Evaluation of Control Measures Implemented in the Severe Acute Respiratory Syndrome Outbreak in Beijing, 2003

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Context  Beijing, China, experienced the world's largest outbreak of severe acute respiratory syndrome (SARS) beginning in March 2003, with the outbreak resolving rapidly, within 6 weeks of its peak in late April. Little is known about the control measures implemented during this outbreak.

Objective  To describe and evaluate the measures undertaken to control the SARS outbreak.

Design, Setting, and Participants  Data were reviewed from standardized surveillance forms from SARS cases (2521 probable cases) and their close contacts observed in Beijing between March 5, 2003, and May 29, 2003. Procedures implemented by health authorities were investigated through review of official documents and discussions with public health officials.

Main Outcome Measures  Timeline of major control measures; number of cases and quarantined close contacts and attack rates, with changes in infection control measures, management, and triage of suspected cases; and time lag between illness onset and hospitalization with information dissemination.

Results  Health care worker training in use of personal protective equipment and management of patients with SARS and establishing fever clinics and designated SARS wards in hospitals predated the steepest decline in cases. During the outbreak, 30178 persons were quarantined. Among 2195 quarantined close contacts in 5 districts, the attack rate was 6.3% (95% confidence interval [CI], 5.3%-7.3%), with a range of 15.4% (95% CI, 11.5%-19.2%) among spouses to 0.36% (95% CI, 0%-0.77%) among work and school contacts. The attack rate among quarantined household members increased with age from 5.0% (95% CI, 0%-10.5%) in children younger than 10 years to 27.6% (95% CI, 18.2%-37.0%) in adults aged 60 to 69 years. Among almost 14 million people screened for fever at the airport, train stations, and roadside checkpoints, only 12 were found to have probable SARS. The national and municipal governments held 13 press conferences about SARS. The time lag between illness onset and hospitalization decreased from a median of 5 to 6 days on or before April 20, 2003, the day the outbreak was announced to the public, to 2 days after April 20 (P<.001).

Conclusions  The rapid resolution of the SARS outbreak was multifactorial, involving improvements in management and triage in hospitals and communities of patients with suspected SARS and the dissemination of information to health care workers and the public.

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the control measures taken to rapidly repress the outbreak in Beijing and evaluate the effectiveness of some of these measures.

**METHODS**

**Setting and Definitions**

Beijing, capital of the People’s Republic of China, has approximately 13.6 million people. The municipal health system, which includes 466 nonmilitary hospitals and 85,000 health care workers, is overseen by the Beijing Municipal Health Bureau, which reports to the China Ministry of Health (MOH). Disease reporting, epidemic investigations, and contact tracing are the responsibility of the section of the Beijing Municipal Health Bureau called the Beijing Center for Disease Prevention and Control (BCDC). Within the BCDC are 18 district Centers for Disease Prevention and Control (DCDC), which are affiliated with community health centers.

Probable and suspect SARS case definitions were disseminated by the MOH. Only probable cases were included in this study because all suspect cases were ultimately excluded or reclassified as probable based on review of an expert panel as part of the Beijing joint SARS leading group. The definition of a probable SARS case changed slightly during the course of the outbreak but always included clinical and epidemiological components. After May 3, 2003, probable cases were defined as meeting 1 of the following categories: close contact with a patient with SARS and symptoms and signs of febrile respiratory illness and chest radiograph changes; visiting or residing in an area with recent local transmission of SARS and symptoms and signs of febrile respiratory illness and chest radiograph changes; or visiting or residing in an area with less than 1% of cases in children of cases was 33 years (1-93 years), and median (range) age of cases was 33 years (1-93 years), with less than 1% of cases in children younger than 10 years, and 51% of cases were men. The outbreak peaked on April 25, when 173 probable SARS cases were hospitalized.

**Data Collection**

Descriptive data of control measures were obtained through review of official documents and discussions with officials in the Beijing municipal health bureau and the BCDC. Data on the number of probable SARS cases were obtained from a standardized case report form issued by the MOH, which was required to be completed and sent to the DCDC by the physician who first diagnosed the SARS case. Public health personnel performed weekly onsite audits of hospitals to ensure complete reporting of all SARS cases. Because date of onset was missing for many cases, the reported date of hospitalization, which was missing in only 3.5% of cases, was used to create the epidemic curve.

Summaries of the number of fever clinic visits were compiled by the hospitals where the clinics were located and sent daily to both the DCDC and BCDC. The number of people placed in quarantine was tracked by the DCDC and reported daily to the BCDC.

Databases on close contacts from 5 districts (Changping, Chongwen, Dongcheng, Shijingshan, and Xicheng) with the most complete records were merged for the analysis of outcomes of quarantined close contacts. Information on close contacts of SARS cases was obtained from a standardized data collection form issued by the MOH. For each new SARS case, DCDC staff would interview the patient in the hospital about their potential close contacts. Staff from the DCDC or community health centers would find the close contacts, enforce quarantine, and complete the close contact data collection forms, which were maintained in a database at the DCDC. Close contacts who were already symptomatic when contacted were not included in the quarantine database. Although close contacts of suspect SARS cases were managed similarly to those of probable cases, they were excluded in our analysis.

**Data Analysis**

Databases at the BCDC and DCDCs were maintained in Microsoft Excel version 2002 (Microsoft Corporation, Redmond, Wash). Data analyses used SPSS version 11.0 (SPSS Inc, Chicago, Ill) and EPI Info version 6.02 (Centers for Disease Control and Prevention, Atlanta, Ga). The chi² test was used to compare proportions and the Kruskal-Wallis test to compare median values. The chi² test for trend was used to compare attack rates by age. The normal theory method for binomial parameters was used to calculate 95% confidence intervals around attack rates. \( P < .05 \) was considered significant.

**RESULTS**

**Timeline of Outbreak and Control Measures**

From March 5, 2003, to May 29, 2003, 2521 probable cases of SARS were reported in Beijing (FIGURE 1). It is unlikely that many patients hospitalized with SARS were not reported because reporting SARS cases was mandatory and weekly audits of hospitalized cases occurred. However, it is possible that some SARS cases were not counted before mid-April when the extent of the outbreak was fully recognized. Of the 2521 cases, 192 (7.6%) died. The median (range) age of cases was 33 years (1-93 years), with less than 1% of cases in children younger than 10 years, and 51% of cases were men. The outbreak peaked on April 25, when 173 probable SARS cases were hospitalized.
Emergency Infrastructure
On April 10, 3565 public health workers were mobilized to assist in the outbreak management. On April 17, the mayor of Beijing established the Beijing joint SARS leading group, which operated from an emergency command center in a downtown hotel. At that time, the Beijing government began purchasing emergency supplies both nationally and from abroad. Relevant local production facilities were directed to shift production toward SARS-related supplies. As of June 17, the following number of supplies had been distributed: 11092000 surgical masks, 7580000 gowns, 2954000 pairs of latex gloves, 621000 shoe covers, 1130000 thermometers, and 302 tons of chemical disinfectant (peracetic acid). In addition, 76 new ambulances, 79 new radiograph machines, and 759 mechanical ventilators were acquired.

Medical Sector Interventions
Of SARS cases, 407 (16%) occurred in health care workers. In 1 hospital, 88 health care workers were infected and 3 other hospitals had more than 20 health care workers infected. All 4 hospitals were closed by May 4. The spread of SARS virus among health care workers occurred more in the early part of the outbreak. Before April 25, the peak day of hospitalization, 55% of all health care worker cases had already been hospitalized compared with 45% of non–health care worker cases (P<.001). Beginning on April 18, 62363 health care workers received training through in-person courses, videotapes, and printed materials in the management of patients with SARS, infection control, and the use of PPE. Two or 3 sets of gowns, gloves, and masks (N95 and/or 12-layer cotton) were required, the outer layer being removed and disposed of after contact with each patient with SARS. Goggles were also required.

On April 27, all patients with SARS started to be placed together on designated hospital wards. Hospitals also started to limit visitors at that time. By May 8, all previously and newly diagnosed patients with SARS were hospitalized in 16 hospitals designated exclusively for probable SARS cases and 30 hospitals for suspected SARS cases. Negative pressure rooms were not available in most Beijing hospitals. As recommended by Chinese authorities and the World Health Organization—Beijing Joint Expert Team, rooms in designated SARS hospitals were fitted with air extraction fans on windows or walls that blew air from the room to the outside, either directly or through air ducts. The primary direction of airflow was from the hospital into the room and then to the outside, with the goal of 20% more air leaving the room than entering it, and was assessed by observing the movement of smoke. A new 1000-bed SARS hospital was built in 7 days by the Beijing municipal government and completed on May 1, after which it treated 40% of Beijing’s patients with probable SARS. No health care workers contracted SARS at this new hospital. After this hospital’s completion, the designated SARS hospitals had a capacity of 6700 beds with 3400 (51%) occupied at the height of the outbreak.

Fever Clinics
On April 17, 123 fever clinics were set up in all secondary and tertiary hospitals in Beijing. However, because some fever clinics were part of emergency departments or health centers where febrile patients went for medical care, transmission of SARS was suspected to have occurred in some clinics. On May 6, the number of fever clinics decreased to 66, all of which were required to be separated from other patient care areas, staffed by trained personnel wearing full PPE, have individual examination rooms with outward-blowing extraction fans, and rooms for overnight medical observation. Fever clinic patients included patients with febrile respiratory or influenza-like illnesses sent from community physicians and quarantine sites, as well as self-referrals. All persons who vis-

Figure 1. Epidemic Curve for Beijing SARS Outbreak and Timeline of Major Control Measures From March 5 to May 29, 2003

<table>
<thead>
<tr>
<th>Date of Hospitalization</th>
<th>No. of Probable Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mar 7</td>
<td>0</td>
</tr>
<tr>
<td>Mar 14</td>
<td>13</td>
</tr>
<tr>
<td>Mar 21</td>
<td>35</td>
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<tr>
<td>Mar 28</td>
<td>46</td>
</tr>
<tr>
<td>Apr 4</td>
<td>68</td>
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<td>Apr 11</td>
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<td>May 16</td>
<td>503</td>
</tr>
<tr>
<td>May 23</td>
<td>538</td>
</tr>
<tr>
<td>May 30</td>
<td>553</td>
</tr>
</tbody>
</table>

SARS indicates severe acute respiratory syndrome; HCW, health care worker; PPE, personal protective equipment; MOH, China Ministry of Health.

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SARS indicates severe acute respiratory syndrome.

Quarantine

The DCDC or community health centers were responsible for reaching all reported close contacts of patients hospitalized with SARS and issuing quarantine orders by telephone within 1 hour of notification about the case. If unable to reach the close contact, local police were notified to help find the individuals. Quarantine for close contacts was enforced for 14 days from the patient's symptom onset, 4 (1.9%) among those quarantined during April 1 to April 15 to 1.1% during May 16 to May 31. A total of 42% of close contacts were put into quarantine on the same day and most (74%) were isolated within 2 days of the day of hospitalization of the related case. Among 206 close contacts whose last contact with a patient with SARS was before the patient's symptom onset, 4 (1.9%) developed SARS. For 2 persons, the

at more than 11000 people (FIGURE 2). Several instances of mass quarantine were instituted, including 4 hospitals (2643 people), 2 universities (517 students), and 7 construction sites (1434 workers).

In the 5 districts in which close contact data were further analyzed (total population 2.6 million [19% of Beijing's population]), there were 582 cases who reported 2195 close contacts, with a mean 3.8 contacts per case (range, 1-80). Of the 2195 contacts, 2120 (96.6%) were located, quarantined, and included in the database. Of the remaining 75, 38 were not quarantined, mostly because they were exposed before standardized criteria for quarantine were enforced, and 37 had incomplete records. However, these 75 cases were included in the analysis of close contacts because the relationship with the patient with SARS was often known by report of the case-patients, as was the clinical outcome through matching the names of the close contacts with the SARS case report forms. The overall attack rate for becoming a probable case among close contacts was 6.3% (range by district, 2.9%-9.7%). The attack rate was highest among spouses (15.4%), other household members (8.8%), and nonhousehold relatives (11.6%) (TABLE 1). The attack rate among work and school contacts was low (0.36%). Among spouses, other household members, and nonhousehold relatives (n=1162), the attack rate increased with the age of the close contact, from 5.0% in children younger than 10 years to 27.6% in adults aged 60 to 69 years (TABLE 2). The attack rate decreased from 22.0% among those quarantined during April 1 to April 15 to 1.1% during May 16 to May 31. A total of 42% of close contacts were put into quarantine on the same day and most (74%) were isolated within 2 days of the day of hospitalization of the related case. Among 206 close contacts whose last contact with a patient with SARS was before the patient's symptom onset, 4 (1.9%) developed SARS. For 2 persons, the
last reported contact was 1 day before the patient’s onset of symptoms. For the other 2, the last contact was 5 days before the patient’s symptom onset; however, both contacts occurred in a hospital where the patient was being treated for an illness before contracting SARS, so that the transmission of SARS might have been from other hospitalized patients with SARS.

**Closing of Facilities**

On April 26, all sites of public entertainment (theaters, bars, libraries, and indoor sports facilities) were closed. By the time these places began opening again during the second week in June, 3500 public places had been closed. Restaurants were never ordered to close, although patronage was much reduced during the height of the outbreak. Of the 68 universities in Beijing, 22 (32%) cancelled classes. All public elementary, middle, and high schools (n=2610) were closed on April 24, not reopening again in some cases until early July. In addition, universities, construction sites, and prisons stopped the entry of all visitors and many residential communities and business places screened visitors for fever at entry.

**Transit Site Surveillance**

In late April, fever checks were instituted at the Beijing airport, major train stations, and all 71 roads connecting Beijing to other areas. Infrared thermometers were used to screen passengers, followed up by axillary thermometers on those found to be febrile on screening. As of June 30, of almost 14 million people screened at these sites, only 12 probable cases of SARS were identified (Table 3).

**Information Dissemination**

The scope of the Beijing outbreak was announced in a press conference given by the executive vice-minister of health on April 20. Subsequently, the MOH participated in 4 press conferences about SARS and the Beijing municipal government had 9 press conferences. Many billboards, bus advertisements, and traditional red neighborhood ban-
break: multiple imported cases, lack of knowledge about hospital spread, lack of awareness about proper PPE, delays in hospitalizing patients with symptoms, the population density of Beijing, and a failure to communicate the problem to hospitals and the public early enough. With these initial disadvantages, the prompt resolution of the Beijing outbreak was surprising and impressive. Beijing rapidly implemented multiple measures to control the SARS outbreak.

Similar to other SARS-affected areas, a large part of the Beijing outbreak occurred in hospitals. This was particularly true early on as suggested by the number of health care worker infections. Part of the reason for the decrease in cases among health care workers was likely the emphasis on training and guidelines on infection control and use of PPE after April 18. The effectiveness of these interventions is highlighted by the fact that no health care workers contracted SARS at the new 1000-bed SARS hospital that opened May 1. In addition to health care workers, many patients without SARS and visitors to the hospital were likely infected by patients with SARS, as observed in other outbreaks. The institution of improved triage, limitation of visitors, and designated SARS wards likely led to a decrease in such hospital exposures. The hospitals designated to SARS began to be established in late April and by May 8, all patients with SARS were hospitalized in such hospitals. Designated hospitals had the advantage of ensuring proper infection control practices, unidirectional airflow rooms, and proper patient triage and flow. However, the earlier decrease in hospital-based infections was likely because of control measures implemented in general hospitals, such as the use of PPE and grouping of patients with SARS on certain wards, because by May 8 the outbreak was already waning. In addition, the establishment of designated fever clinics identified the majority of new cases (84%) late in the outbreak. The earlier implementation of dedicated fever clinics, separated from general medical care areas, might have stemmed some of the transmission earlier in the outbreak.

Rigorous quarantine measures in Beijing were possible through both community-based and governmental involvement. Some categories of quarantined close contacts, such as family members, had much higher attack rates than others, such as school and workplace contacts. The high attack rate among family members might partially reflect contact with patients with SARS not just at home but at the hospital while visiting their ill relatives. Elderly close contacts had significantly higher attack rates than did children, although it is unclear if this is because of differences in the type of contact with the case, susceptibility to SARS, or the likelihood of developing symptoms after infection. The attack rate among quarantined persons was significantly higher in Beijing than in Taiwan, where among 50139 quarantined close contacts the attack rate, even for family members of patients with SARS, was less than 1%. The reasons for this difference might be because of differences in the case definitions of SARS, the higher incidence of SARS in Beijing, and the fact that only close contacts of probable SARS cases were included in our analysis, whereas in the Taiwan analysis contacts of both probable and suspected cases were included. Who should be quarantined during a SARS outbreak likely depends on several factors, such as resource availability, ability to mobilize public health personnel, and societal acceptability. Public health departments must weigh these factors in setting quarantine guidelines. For example, in smaller outbreaks or when resources are limited, public health authorities might consider active but nonquarantined surveillance in lower-risk settings, such as workplaces and schools, and among those whose contact with patients with SARS was only during the asymptomatic incubation phase.

In retrospect, several control measures undertaken by the Beijing municipality seemed to have less direct impact in resolving the outbreak; however, this was not known at the time of their implementation in the face of an accelerating outbreak of an unknown disease. The screening at points of transportation required a large amount of human and financial resources to maintain but identified very few cases of SARS. Such measures, however, might have prevented SARS cases indirectly by persuading symptomatic people to stay home. Moreover, these checkpoints assured the local as well as international community that proactive steps were being made toward controlling the outbreak. Second, the closing of the public schools for more than a month likely had a minimal effect on the prevention of SARS because of the low attack rate among schoolmates and the rarity of pediatric SARS in Beijing, as observed in other SARS-affected sites. However, the closing of schools may have contributed to the widespread self-quarantine that occurred in Beijing in early May, when the streets were virtually empty.

Besides these specific control measures, a general increase in the awareness about SARS played an important role in controlling the outbreak. Early in the outbreak before information about the number of patients with SARS

| Table 4. Lag Time Between Onset of Symptoms and Hospitalization of Probable SARS Cases, Beijing |
|-----------------------------|-----------------------------|-----------------------------|
| Date of Onset, 2003          | No. of SARS Cases | Lag Time, Median (Interquartile Range), d* |
| March 5 to April 9 (SARS becomes reportable) | 146 | 6 (0-14) |
| April 10 to April 20 (SARS announced publicly) | 476 | 5 (2-7) |
| April 21 to May 6 (designated fever clinics) | 1046 | 2 (1-4) |
| May 7 to June 15          | 192 | 2 (1-3) |

Abbreviation: SARS, severe acute respiratory syndrome.

*P<.001 comparing median times (Kruskal-Wallis test).
in the city was disseminated, the outbreak amplified because of underrecognition and mismanagement of patients with SARS in both the hospitals and the community. The control of the outbreak followed improvements in communication and awareness among health care workers, public health personnel, and the general public, as suggested by the decrease in the time between illness onset and hospitalization as the outbreak progressed.

Our analysis had several limitations. Because of the simultaneous and overlapping implementation of multiple control measures, it was difficult to pinpoint which one or several interventions were the most effective. Evaluation of the control measures was further complicated by the lag of at least an incubation period between implementation and effect. Laboratory testing for SARS coronavirus infection was not widely available during the outbreak in Beijing and was not part of the SARS case definition; therefore, circulation of other agents causing febrile respiratory illness in 1 or more of the districts in which quarantine was evaluated might have led to SARS attack rates that were falsely elevated. The 5 districts selected to evaluate contact tracing and quarantine might not have been representative of all of Beijing. Three districts were urban and 2 suburban, which might have overrepresented urban Beijing because of the 18 districts in Beijing, 8 are urban and 10 suburban. Attack rates tended to be higher in urban districts because of the presence of more hospitals and a greater density of people.

The multiple control measures implemented in Beijing likely led to the rapid resolution of the SARS outbreak. Improvements in infection control practices, use of PPE, grouping of patients with SARS in the hospital, establishment of designated fever clinics, quarantine of high-risk close contacts, and improved public information and awareness of SARS likely played important roles in controlling the outbreak. Some interventions, in retrospect, such as quarantine of low-risk contacts and fever checks at transportation sites, seemed to have less direct impact in curbing the outbreak. The lessons learned from controlling this outbreak can hopefully serve to inform future responses to SARS, if it were to reemerge in Beijing or elsewhere.

**Author Contributions:** Drs Xu and Feikin had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design: Pang, Zhu, Xu, Guo, Z. Liu, Chi, Feikin. Acquisition of data: Pang, Gong, D. Liu. Analysis and interpretation of data: Pang, Xu, Gong, D. Liu, Feikin. Drafting of the manuscript: Pang, Zhu, Xu, Feikin. Critical revision of the manuscript for important intellectual content: Pang, Zhu, Guo, Gong, D. Liu, Z. Liu, Chi. Statistical expertise: Xu, D. Liu. Administrative, technical, or material support: Zhu, Guo, Z. Liu, Chi. Study supervision: Zhu, Guo, Feikin.

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