Coordinated Response to SARS, Vancouver, Canada

Danuta M. Skowronska, Martin Petric, Patricia Daly, Robert A. Parker, Elizabeth Bryce, Patrick W. Doyle, Michael A. Noble, Diane L. Roscoe, Joan Tomblin, Tung C. Yung, Mel Krajden, David M. Patrick, Babak Pourbohloul, Swee Han Goh, William R. Bowie, Tim F. Booth, S. Aleina Tweed, Thomas L. Perry, Allison McGeer, and Robert C. Brunham

Two Canadian urban areas received returning travelers with severe acute respiratory syndrome (SARS) before the World Health Organization issued its alert. By July 2003, Vancouver had identified 5 cases (4 imported); Toronto reported 247 cases (3 imported) and 43 deaths. Baseline preparedness for pandemic threats may account for the absence of sustained transmission and fewer cases of SARS in Vancouver.

In Canada, 2 urban areas received returning travelers infected with severe acute respiratory syndrome–associated coronavirus (SARS-CoV) from the original Hotel M cluster in Hong Kong. These travelers returned to Canada before the World Health Organization (WHO) issued its first global alert on March 12, 2003. One infected traveler from Hotel M returned to the greater Toronto area (GTA, population 4.7 million), Ontario; 2 returned to the Vancouver census metropolitan area (VCMA, population 2.0 million), British Columbia (BC). GTA, Ontario, is located in central Canada, approximately 4,000 km from VCMA, BC, which is the westernmost province of Canada. Control of SARS in both GTA and VCMA was by a national, publicly funded, but provincially administered healthcare system. Whereas GTA experienced sustained transmission, VCMA did not. Ultimately, GTA reported 247 patients with SARS and 43 related deaths; 3 cases were imported. VCMA identified 5 confirmed cases, 4 of which were imported (1–5).

The experience with SARS in Vancouver highlights how a well-coordinated response of baseline precautions, reinforced through timely public health alerts and periodic infection control audits, can mitigate outbreaks due to emerging respiratory-borne pathogens.

The Outbreak

Neutralization antibody titers to SARS-CoV among patients in VCMA are shown in Table 1. SARS-CoV was also confirmed in all but patient 1 by reverse transcription–polymerase chain reaction with multiple distinct primer sets applied to multiple specimens (3,6–9).

Patient 0 and patient 1 were a couple, who stayed on the 14th floor of Hotel M from February 20 to 24, 2003, and again from March 3 to 6. Both became ill on February 26 (Table 2). They returned to Canada on March 6 and went directly from the airport to their physician in Vancouver on March 7 (day 9 of illness). The husband (patient 0) was sent directly to the emergency room of a tertiary-care hospital (hospital A), arriving at 1:55 p.m. Within 15 minutes, full respiratory precautions were instituted. He was moved to a private room in the emergency room at 2:20 p.m. and transferred to a negative-pressure isolation room (NPIR) at 4:20 p.m. He was admitted into an NPIR of the intensive care unit (ICU) with full respiratory precautions at 6 a.m. on March 8 (Table 2).

His wife, patient 1, was recovering from mild illness, and no further follow-up was arranged. The couple had no other household contacts. Review confirmed that symptoms had not developed in any of the 148 hospital workers involved in patient 0’s care by 10 days after his arrival at the hospital. The family physician had no detectable neutralizing antibody to SARS-CoV when tested at day 496.

Patient 2 of the VCMA had prolonged contact abroad with 2 family members in Hong Kong, who subsequently died from SARS. Although asymptomatic, she went to her physician in VCMA on March 26 because she was concerned about her exposure. Chest radiograph showed bilateral consolidation, and she was directed, masked, to hospital B, where she was admitted directly to an NPIR. She was transferred to the ICU of hospital C for assisted ventilation (Table 2). Neither of her 2 household contacts had detectable SARS-CoV antibody at day 215.

Patient 3 stayed at Amoy Gardens March 28–30 (10). Upon return, he remained self-isolated in the VCMA in the basement suite of his home with no contacts (household members were nevertheless quarantined, but they remained asymptomatic). Masked and short of breath, he sought treatment at hospital A on April 3. Initial chest radiograph was normal, but computed tomography scan showed widespread, patchy, ground-glass opacification of both lungs.
He was admitted to hospital D directly to an NPIR (Table 2). His son, who drove him to hospital masked, had no detectable antibody to SARS-CoV at day 200.

Patient 4 of the VCMA was a nurse who cared for patient 2 at hospital B from March 29 to 30. At the time, patient 2 was receiving oxygen by mask and nebulization therapy. Patient 4 assisted patient 2 in using the toilet, which was flushed with lid raised in her presence. She followed guidelines in place at the time, but these did not include eye protection. Symptoms developed in the nurse on April 4. She went to hospital E on April 15, where she was admitted directly to an NPIR. Her only household contact remained asymptomatic. Neither he, nor a physician who examined her on April 11, had detectable SARS-CoV antibody at 200 and 365 days, respectively.

All 5 patients with SARS in VCMA recovered fully. No additional unrecognized spread was evident. None of 442 staff members of hospitals A–E who participated in a voluntary serosurvey had detectable SARS-CoV antibody by microneutralization assay (details available from corresponding author, upon request).

Conclusions
Mathematical models for SARS, incorporating contact network theory, stress the importance of patient 0 in predicting the likelihood of an epidemic (11). This likelihood can be determined by the transmissibility of the agent, number of contacts of patient 0, and number of persons infected between patient 0 (the first patient infected) and intervention on the index patient (the first recognized case-patient). From this perspective, the circumstances of patient 0 in Vancouver compared to patient 0 in the Toronto, Canada, outbreak, merit closer examination.

Conclusions
Mathematical models for SARS, incorporating contact network theory, stress the importance of patient 0 in predicting the likelihood of an epidemic (11). This likelihood can be determined by the transmissibility of the agent, number of contacts of patient 0, and number of persons infected between patient 0 (the first patient infected) and intervention on the index patient (the first recognized case-patient). From this perspective, the circumstances of patient 0 in Vancouver compared to patient 0 in the Toronto, Canada, outbreak, merit closer examination.

When SARS arose in Ontario, a comparable agency to BCCDC did not exist. Responsibility for communicable disease control had shifted over the course of several years to local health boards, which created a decentralized system (12). Patient 0 in Toronto also stayed at Hotel M with her spouse from February 18 to 21. She returned to the GTA on February 23 to an apartment she shared with 5 family members (5,13). She died at home on March 5. During this period, she infected her 43-year-old son. This son became Toronto’s index patient, a locally acquired, second-generation case (5,13). He went to a community hospital on March 7, the same day as Vancouver’s patient 0, but was not recognized as a special threat. He was placed in general observation in the emergency room, where he remained for 18 hours and where he was given nebulized salbutamol. He was not placed in airborne isolation until he had been at the hospital for 21 hours; droplet and contact precautions were later begun on March 10 (5,13). By the time WHO issued its global alert, at least 14 persons in GTA had already become infected through 4 generations of spread: half within patient 0’s family and the remainder among

Table 1. SARS CoV antibody titers by microneutralization assay in persons with laboratory-confirmed SARS in VCMA*

| Serum sample no. | Days after onset Titer | Days after onset Titer | Days after onset Titer | Days after onset Titer |
|------------------|------------------------|------------------------|------------------------|------------------------|
|                  | Patient 0              | Patient 1              | Patient 2              | Patient 3              | Patient 4              |
| 1                | 10                     | 1:32                   | 16                     | 1:128                  | 4                      | ≤1:8                   |
| 2                | 19                     | 1:128                  | 29                     | 1:32                   | 14                     | 3                      | ≤1:8                   |
| 3                | 45                     | 1:32                   | 637                    | 1:64                   | 20                     | 1:128                  | 224                    | 1:128                  | 203                    | 1:128                  |
| 4                | 217                    | 1:128                  | 466                    | 1:64                   | 481                    | 1:84                   |

*By number of days after symptom onset that serum was collected. SARS, severe acute respiratory syndrome; CoV, coronavirus; VCMA, Vancouver census metropolitan area.
healthcare contacts. Concern about severe illness in family members as they sought treatment at the hospital prompted an evening phone consultation on March 13 from an infection control practitioner in Toronto to the BCCDC in Vancouver. This call linked the separate Toronto and Vancouver cases to events in Asia and led to recognition that SARS had spread beyond that region. It also prompted WHO to issue a rare travel advisory on March 15 (14). Thereafter, awareness of precautions to be taken was enhanced everywhere, and further importations into Canada (Vancouver and Toronto) did not result in spread.

Ultimately, standard droplet and contact precautions proved an effective barrier to SARS except in the context of superspreading events such as aerosolizing procedures (3). Low inherent transmissibility, combined with the delay in peak infectivity until well into the course of

Table 2. Epidemiologic and clinical profile of patients with confirmed SARS, Vancouver*

| Patient characteristics | Patient 0 | Patient 1 | Patient 2 | Patient 3 | Patient 4 |
|-------------------------|-----------|-----------|-----------|-----------|-----------|
| Baseline characteristics |           |           |           |           |           |
| Sex                     | Male      | Female    | Female    | Male      | Female    |
| Age (y)                 | 55        | 54        | 64        | 49        | 44        |
| Medical condition       | No        | Diabetes  | Hypertension | No        | No        |
| Epidemiologic characteristics |       |           |           |           |           |
| Travel related          | Yes       | Yes       | Yes       | Yes       | No        |
| City of likely source of SARS | Hong Kong | Hong Kong | Hong Kong | Hong Kong | VCMA      |
| Known contact with SARS | No        | No        | Yes       | No        | Yes       |
| Likely date(s) of exposure, 2003 | Feb 21   | Feb 21    | Mar 19    | Mar 28–30 | Mar 29 or Mar 30 |
| Likely setting of exposure | Hotel M  | Hotel M   | Dinner party | Amoy Gardens | Hospital B |
| Date of return to Canada, 2003 | Mar 6     | Mar 6     | Mar 20    | Mar 30    | NA        |
| Clinical profile        |           |           |           |           |           |
| Symptoms and onset, 2003 |           |           |           |           |           |
| Malaise                 | Feb 26    | Feb 26    | Mar 24    | No        | Apr 4     |
| Myalgia                 | No        | Feb 28    | Mar 24    | Apr 1     | Apr 10    |
| Headache                | Feb 28    | Feb 28    | Mar 27    | Apr 1     | Apr 4     |
| Fever                   | Feb 28    | Feb 28    | Mar 29    | Apr 1     | Apr 15    |
| Chills                  | Feb 28    | Feb 28    | Mar 29    | No        | No        |
| Chest discomfort        | No        | No        | Mar 24    | No        | No        |
| Cough                   | Mar 1     | No        | Mar 29    | No        | Apr 11    |
| Shortness of breath     | Mar 1     | No        | Mar 29    | Apr 3     | Apr 11    |
| Nausea                  | No        | No        | Mar 27    | No        | No        |
| Vomiting                | No        | No        | No        | No        | No        |
| Diarrhea                | Mar 7     | No        | Mar 28    | Apr 6     | Apr 11    |
| Hospitalized            | Yes       | No        | Yes       | Yes       | Yes       |
| Oxygen saturation (%) on room air at admission | 45  | NA | 80 | 97; fell to 62 within 3 h | 86 |
| Aerosolized medication or nebulizer before isolation | No | No | No | No | No |
| Date of hospital admission | Mar 7    | NA        | Mar 28    | Apr 3     | Apr 15    |
| No. days after symptom onset that patient was hospitalized | 10 | 4 | 2 | 11 |
| Date of final hospital discharge | Jun 12 | NA | Apr 21 | Apr 21 | May 24 |
| ICU                     | Yes       | No        | Yes       | No        | Yes       |
| Date of ICU admission   | Mar 8     | NA        | Apr 1     | NA        | Apr 15    |
| Date of ICU discharge   | May 13    | NA        | Apr 18    | NA        | Apr 24    |
| Mechanical ventilation  | Yes       | No        | Yes       | No        | No        |
| Delay to implementation at hospital of: |           |           |           |           |           |
| Respiratory precautions† | 15 min‡   | NA        | Immediate§ | Immediate§ | 7 min¶ |
| Negative-pressure isolation | 165 min‡  | NA        | Immediate§ | Immediate§ | 11 min¶ |

*SARS, severe acute respiratory syndrome; VCMA, Vancouver census metropolitan area; NA, not applicable; ICU, intensive care unit; ER, emergency room; NPIR, negative-pressure isolation room.
†Defined as standard precautions (gloves, gown, eyewear) plus N95 mask and mask on patient when transported. Full respiratory precautions also include NPIR.
‡Arrived in triage March 2, 2003 1:55 p.m. By 2:10 p.m., admission sheet advises "full respiratory precautions" be taken. By 2:20 p.m. in single room in ER. Transferred to NPIR in ER at 4:40 p.m.
§Arrived at hospital masked and admitted directly into NPIR.
¶Arrived in ER on April 14, 2003, at 9:49 p.m. Identified as suspected SARS patient at 9:56 p.m. Masked and transferred to NPIR in ER at 10 p.m. Admitted to ICU NPIR on April 15.
serious illness, may explain why SARS was primarily a nosocomial infection and why so few countries experienced outbreaks (3). Patient 0 tests the baseline capacity of a system to respond to emerging threats before they are known or recognized. While favorable random chance may have played a role, Vancouver’s response to SARS should not be dismissed on the basis of luck alone. Pasteur’s edict that “chance favors only the prepared mind” may have modern relevance to the prepared healthcare system (15). The response to patient 0 in Vancouver highlights the importance of central coordination, baseline preparedness at the local level, and an efficient network of communication in mitigating outbreaks. Baseline preparedness should include barrier precautions in the care of all acute-onset respiratory infections. These should be reinforced through timely public health alerts and periodic infection control audits.

Acknowledgments

We thank the patients who generously shared their experience with SARS illness. We acknowledge the health professionals who, during a period of great uncertainty, provided selfless care to them.

This study was funded by the Canadian Institute for Health Research and the BC Centre for Disease Control.

Dr Skowronski is an epidemiologist at the BC Centre for Disease Control, responsible for surveillance, program and policy recommendations, and research related to respiratory-borne and vaccine-preventable diseases.

References

1. World Health Organization. Consensus document on the epidemiology of severe acute respiratory syndrome (SARS). Report no. WHO/CDS/CSR/GAR/2003.11. Geneva: The Organization; 2003.
2. World Health Organization. Severe acute respiratory syndrome (SARS): report by the Secretariat. Report EB113/33 Rev.1. 1-23-2004. Geneva: The Organization; 2004.
3. Skowronski DM, Astell C, Brunham RC, Low DE, Petric M, Roper RL, et al. Severe acute respiratory syndrome: a year in review. Annu Rev Med. 2005;56:357–81.
4. World Health Organization. Summary of probable SARS cases with onset of illness from 1 November 2002 to 31 July 2003. [cited 2004 Sep 20]. Available from: http://www.who.int/csr/sars/country/table2004_04_21/en
5. Poutanen SM, Low DE, Henry B, Finkelstein S, Rose D, Green K et al. Identification of severe acute respiratory syndrome in Canada. N Engl J Med. 2003;348:1995–2005.
6. World Health Organization. Sampling for severe acute respiratory syndrome (SARS): diagnostic tests. 2003 Apr 29. [cited 2004 Sept 20]. Available from http://www.who.int/csr/sars/sampling/en/
7. Guo JP, Petric M, Campbell W, McGee PL. SARS coronavirus peptides recognized by antibodies in the sera of convalescent cases. Virology. 2004;324:251–6.
8. Adachi D, Johnson G, Draker R, Ayers M, Mazzulli T, Talbot PJ, et al. Comprehensive detection and identification of human coronaviruses, including the SARS associated coronavirus, with a single RT-PCR assay. J Virol Methods. 2004;122:29–36.
9. Tang P, Louie M, Richardson SE, Smieja M, Simor AE, Jamieson F, et al. Interpretation of diagnostic laboratory tests for severe acute respiratory syndrome: the Toronto experience. CMAJ. 2004;170:47–54.
10. Yu ITS, Li Y, Wong TW, Tam W, Phil M, Chan AT, et al. Evidence of airborne transmission of the severe acute respiratory syndrome virus. N Engl J Med. 2004;350:1731–9.
11. Meyers LA, Pourbohloul B, Newman MEJ, Skowronski DM, Brunham RC. Network theory and SARS: predicting outbreak diversity. J Theor Biol. 2005;232:71–81.
12. Lim S, Closson T, Howard G, Gardam M. Collateral damage: the unforeseen effects of emergency outbreak policies. Lancet Infect Dis. 2004;4:697–703.
13. Varia M, Wilson S, Sarwal S, McGeer A, Gournis E, Galanis E. Investigation of a nosocomial outbreak of severe acute respiratory syndrome (SARS) in Toronto, Canada. CMAJ. 2003;169:285–92.
14. Patrick DM. The race to outpace severe acute respiratory syndrome (SARS). CMAJ. 2003;168:1265–6.
15. Pasteur L. Lecture. University of Lille. 1865 Dec 7.

Address for correspondence: Danuta M. Skowronski, BC Centre for Disease Control, 655 West 12th Ave, Vancouver, BC, Canada; fax: 604-660-0197; email: danuta.skowronski@bccdc.ca

Use of trade names is for identification only and does not imply endorsement by the Public Health Service or by the U.S. Department of Health and Human Services.