Risk of Severe Acute Respiratory Syndrome–Associated Coronavirus Transmission Aboard Commercial Aircraft

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Background. Severe acute respiratory syndrome–associated coronavirus (SARS-CoV) was introduced to the United States through air travel. Although the risk of SARS-CoV transmission within aircraft cabins has been addressed by several studies, the magnitude of the risk remains unclear.

Methods. We attempted to contact all persons with working US telephone numbers aboard seven US-bound flights carrying SARS patients. Consenting participants responded to a questionnaire, and a serum sample was collected at least 38 days after the flight and tested for SARS-CoV-associated antibodies. Participants reporting an illness compatible with SARS, with onset during the 2- to 10-day incubation period, were considered suspect cases; positive serology was required for confirmed cases.

Results. Among 1,766 passengers and crew, 339 (19%) persons were contacted. Of these, 312 (92%) completed questionnaires, and blood was collected from 127 (37%). Serology was negative for all 127 participants, including three of four who met the clinical case criteria for SARS, and the fourth had a mild illness that lasted only 5 days.

Conclusions. Transmission of SARS-associated CoV was not observed, suggesting that the risk of transmission is not amplified aboard aircraft.

Severe acute respiratory syndrome (SARS) is a new disease caused by a novel SARS coronavirus (SARS-CoV).[1,2] It is characterized by fever and respiratory symptoms such as cough and shortness of breath[3] and is fatal in about 10% of cases.[4] The virus is thought to be transmitted from person to person, primarily through large respiratory droplets.[5]

The first SARS cases appeared in Southern China in November 2002.[6] By July 2003, when the outbreak was considered over, 8,096 probable cases, including 774 deaths, had been reported from 29 countries.[4] In the United States, 72 probable cases were identified, only 8 of which were laboratory confirmed as SARS-CoV infections.[6]

Public concern that the environment in aircraft cabins could enhance SARS-CoV transmission may have contributed to decreased air travel during the outbreak.[7] Although several reports have been published on possible SARS-CoV transmission aboard aircraft,[8–11] the risk of transmission remains unclear. To assess the risk of in-flight SARS-CoV transmission, we conducted an investigation of passengers and crew aboard US-bound aircraft carrying passengers with SARS-CoV infection who were ill within 1 week of the flight.

Methods

The five index patients included in this evaluation became ill in February or March 2003 after traveling to a SARS-affected region (Table 1). Four index patients were laboratory-confirmed to have SARS-CoV infection. The fifth patient (Patient B) was the

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Table 1 Characteristics of flights carrying SARS index patients and study participation rates, 2003

Flight	Index patient	Equipment	Origin	Destination	Departure date	Number of passengers and crew aboard	Number of passengers and crew contacted (% of those aboard)¶	Number completing survey (% of those contacted)	Number completing survey and blood draw (% of those contacted)
1	A*	747-400	Tokyo	New York City	3/2/2003	334	108 (32)	104 (96)	34 (31)
2	B†	777-200	Hong Kong	Newark	2/23/2003	296	46 (16)	33 (72)	10 (22)
3	C‡	747-400	Hong Kong	Los Angeles	3/8/2003	374	47 (13)	45 (96)	27 (57)
4	C‡	737-800	Los Angeles	Salt Lake City	3/8/2003	133	73 (55)	69 (95)	37 (51)
5	D§	340-300	Taipei	New York City	3/12/2003	212	25 (12)	23 (92)	7 (28)
6	D§	Canadair Regional Jet	New York City	Norfolk	3/13/2003	32	8 (25)	8 (100)	3 (38)
7	E‖	747-400	Hong Kong	San Francisco	3/6/2003	385	32 (8)	30 (94)	9 (28)
Total						1,766	339 (19)	312 (92)	127 (37)

SARS = severe acute respiratory syndrome.
*Symptom onset was 2/24/2003; symptoms during the flight included fever and cough.
†Symptom onset was 2/25/2003; no symptoms during the flight.
‡Symptom onset was 3/6/2003; symptoms during the flight included fever but did not include cough.
§Symptom onset was 3/9/2003; symptoms during the flight included fever and cough.
‖Onset of mild symptoms was 3/3/2003 with recovery 3/4/2003. Onset of more severe symptoms was 3/13/2003; no symptoms during the flight.
¶Includes only passengers and crew with US telephone numbers.

index case for an outbreak in Toronto, Canada, who died of probable SARS before specimens could be collected for laboratory confirmation.[12] Three patients (patients A, C, and D) experienced symptoms during a total of five flights; two of these patients (patients A and D) were coughing on a total of three flights. One patient (patient B) became ill 2 days after the flight.[12] The onset date for the final patient (patient E) is unclear, as mild symptoms appeared 3 days before the flight, resolved 1 day after they appeared, and then reappeared 1 week after the flight. For two of the patients (patients B and E), there was evidence of secondary transmission.[12]

Each of seven flights carried one index patient. Two flights were domestic, three originated in Hong Kong, one in Taipei, and one in Tokyo (Table 1). Hong Kong and Taiwan began experiencing SARS outbreaks in February and March 2003, respectively.[6,13] Flight durations were more than 12 hours and less than 2 hours for international and domestic flights, respectively.

All passengers listed on the flight manifests and crew members who were aboard the selected flights were eligible to participate in the study. Additionally, participants were required to have working US telephone numbers and to speak English or a language spoken by one of our translators (Mandarin, Cantonese, Korean, and Spanish). Flight manifests, which included passenger names and seat assignments, were requested from the airlines. Reservations records, frequent flyer data, and crew employment records, all of which included limited contact information, were also requested from the airlines. For international flights, customs declarations were obtained from US Customs and Border Protection, Department of Homeland Security. Centers for Disease Control and Prevention (CDC) staff attempted to locate US telephone numbers for passengers and crew when this information was not provided or was incorrect.

This investigation was conducted as part of the public health response to the SARS outbreak. Informed consent was obtained from participants before epidemiologic and clinical information, and blood specimens were collected. Staff from either CDC or state or local health departments contacted passengers and crew by telephone and asked them to complete a standardized, interviewer-administered questionnaire, inquiring about demographics, potential SARS-CoV exposures, and SARS-compatible symptoms experienced within 10 days of the flight. If participants consented to have blood drawn for SARS-CoV testing, arrangements were made for a home visit to occur ≥38 days after the flight (28 days after the maximum 10-day incubation period).[14] Sera were sent to CDC and tested for SARS-CoV antibodies by enzyme-linked immunosorbent assay (ELISA) and indirect fluorescent antibody test.[2]

Our case definition was based on the SARS case definition established by CDC.[14] Participants with an illness that met the clinical criteria [fever >38°C plus cough or shortness of breath 2 to 10 days after the flight (the SARS incubation period)] and who were laboratory confirmed to have detectable SARS-CoV antibody ≥38 days after the flight would be considered confirmed cases of SARS. If clinical criteria were met but serologic status was unknown or inconclusive, the participant would be considered a suspect case patient. All participants without detectable SARS-CoV antibodies would be considered noncases, regardless of symptoms.

Results

Flight manifests demonstrated that a total of 1,766 passengers and crew members were aboard the seven flights; working US telephone numbers enabled us to contact 339 (19%) persons (Table 1). Of those contacted, an interview was completed for 312 (92%), and blood was drawn from 127 (37%) for serologic testing. Interviews were conducted a median of 75 days after the flight (range 45–214 days), and blood was drawn a median of 124 days after the flight (range 58–279 days). Among 1,082 passengers aboard international flights who completed a customs declaration form, 552 (51%) were not US residents and were, therefore, not likely to have US telephone numbers. Of the 208 passengers who were seated within three rows (to the front and rear) of the index patient, 39 were interviewed participants and 12 were serologically tested. Fifteen participants were seated within three rows of an index patient who was coughing during the flight. Four of the 12 interviewed crew members reported working in the same section as the ill patient.

Serum samples were collected from 127 (41%) of the 312 participants and tested for SARS-CoV antibodies; all the samples were negative (Table 2). One or more potential SARS symptoms were reported by 17 participants, 8 (47%) of whom provided samples for testing and had no detectable SARS-CoV antibodies. Four of these participants reported a combination of symptoms that met the clinical criteria for SARS. However, three were tested and had no detectable SARS-CoV antibodies. The fourth was an adolescent whose parents did not consent to having a blood sample drawn. Other than being

Table 2 Description of participant symptoms and SARS-CoV antibody serologic status, 2003[*†]

		SARS-CoV status	
	Total number of participants	Number tested (% of total)	Number positive
Total completing interview	312	127 (41)	0
No symptoms[‡]	258	95 (37)	0
At least one symptom[‡]	17	8 (47)	0
Fever	9	5 (56)	0
Cough	12	6 (50)	0
Shortness of breath	4	4 (100)	0
SARS-like illness[‡]	4	3 (75)	0

*SARS = severe acute respiratory syndrome; SARS-CoV antibody = antibody to SARS coronavirus.
†Denominators vary because of missing values.
‡Refers to the period 2 to 10 days after flight.

seated three rows in front of the index patient on a domestic flight, she had no known exposures to SARS patients and had never traveled to any SARS-affected regions. Her illness was mild and resolved after 5 days.

To assess the randomness of participant distribution throughout the aircraft cabins, a nearest neighbor analysis[15] was performed. Results did not demonstrate significant geographic clustering of participants ($p > 0.05$) in any of the flights. In addition, analyses were performed to address concerns that this investigation had insufficient power to detect SARS-CoV transmission aboard aircraft. Using the Poisson distribution, we calculated a hypothetical attack rate, given our sample size of 127 (the total number of participants with serologic results), an alpha of 0.05, and a beta of 0.2. We determined that the probability of observing zero cases was consistent with an attack rate of less than 3%. If the true rate of transmission aboard aircraft is greater than 3%, then there would have been a 95% probability of finding at least one case of aircraft exposure-related SARS among the 127 persons tested for SARS-CoV antibodies.

Discussion

No infection resulting from transmission of SARS-CoV was documented aboard seven commercial flights that carried persons with SARS. Among the 312 passengers and crew interviewed and the 127 whose serum samples were tested, 4 met the clinical case criteria but 3 were found to be negative for SARS-CoV antibodies and did not meet the SARS clinical case definition. Because the fourth suspect case patient did not consent to provide a blood sample, laboratory evaluation was not possible.

Other investigations that examined the risk of SARS-CoV transmission aboard aircraft have recently been published.[8–11] However, we questioned whether all reported cases truly represented in-flight transmission because not all index patients included in these studies had laboratory-confirmed SARS-CoV infection. Moreover, most cases of presumed secondary transmission occurred among persons who had visited SARS-affected regions within the incubation period, leaving open the possibility that transmission could have occurred before boarding the flight. For example, Olsen[10] and colleagues reported that 22 of 119 passengers and crew were potentially infected during a flight from Hong Kong to Beijing. Although transmission seems likely to have occurred, the index patient was not laboratory confirmed and the flight originated in a SARS-affected area.

Our finding that no confirmed cases of in-flight transmission were identified aboard any of the seven aircraft included in the investigation suggests that the risk of SARS-CoV transmission is not high aboard aircraft. However, other explanations for this finding are possible. For example, the five index patients, all of whom were well enough to travel, may not have been infectious during the flight, despite the presence of symptoms. Only one flight carried an index patient (patient A) who flew approximately 1 week after symptom onset when viral loads are peaking and risk of transmission is likely increased.[16–18]

Even though most of the passengers and crew we were able to contact were willing to participate, the major weakness of our investigation was its limited sample size. The large proportion of passengers and crew living outside the United States restricted the number of eligible participants. Contact information from the airlines was of variable quality and incomplete since airlines typically purge reservations data 48 hours after landing.[19] Customs declarations, available only for international flights, are handwritten, difficult to read, and often do not include adequate contact information. The process

of locating airline passengers for public health purposes could be significantly improved if data such as telephone numbers and addresses were provided from the airlines to public health agencies rapidly and in an electronic format. Another potential weakness involves the possibility that SARS symptoms might have been inaccurately recalled by participants, especially if interviews took place well after the flight occurred. However, because SARS symptoms are generally quite severe, we feel that inaccurate recall is unlikely to have caused us to miss a case.

SARS-CoV could potentially be transmitted anywhere people are gathered, including aircraft cabins. However, the relevant question is whether the aircraft cabin environment leads to a higher risk of transmission. Although our sample size was limited, our findings suggest that risk of SARS-CoV transmission is not high aboard aircraft, even among passengers seated near the index patient on long flights. The probability of transmission is more likely to be determined by the infectiousness of the index patient rather than the physical setting (eg, aircraft, classroom, or hospital). Thus, prevention efforts for air travel should continue to focus on reducing infectious particles on aircraft by discouraging persons who are acutely ill from traveling and reminding passengers to wash their hands frequently and cover their noses and mouths when coughing or sneezing.

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Declaration of Interests

The authors state that they have no conflicts of interest.

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