issued. Hospitals provided with an updated list of all contacts of suspected and probable SARS patients.
5 April	Cluster of 21 HCWs at wards 57 and 58, SGH, reported to be down with fever. Ninety-one staff and 80 inpatients in these 2 wards moved to TTSH on 6 and 7 April.
	Midwife in KK Women's & Children's Hospital reported to have SARS. About 500 patients and 30 HCWs known to be exposed. All contacts traced but none diagnosed to have SARS.
	MOE announced phased re-opening of schools: • JCs and centralised institutions on 9 April; • secondary schools on 14 April; and • primary schools on 16 April.
7 April	Ministerial Committee on SARS set up to oversee the formulation and implementation of operational response plans for various scenarios that could arise, resolve cross-Ministry policy issues and give political guidance in handling the impact of SARS cases on the economy and society.
	Two nurses at Changi General Hospital and one nursing aide at Orange Valley Nursing Home contracted SARS.
8 April	Standard operating procedures (SOP) on handling and disposal of bodies due to SARS (cremation for non-Muslims within 24 hours, neither embalming nor wakes allowed) issued to all acute hospitals. Transfer of patients from TTSH to nursing homes disallowed. For other hospitals, transfer allowed if patient had been afebrile for more than 3 days and had no contact history. (Patient was to be isolated for 10 days.)
9 April	Visitors to hospitals restricted. Number allowed per non-SARS patient reduced to 2. All visitors registered and logged.
	All HCWs in inpatient wards required under the Private Hospitals and Medical Clinics Act to wear masks, gloves and gowns while on duty and monitor their health status through thrice-daily temperature monitoring. Those found to have fever were not allowed to work.
	Passengers of all inbound flights (from both affected and non-affected areas) required to complete health declaration cards. All incoming air travellers from affected areas checked for temperature. Roman Catholic Church ceased hearing of confessions.
10 April	CISCO (a security agency) engaged to serve and enforce HQOs.
11 April	Outbreak at NUH identified. The Ministry of Manpower imposed 10-day quarantine for holders of work permit and employment pass from SARS-affected countries. The Courage Fund launched to provide financial assistance to SARS patients and their family members.
12 April	All restructured hospitals and institutions directed to ensure that compulsory temperature checks were conducted for all non-HCWs before they commenced work.
14 April	Audits started on hospitals to ensure good infection control practices were fully implemented in all hospitals.

Date	Key events/actions taken
15 April	All SARS patients who had recovered were issued HQOs for 14 days upon their discharge from TTSH. Additional precautionary measures implemented at SGH: • patients discharged only when free of fever for 72 hours; • temperature records of all staff, including housekeeping and maintenance staff, reviewed on a thrice-daily basis; and • movement of housekeeping and maintenance staff into clinical care areas restricted.
17 April	HQOs issued for 10 days for non-SARS patients with chronic co-morbid conditions upon discharge from SGH and TTSH. Other discharged patients who did not have any chronic conditions placed on phone surveillance for 21 days.
18 April	Only one visitor per patient per day allowed for all public hospitals.
19 April	Web-based system made available to all hospitals and medical clinics for checking whether a person was a SARS case, a contact of known SARS cases under HQO or had been discharged in the preceding month from hospital (checking previously done via manual lists). Pasir Panjang Wholesale Centre (PPWC) outbreak identified: • The MOH announced that PPWC was to be closed for 10 days, from 20 to 29 April. • All stallholders and employees placed on 10-day HQOs. Ministerial SARS "Combat Team" set up to prevent SARS infection in all public and private hospitals. Inter-hospital movement of inpatients in non-emergency situations restricted: • inter-hospital transfer of inpatients ceased; and • patients requiring re-admission within 21 days of their discharge from any public/private hospitals to be re-admitted to the same hospital, except for private patients who preferred to be admitted to a public hospital due to financial considerations.
20 April	Precautionary measures and procedures for haemodialysis centres issued.
22 April	All doctors employed or working in the private sector hospitals, locum doctors as well as nurses who were self-employed or from private nursing agencies, required to register to work in only one hospital.
23 April	Changi Airport extended temperature checks to all departing passengers using thermal scanners. Thermal imaging system introduced at the land checkpoints as part of a trial to assess their suitability for deployment there. Two units deployed at the Woodlands checkpoint and 1 unit at the Tuas checkpoint.
25 April	Infectious Diseases Act amended to allow the MOH to fine or imprison those who disobeyed HQOs, without the need to take them to court. Amendments also introduced to compound fines for persons who broke home quarantine.
28 April	Closure of Pasir Panjang Wholesale Centre extended for another 5 days till 4 May. Wet markets closed for cleaning and disinfection. Thermal scanners installed at Singapore Cruise Centre and Tanah Merah Ferry Terminal. Temperature checks with ear thermometers at Changi Ferry Terminal, Changi Immigration Checkpoint, West Coast Pier and Clifford Pier. All shipmasters required to make health declaration 4 hours before arrival. The MOH's general enquiry and special ambulance service numbers changed to 1800-333-9999 and 993, respectively.
29 April	No-visitor rule enforced for all public hospitals, except for those departments or hospitals treating children or providing obstetric care.
30 April	Home quarantine allowance scheme implemented for self-employed persons and employees who had been served with HQOs, as well as small business establishments (not more than 50 employees) that had been ordered to close by the government as a result of SARS and suffered a loss due to the closure. 200,000 primary school students issued with oral digital thermometers for personal use.
Early May	Alleged "exported SARS cases from Singapore" reported in media. The possibility of the WHO issuing a travel advisory against Singapore.
1 May	Contact tracing operations enhanced: • The MOH Contact Tracing Centre (number of personnel increased from 45 to 140) shifted from National Environment Agency (NEA) to the MOH and supported by integrated IT system to speed up contract tracing; • The MOH Operations Group (Operations Centre) set up to manage SARS control operations; and • criteria to trigger contact tracing and issuance of HQOs established, in line with the WHO case definitions. Fever clinics with enhanced infection control measures set up at Choa Chu Kang, Yishun, Geylang and Tampines polyclinics. Febrile patients seen in separate tents.

Date	Key events/actions taken
3 May	HQO revised: If a member of a household with children was under home quarantine, his or her HQO would also list the children's particulars; a condition of the HQO was that the children listed were also quarantined.
4 May	Revised SOP on handling of bodies of persons who died while they were, or suspected to be, cases or contacts of SARS issued to all restructured and private hospitals.A 50-year-old man who breached HQO charged under the Infectious Diseases Act.
6 May	The US CDC lifted its traveller's notification for Singapore from a travel advisory to a travel alert.
7 May	All incoming social visitors at the land checkpoints required to fill up Health Declaration Cards. The Immigration and Checkpoint Authority (ICA) also conducted random temperature checks on travellers arriving or departing by car, van, lorry or motorcycle. These measures would reinforce the temperature checks, conducted with the use of the thermal scanners which had been in place for both arriving and departing bus and foot travellers since 23 April 2003. These additional measures aimed to ensure that SARS was not inadvertently "exported" to other countries or "imported" into Singapore.
12 May	Alternative quarantine facilities available at the government chalets at Loyang for Singaporeans under HQOs. Routine laboratory testing for dengue by PCR to differentiate it from SARS provided. SARS preparedness extended to traditional Chinese medicine (TCM) clinics and Chinese medical halls: • The MOH issued directives and interim advisories to all registered TCM practitioners, TCM clinics and Chinese medical halls to reiterate the need for compulsory training on SARS prevention for registered TCM practitioners and referral of suspected SARS cases to TTSH, as well as to set up guidelines on infection control procedures for TCM clinics and Chinese medical halls. • Survey conducted in all GP clinics, specialist clinics, dental clinics and TCM clinics to assess their level of knowledge on infection control measures for SARS, followed by on-site audits between 12 and 31 May to confirm the telephone survey findings and provide advice on proper infection control procedures.
13 May	Outbreak of febrile illness at the Institute of Mental Health (IMH) with 24 inpatients and 6 staff admitted to TTSH. Preventive measures implemented: • no admission of new inpatients, and no discharge of existing inpatients; • closure of outpatient and A&E services; • recall of patients discharged from IMH between 23 April and 2 May for medical review at TTSH; • home quarantine for patients discharged from 3 May onwards; • housing of all IMH staff at designated quarantine facilities for 10 days; and • thrice-daily temperature check for all staff.
17 May	The cluster of IMH patients and staff who came down with fever from 11 to 12 May established to be not due to SARS. PCR testing for SARS coronavirus negative in samples taken from 31 patients and 9 staff. Of 9 persons tested for influenza B virus, 2 patients and 4 staff positive.
18 May	Last probable SARS case reported in a patient who was admitted to TTSH since 11 May 2003.
19 May	The cluster of febrile illness in the IMH confirmed to be non-SARS in origin. Preventive measures adopted by the IMH lifted.
21 May	SARS TV channel launched.
31 May	Singapore removed from the WHO's list of areas with recent local transmission of SARS.
1-30 June	• Implementation of OK campaign for community to promote personal hygiene, environmental cleanliness and public health (1 June). • No-visitor rule lifted in all public hospitals with effect from 1 June. However, visiting hours strictly enforced and only 1 visitor allowed per patient. The visitor to be the same person who visited the patient throughout his/her entire hospitalisation. • Restrictions on inter-hospital movement for HCWs lifted in phases. As a safeguard against cross-institutional spread of infection, all healthcare institutions (HCIs) required to closely monitor those HCWs who had been practising within the last 10 days in another institution, to ensure that they were afebrile and well. • US removed travel alert from Singapore (4 June). • The People's Association's Constituency SARS Taskforces started distributing 1.1 million SARS toolkits to every home on 5 June. • The MOH's case finding and surveillance efforts broadened. In addition to daily review of all observation and suspect cases and of clusters of fevers among patients in hospitals, surveillance extended to identify and review clusters of fevers in nursing homes and other step-down facilities. • A framework of measures to be adopted in the healthcare setting at different SARS alert levels developed. • A Patient Declaration Form under the Infectious Diseases Act to help doctors and HCIs obtain accurate and truthful information about the patients' travel and contact history as well as key symptoms which may suggest SARS instituted, but subsequently rescinded.

Date	Key events/actions taken
	• All nursing homes (NHs) linked to the respective restructured hospitals to reduce frequent movement of ill patients between different hospitals and nursing homes, minimising risk of spreading infections such as SARS throughout the healthcare delivery system. Patients in a restructured hospital who required step-down care would be transferred to one of the NHs linked to the hospital and vice versa. • With the start of the June school holidays, the MOH issued a travel advisory through the media to urge all Singaporeans to avoid travel to SARS-affected countries and areas as recommended by the WHO.
7 July	Hospital patients allowed to have up to 4 designated visitors. (However, only 1 visitor per patient allowed.)
13 July	Last SARS patient discharged from TTSH.
19 July	Full personal protective equipment only needed in high-risk areas in hospitals: ICUs, A&E depts, isolation rooms and during triage. In other areas, including outpatient clinics, masks only needed when dealing with febrile patients.
26 July	• Temperature screening of visitors to buildings suspended. • Temperature monitoring in all workplaces and schools suspended. • Temperature screening of outbound travellers suspended.
28 July	Special requirements on handling of bodies in non-SARS deaths due to pneumonia lifted.
31 July	Issue of health alert notices for inbound and outbound travellers suspended.
1 August	• Temperature screening of visitors to hospitals and other HCIs lifted. Hospitals and step-down care facilities continued to record details of visitors. • Fever clinics in 4 polyclinics discontinued. • Frequency of audits on HCIs reduced.
18 August	• Hospital patients allowed to have 2 visitors at a time from a list of 4 designated persons. • Restrictions on patient transfers between hospitals lifted. • Restrictions on zoning of restructured hospitals and nursing homes lifted. • New surveillance measures for SARS implemented in all hospitals. • Use of health declaration card suspended.