Severe Acute Respiratory Syndrome Beyond Amoy Gardens: Completing the Incomplete Legacy

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The temporal and spatial distributions of the 2003 severe acute respiratory syndrome (SARS) outbreak in Amoy Gardens of Hong Kong was reexamined using all confirmed cases. The outbreak actually extended to nearby residential complexes. Airborne spread was the most likely explanation, and the SARS coronavirus could have spread over a distance of 200 m.

Keywords. SARS; outbreak; airborne.

This year (2013) is the 10th anniversary of the pandemic of severe acute respiratory syndrome (SARS) [1], and we take this opportunity to update the medical community on what actually happened in the largest community outbreak in the Amoy Gardens in 2003.

In 2004, we analyzed the temporal and spatial distributions of the initial 187 cases in 7 blocks (A–G) of Amoy Gardens, a residential building complex with 19 buildings, where the largest community outbreak of SARS took place. Coupled with computational fluid dynamics modeling on the 3-dimensional spread of a hypothetical plume of virus-laden aerosols, our analyses supported the probability of an airborne spread of the SARS virus in that outbreak [2].

A year later, we reported the temporal-spatial distribution of SARS among inpatients in a major nosocomial outbreak and concluded that the spread of SARS in the ward was consistent with airborne transmission [3]. At the same time, a Canadian group of researchers reported the detection of SARS coronavirus in 2 air samples obtained from a room occupied by a patient with SARS, which provided the first experimental confirmation of viral aerosol generation by a patient with SARS, supporting the possibility of airborne transmission [4]. An earlier report on transmission of SARS on aircraft also supported airborne spread [5].

It is now widely accepted that the SARS coronavirus could be transmitted through aerosols under certain circumstances in medical facilities [6], but fear of panic and political blame led to the reluctance of various health authorities in admitting airborne spread of SARS in the community. There was also a query if SARS spread beyond the Amoy Gardens through the air in 2003 [7]. In general, respiratory droplet spread can occur only through direct contact or at close distance (approximately 1 m), is less efficient, and has a lag time between generations of cases that is influenced by the incubation period and the infectious period, whereas in airborne spread, many cases can be affected within a short period of time by a common source and at distances much greater than 2 m.

METHODS

Information on all confirmed cases of SARS in Hong Kong was obtained from the Centre for Health Protection, Department of Health, in Hong Kong, including date of symptom onset, occupation, and residential address. Subjects were divided into 3 groups according to their proximity to the common source of SARS coronavirus present in the Amoy Gardens: (1) Amoy Gardens residents, (2) residents in the surrounding residential buildings (North: Lee Kee Building, Wang Kwong Building, Jade Field Gardens [Ka Lai Mansion, Ka Yin Mansion, Ka Yan Mansion], Tak Bo Gardens; East: Choi Ha Estate; South: Upper Ngau Tau Kok Estate, Lok Wah Estate; West: Lower Ngau Tau Kok Estate, Telford Gardens), and (3) residents elsewhere in Kwun Tong (KT) District, 1 of 18 districts of Hong Kong, where the Amoy Gardens was located. Epidemic curves were produced for each group and compared. The spatial distribution of all cases in Amoy Gardens and surrounding residential buildings was located on a map, focusing on cases with symptom onset during the period 24–29 March 2003, that is, 5–10 days after the index patient visited a unit in Block E of Amoy Gardens on March 19 and used the toilet there [2]. The index patient was receiving renal dialysis in the Prince of Wales Hospital during the largest nosocomial outbreak [3], had diarrhea, and was subsequently found to have very high viral load.
RESULTS

The temporal distributions of dates of symptom onset for cases in the 3 groups during the period 20 March to 10 April 2003 are depicted in Figure 1. The peak of the epidemic curve for Amoy Gardens residents occurred on 24–25 March 2003. The numbers of cases in the surrounding buildings were much smaller, but a small peak could be seen on 25 March 2003. In contrast, no peaks of the epidemic curve among residents elsewhere in KT District were noted, and the number of cases was small. The proportion of cases with symptom onset during the period 24–29 March was 76.4% (253/331), 55.3% (57/103), and 16.2% (16/99), respectively, for Amoy Gardens residents, residents in the surrounding residential buildings, and residents elsewhere in KT District.

The spatial distributions of all cases in Amoy Gardens and surrounding residential buildings are shown in Figure 1. Amoy Gardens had the largest number of cases (n = 331); only 12 of 331 cases in the Amoy Gardens occurred in the other 12 blocks (blocks H–S) outside the ring consisting of blocks A–G reported by us in 2004 [2]. A substantial number of cases also occurred in residential buildings near the Amoy Gardens (n = 103). In the Lower Ngau Tau Kok Estate (LNTKE), a public housing estate with 14 large apartment buildings, 48 cases were reported. All but 1 case concentrated in the 7 buildings (blocks 8–14) situated directly downwind (southwest) from blocks A–G of Amoy Gardens. To the west of the LNTKE, across a major highway and railroad, is a huge residential complex (Telford Gardens) comprising 41 buildings where 6 cases were reported, 5 of which were from buildings directly facing LNTKE. Furthermore, 14 cases were reported in another private housing estate (Lee Kee Building) with 4 buildings about 30 m northwest of buildings C and D of Amoy Gardens. The next housing estate (Wang Kwong Building) in the northwest direction with 3 buildings reported 8 cases. Farther northwest, 3 cases were reported from the next housing estate of 3 buildings (Jade Field Gardens) and 5 cases from the last housing estate with 8 buildings (Tak Bo Gardens) in that direction (about 200 m from block E of Amoy Gardens). If only cases with symptom onset during 24–29 March were included, the directional localization of infected subjects became clearer, with an apparent gradient to the north/northwest (Figure 2). No cases occurred in Choi Ha Estate to the northeast of Amoy Gardens, and only 1 case occurred in Upper Ngau Tau Kok Estate and 2 cases in Lok Wah Estate to the south and southeast.

DISCUSSION

The temporal similarity of the epidemic curves between surrounding buildings and Amoy Gardens suggested that the majority of cases in these 2 groups arose from the same common-source outbreak, and could not be adequately explained by person-to-person spread alone. It was impossible for the index patient in the Amoy Gardens outbreak to come into close contact with so many secondary cases within a short time, and a lag time of several days would have been expected before secondary SARS patients in Amoy Gardens developed symptoms and then became infective [8]. Common sources of contaminated food or water were not reported, and the only mode of spread that could adequately explain this common-source outbreak was airborne transmission.

Analysis on the spatial distribution of cases showed strong directional preference, with residential buildings located to the north, west, and southwest of Amoy Gardens having many more cases than those to the east, southeast, and south, especially during the period 24–29 March. The prevailing northeasterly wind at the time could explain the spread to LNTKE and then Telford Gardens on the west/southwest of blocks A–G of Amoy Gardens. The spread to the residential buildings located to the north/northwest was in line with our earlier computational fluid dynamics modeling that showed a portion of the hypothetical virus-laden plume passing through the space between blocks C and D and spreading toward the northwest [2]. No cases occurred during the period 24–29 March in the 2 housing estates (Kai Tai Court and Kai Yip Estate) about 300 m northwest of Telford Gardens, which suggested that the spread through the wind did not extend that far, possibly due to too much dilution over the distance. Considering that cases in Telford Gardens and Tak Bo Garden with symptom onset during 24–29 March were most likely resulting from the common source originating in block E of Amoy Gardens, the distance of airborne transmission in that outbreak could be >200 m.

The probable long-range airborne transmission of SARS in the community should sound an alarm to health authorities of the world, and now is the right time for all to rethink the strategy for managing future emerging infectious diseases. Infectious disease scientists should keep an open mind to all possible routes of transmission by objectively analyzing the available data, instead of emphasizing too much their historical understanding of models for person-to-person transmission.

Our results should be valid, as our dataset included all reported SARS cases that were subsequently confirmed. Although a few affected persons might not have stayed in the reported residential address, this should not cause serious misclassification.

In conclusion, the airborne spread in the largest community outbreak of SARS in 2003 actually extended beyond the Amoy Gardens and affected residential buildings >200 m from the source. Admitting such long-distance transmissions through the air and wind would enable governments, public health
Figure 1. Spatial distribution of cases in and around Amoy Gardens. Numbers on the right inside of the circles are the total numbers of cases in the different residential blocks or estates during the entire epidemic; the corresponding numbers on the left indicate the subsets of cases with symptom onset limited to the period 24–29 March 2003. Top: Epidemic curves for the 3 groups of residents in the larger Kwun Tong District of Hong Kong. Abbreviations: KT, Kwun Tong District; SARS, severe acute respiratory syndrome.
authorities, and communities to be more adequately prepared for the next possible outbreak from any airborne virus.

Notes

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