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Cover Image: A Colorized Scanning Electron Microscope Image of the 2019-nCoV. (adapt from NIAID-RML)

Vital Surveillances

The Epidemiological Characteristics of an Outbreak of 2019 Novel Coronavirus Diseases (COVID-19) — China, 2020

The Novel Coronavirus Pneumonia Emergency Response Epidemiology Team

Abstract

Background: An outbreak of 2019 novel coronavirus diseases (COVID-19) in Wuhan, Hubei Province, China has spread quickly nationwide. Here, we report results of a descriptive, exploratory analysis of all cases diagnosed as of February 11, 2020.

Methods: All COVID-19 cases reported through February 11, 2020 were extracted from China's Infectious Disease Information System. Analyses included the following: 1) summary of patient characteristics; 2) examination of age distributions and sex ratios; 3) calculation of case fatality and mortality rates; 4) geo-temporal analysis of viral spread; 5) epidemiological curve construction; and 6) subgroup analysis.

Results: A total of 72,314 patient records—44,672 (61.8%) confirmed cases, 16,186 (22.4%) suspected cases, 10,567 (14.6%) clinically diagnosed cases (Hubei Province only), and 889 asymptomatic cases (1.2%)—contributed data for the analysis. Among confirmed cases, most were aged 30–79 years (86.6%), diagnosed in Hubei (74.7%), and considered mild (80.9%). A total of 1,023 deaths occurred among confirmed cases for an overall case fatality rate of 2.3%. The COVID-19 spread outward from Hubei Province sometime after December 2019, and by February 11, 2020, 1,386 counties across all 31 provinces were affected. The epidemic curve of onset of symptoms peaked around January 23–26, then began to decline leading up to February 11. A total of 1,716 health workers have become infected and 5 have died (0.3%).

Conclusions: COVID-19 epidemic has spread very quickly taking only 30 days to expand from Hubei to the rest of Mainland China. With many people returning from a long holiday, China needs to prepare for the possible rebound of the epidemic.

Introduction

A cluster of pneumonia cases of unknown origin in Wuhan, China caused concern among health officials in late December 2019. On December 31, an alert was issued by the Wuhan Municipal Health Commission, a rapid response team was sent to Wuhan by the Chinese Center for Disease Control and Prevention (China CDC), and a notification was made to the World Health Organization (WHO) (*1–4*). Likely potential causes including influenza, avian influenza, adenovirus, severe acute respiratory syndrome coronavirus (SARS-CoV), and Middle East respiratory syndrome coronavirus (MERS-CoV) were ruled out. Epidemiological investigation implicated Wuhan's Huanan Seafood Wholesale Market, which was shut down and disinfected, and active case finding was initiated and vigorously pursued (*2,4–5*).

On January 7, 2020, the causative pathogen was identified as a novel coronavirus, and genomic characterization and test method development ensued (*2–6*). Now named 2019-nCoV, the virus is distinct from both SARS-CoV and MERS-CoV, yet closely related (*5,7*). Early cases suggested that COVID-19 (i.e. the new name for disease caused by the novel coronavirus) may be less severe than SARS and MERS. However, illness onset among rapidly increasing numbers of people and mounting evidence of human-to-human transmission suggests that 2019-nCoV is more contagious than both SARS-CoV and MERS-CoV (*3,8–11*).

On January 20, China's "*National Infectious Diseases Law*" was amended to make 2019-novel coronavirus diseases (COVID-19) a Class B notifiable disease and its "*Frontier Health and Quarantine Law*" was amended to support the COVID-19 outbreak response effort. Then, on January 23, the Chinese Government began to limit movement of people in and out of Wuhan, and two days later, it announced its highest-level commitment and mobilized all sectors to respond to the epidemic and prevent further spread of COVID-19. Characterization of the epidemiological features of COVID-19 is crucial for the development and implementation of effective control strategies. Here, we report the results of a descriptive, exploratory analysis of all cases found through February 11, 2020.

Method

Study Design

This study was a descriptive, exploratory analysis of all cases of COVID-19 diagnosed nationwide in China as of the end of February 11, 2020. As such, it in some respects uses a cross-sectional study design and hence, we have used the STROBE Guidelines (www.equator-network.org) to aid our thorough reporting of this observational study.

A public health emergency was declared, and a formal investigation began on December 31, 2019, supported by city (Wuhan Municipal Health Commission and Wuhan CDC), provincial (Health Commission of Hubei Province and Hubei Provincial CDC), and national (National Health Commission and China CDC) authorities and resources. This study was reviewed by the China CDC Institutional Review Board via a fast-track mechanism. Although individual informed consent was not required for this study, all data were handled as a deidentified set to protect patient privacy and confidentiality.

Data Source

By categorizing COVID-19 as a Class B notifiable disease, Chinese law required all cases to be immediately reported to China's Infectious Disease Information System. Entry of each case into the system was performed by local epidemiologists and public health workers who investigated and collected information on possible exposures. All case records contain national identification numbers, and therefore, all cases have records in the system and no records are duplicated. All data contained in all COVID-19 case records in the Infectious Disease Information System through the end of February 11, 2020 were extracted from the system as a single dataset and were then stripped of all personal identifying information. No sampling was done to achieve a predetermined study size and no eligibility criteria were used—all cases were included.

Variables

Patient characteristics were collected at baseline, meaning the time of diagnosis, epidemiological investigation, and entry into the Infectious Disease Information System. Patients were categorized as health workers for the occupation variable if they had active employment of any kind in a health facility (i.e. this category did not just include physicians and nurses). Patients were categorized as having a Wuhan-related exposure if they had recently resided in or visited Wuhan or if they had close contact with someone who had. The comorbid conditions variable was determined upon epidemiological investigation by patient self-reported medical history, which was not independently verified using medical records for all cases. The severity of symptoms variable was categorized as mild, severe, or critical. Mild included non-pneumonia and mild pneumonia cases. Severe was characterized by dyspnea, respiratory frequency $\geq$ 30/minute, blood oxygen saturation $\leq$93%, PaO_2/FiO_2 ratio <300, and/or lung infiltrates >50% within 24–48 hours. Critical cases were those that exhibited respiratory failure, septic shock, and/or multiple organ dysfunction/failure.

As some variables of interest (i.e., Wuhan-related exposure, comorbid condition, and case severity) are not required fields when creating records in the Infectious Disease Information System, some records have missing data for these variables.

For construction of epidemiological curves, date of onset was defined as the date on which patients self-reported the start of either fever or cough during epidemiological investigation. Cases were categorized as confirmed, suspected, clinically diagnosed (Hubei Province only), or asymptomatic. Confirmed cases were diagnosed based on positive viral nucleic acid test results on throat swab samples (some samples were tested retrospectively). Suspected cases were diagnosed clinically based on symptoms and exposures. Clinically diagnosed cases were suspected cases with lung imaging features consistent with coronavirus pneumonia. Asymptomatic cases were diagnosed based on positive viral nucleic acid test results but without any COVID-19 symptoms (e.g., fever, dry cough). The date of positive viral nucleic acid test result is used as onset date for asymptomatic cases

Analysis

For confirmed cases, demographic and clinical characteristics were summarized using descriptive statistics. Age distribution graphs were constructed using patient age at baseline for confirmed cases diagnosed in Wuhan, Hubei Province (including Wuhan), and China (including Hubei Province). Sex ratio (i.e., male:female [M:F] ratio) was also calculated. Case fatality rates were calculated as the total number of deaths (numerator) divided by the total number of cases (denominator), expressed as a percent. Observed time was summarized using person-days (PD) and mortality was calculated as the number of deaths (numerator) divided by the total observed time (denominator), expressed per 10 PD.

For geo-temporal analysis, the county-level location of each case at time of diagnosis was used to build color-coded maps of China to indicate the numbers of cases in each province on December 31, 2019; January 10, 2020; January 31, 2020; and February 11, 2020. This analysis was performed using ArcGIS Desktop software (version 10.6; Esri; Redlands, California, USA).

The epidemiological curve for all cases was constructed by plotting the number of cases (y-axis) versus self-reported date of symptom onset (x-axis). Date of symptom onset for confirmed, suspected, clinically diagnosed, and asymptomatic cases were stacked to show total cases over time. The epidemiological curve for confirmed cases was also overlaid with the number of cases versus date of diagnosis to show the delay between onset of symptoms and diagnosis of disease.

Two subgroups were also analyzed separately using epidemiological curves: confirmed cases diagnosed outside of Hubei Province (with and without Wuhan-related exposure) and all cases diagnosed among health workers (confirmed, suspected, clinically diagnosed, and asymptomatic).

Results

Patients

A total of 72,314 unique records were extracted and data from all records were included in the analysis. Thus, all 72,314 individuals diagnosed with COVID-19 as of February 11, 2020, were included in the analysis. Among them, 44,672 cases (61.8%) were confirmed, 16,186 cases (22.4%) were suspected, 10,567 cases (14.6%) were clinically diagnosed, and 889 cases (1.2%) were asymptomatic.

Baseline characteristics of confirmed cases (n=44,672) are presented in Table 1. A majority were aged 30–69 years (77.8%), male (51.4%), farmers or laborers (22.0%), and diagnosed in Hubei Province (74.7%). Most patients reported Wuhan-related exposures (85.8%) and were classified as mild cases (80.9%).

TABLE 1. Patients, deaths, and case fatality rates, as well as observed time and mortality for n=44,672 confirmed COVID-19 cases in Mainland China as of February 11, 2020.

Baseline characteristics	Confirmed cases, N (%)	Deaths, N (%)	Case fatality rate, %	Observed time, PD	Mortality, per 10 PD
Overall	44,672	1,023	2.3	661,609	0.015
Age, years					
0–9	416 (0.9)	–	–	4,383	–
10–19	549 (1.2)	1 (0.1)	0.2	6,625	0.002
20–29	3,619 (8.1)	7 (0.7)	0.2	53,953	0.001
30–39	7,600 (17.0)	18 (1.8)	0.2	114,550	0.002
40–49	8,571 (19.2)	38 (3.7)	0.4	128,448	0.003
50–59	10,008 (22.4)	130 (12.7)	1.3	151,059	0.009
60–69	8,583 (19.2)	309 (30.2)	3.6	128,088	0.024
70–79	3,918 (8.8)	312 (30.5)	8.0	55,832	0.056
≥80	1,408 (3.2)	208 (20.3)	14.8	18,671	0.111
Sex					
Male	22,981 (51.4)	653 (63.8)	2.8	342,063	0.019
Female	21,691 (48.6)	370 (36.2)	1.7	319,546	0.012
Occupation					
Service industry	3,449 (7.7)	23 (2.2)	0.7	54,484	0.004
Farmer/laborer	9,811 (22.0)	139 (13.6)	1.4	137,992	0.010
Health worker	1,716 (3.8)	5 (0.5)	0.3	28,069	0.002
Retiree	9,193 (20.6)	472 (46.1)	5.1	137,118	0.034
Other/none	20,503 (45.9)	384 (37.5)	1.9	303,946	0.013

TABLE 1. (continued)

Baseline characteristics	Confirmed cases, N (%)	Deaths, N (%)	Case fatality rate, %	Observed time, PD	Mortality, per 10 PD
Province					
Hubei	33,367 (74.7)	979 (95.7)	2.9	496,523	0.020
Other	11,305 (25.3)	44 (4.3)	0.4	165,086	0.003
Wuhan-related exposure*					
Yes	31,974 (85.8)	853 (92.8)	2.7	486,612	0.018
No	5,295 (14.2)	66 (7.2)	1.2	71,201	0.009
Missing	7,403	104	2.8	103,796	0.010
Comorbid condition†					
Hypertension	2,683 (12.8)	161 (39.7)	6.0	42,603	0.038
Diabetes	1,102 (5.3)	80 (19.7)	7.3	17,940	0.045
Cardiovascular disease	873 (4.2)	92 (22.7)	10.5	13,533	0.068
Chronic respiratory disease	511 (2.4)	32 (7.9)	6.3	8,083	0.040
Cancer (any)	107 (0.5)	6 (1.5)	5.6	1,690	0.036
None	15,536 (74.0)	133 (32.8)	0.9	242,948	0.005
Missing	23,690 (53.0)	617 (60.3)	2.6	331,843	0.019
Case severity§					
Mild	36,160 (80.9)	–	–	–	–
Severe	6,168 (13.8)	–	–	–	–
Critical	2,087 (4.7)	1,023 (100)	49.0	31,456	0.325
Missing	257 (0.6)	–	–	–	–
Period (by date of onset)					
Before Dec 31, 2019	104 (0.2)	15 (1.5)	14.4	5,142	0.029
Jan 1–10, 2020	653 (1.5)	102 (10.0)	15.6	21,687	0.047
Jan 11–20, 2020	5,417 (12.1)	310 (30.3)	5.7	130,972	0.024
Jan 21–31, 2020	26,468 (59.2)	494 (48.3)	1.9	416,009	0.012
After Feb 1, 2020	12,030 (26.9)	102 (10.0)	0.8	87,799	0.012

Abreviation: PD, person-days. -, not applicable.

* The Wuhan-related exposure variable, only includes a total of 37,269 patients and 919 deaths and these values were used to calculate percentages in the confirmed cases and deaths columns.

† The comorbid condition variable, only includes a total of 20,812 patients and 504 deaths and these values were used to calculate percentages in the confirmed cases and deaths columns.

§ The case severity variable, only includes a total of 44,415 patients and 1,023 deaths and these values were used to calculate percentages in the confirmed cases and deaths columns.

Deaths, Case Fatality Rates, and Mortality

As shown in Table 1, a total of 1,023 deaths have occurred among 44,672 confirmed cases for an overall case fatality rate of 2.3%. Additionally, these 1,023 deaths occurred during 661,609 PD of observed time, for a mortality rate of 0.015/10 PD.

The ≥80 age group had the highest case fatality rate of all age groups at 14.8%. Case fatality rate for males was 2.8% and for females was 1.7%. By occupation, patients who reported being retirees had the highest case fatality rate at 5.1%, and patients in Hubei Province had a >7-fold higher case fatality rate at 2.9% compared to patients in other provinces (0.4%). While patients who reported no comorbid conditions had a case fatality rate of 0.9%, patients with comorbid conditions had much higher rates—10.5% for those with cardiovascular disease, 7.3% for diabetes, 6.3% for chronic respiratory disease, 6.0% for hypertension, and 5.6% for cancer. Case fatality rate was also very high for cases categorized as critical at 49.0%.

Age Distribution and Sex Ratio

The age distribution of cases in Wuhan only, in Hubei Province overall, and in China overall are presented in Figure 1. The proportion of confirmed cases 30–79 years of age at baseline (i.e., date of diagnosis) was 89.8% for cases in Wuhan city versus 88.6% in Hubei overall (which includes Wuhan) and 86.6% in China overall (which includes Hubei Province and all 30 other provincial-level administrative divisions, or PLADs). The male-to-female ratio was 0.99:1 in Wuhan, 1.04:1 in Hubei, and 1.06:1 in China overall.

Geo-Temporal Findings

On January 19, 2020, National Health Commission of the People's Republic of China confirmed that Guangdong Provincial CDC reported first imported cases of COVID-19, via the Chinese Infectious Diseases Reporting System. This was the first time COVID-19 had been reported outside of Hubei Province via the System. As of January 22, 2020, a total of 301 confirmed COVID-19 cases were reported from 83 counties in 23 provinces. On January 30, 2020, Xizang Autonomous Region (Tibet) reported its first confirmed COVID-19 case coming from Hubei Province. Thus, COVID-19 cases have been reported from all 31 PLADs (Figure 2).

As of February 11, 2020, a total 44,672 confirmed cases were reported from 1,386 counties of 31 provinces, autonomous regions, and municipalities and Hubei Province accounted for 74.7% (Figure 2E). Among them, 0.2% of cases had onset of illness before December 31, 2019 and all were from Hubei Province (Figure 2A); 1.7% had onset of illness during January 1–10, 2020, distributed in 113 counties of 22 PLADs and Hubei Province accounted for 88.5% (Figure 2B); 13.8% had onset of illness during January 11–20, 2020, distributed in 627 counties of 30 PLADs and Hubei Province accounted for 77.6% (Figure 2C); 73.1% had onset of illness during January 21–31, 2020, distributed in 1310 counties of 31 PLADs and Hubei Province accounted for 74.7% (Figure 2D).

Epidemiological Curve

Figure 3A shows the COVID-19 epidemic curve with number of cases plotted by date of patient onset of symptoms from December 8, 2019 to February 11, 2020. Confirmed, suspected, clinically diagnosed, and asymptomatic cases are stacked to show total daily cases by date of symptom onset. The inset shows that in December 2019 only 0–22 cases/day began to experience symptoms. The peak onset of symptoms for all cases overall occurred on February 1, 2020. Since then, onset of illness has declined.

Figure 3B shows the same COVID-19 epidemic curve for confirmed cases only with number of cases plotted by date of patients' onset of symptoms from December 8, 2019 to February 11, 2020. These data are overlaid with confirmed cases plotted by date of diagnosis to show the lag between the time patients fall ill and the time they actually are diagnosed and are reported to the Infectious Disease Information System. Although for confirmed cases onset of illness peaked around January 23–27, diagnosis of infection by nucleic acid testing of throat swabs did not peak until February 4.

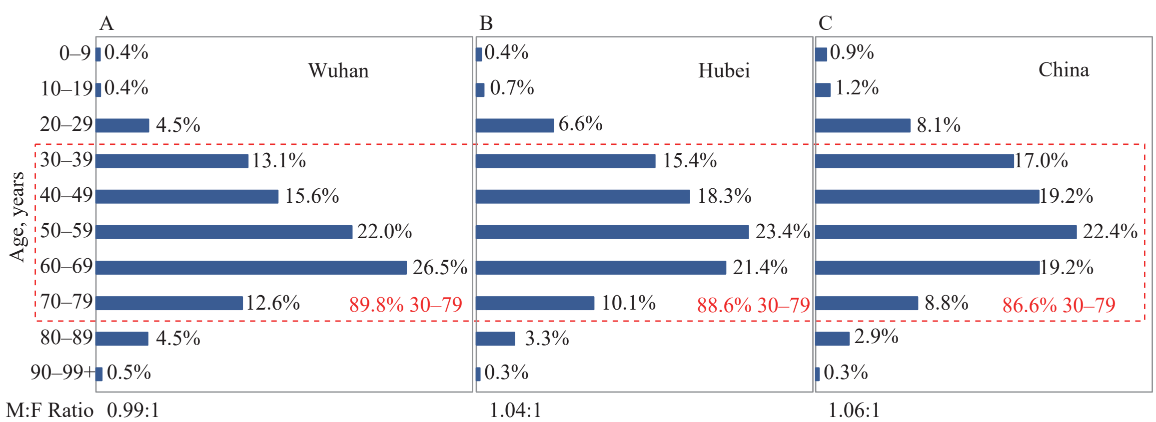

FIGURE 1. Age distribution and sex ratio of all confirmed COVID-19 cases in China through February 11, 2020. (A) patients diagnosed in the city of Wuhan only; (B) patients diagnosed in Hubei Province, which includes Wuhan as its capital city; and (C) patients diagnosed in China overall, including Hubei Province and all 30 other provincial-level administrative divisions (PLADs). Dashed red line highlights the proportion of patients in the 30–79 years age range. Sex ratio (i.e. male-to-female [M:F] ratio) is shown below each graph.

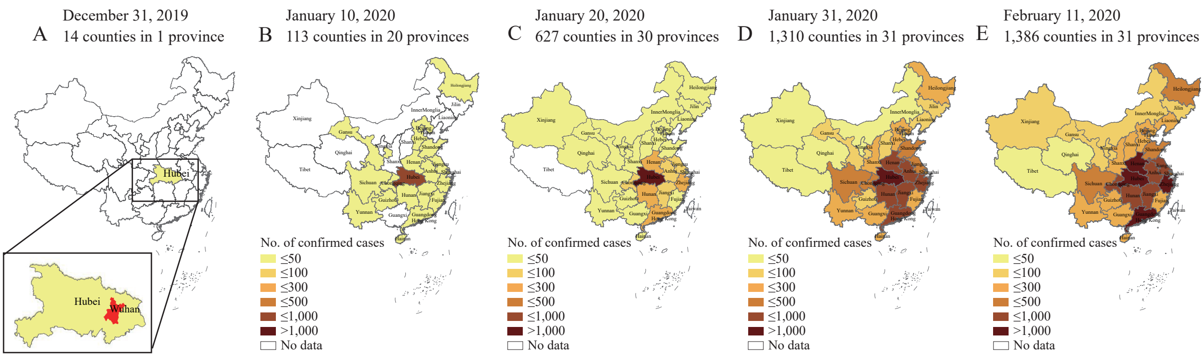

FIGURE 2. Geo-temporal spread of COVID-19 in China through February 11, 2020. (A) a total of 14 county-level administrative areas (hereafter counties) in Hubei Province only (inset) had reported cases as of December 31, 2019; (B) by January 10, 2020, 113 counties in 20 PLADs had reported cases with the highest prevalence still in Hubei Province; (C) nine days later, on January 20, 627 counties in 30 PLADs had reported cases and PLADs neighboring Hubei Province observed increasing prevalence; (D) by the end of January 31, 1,310 counties across all 31 PLADs were affected and prevalence in the central, south, and south-central regions had risen dramatically; (E) by the end of February 11, 1,386 counties nationwide were affected and prevalence in the south-central PLADs had risen to the level of Hubei.

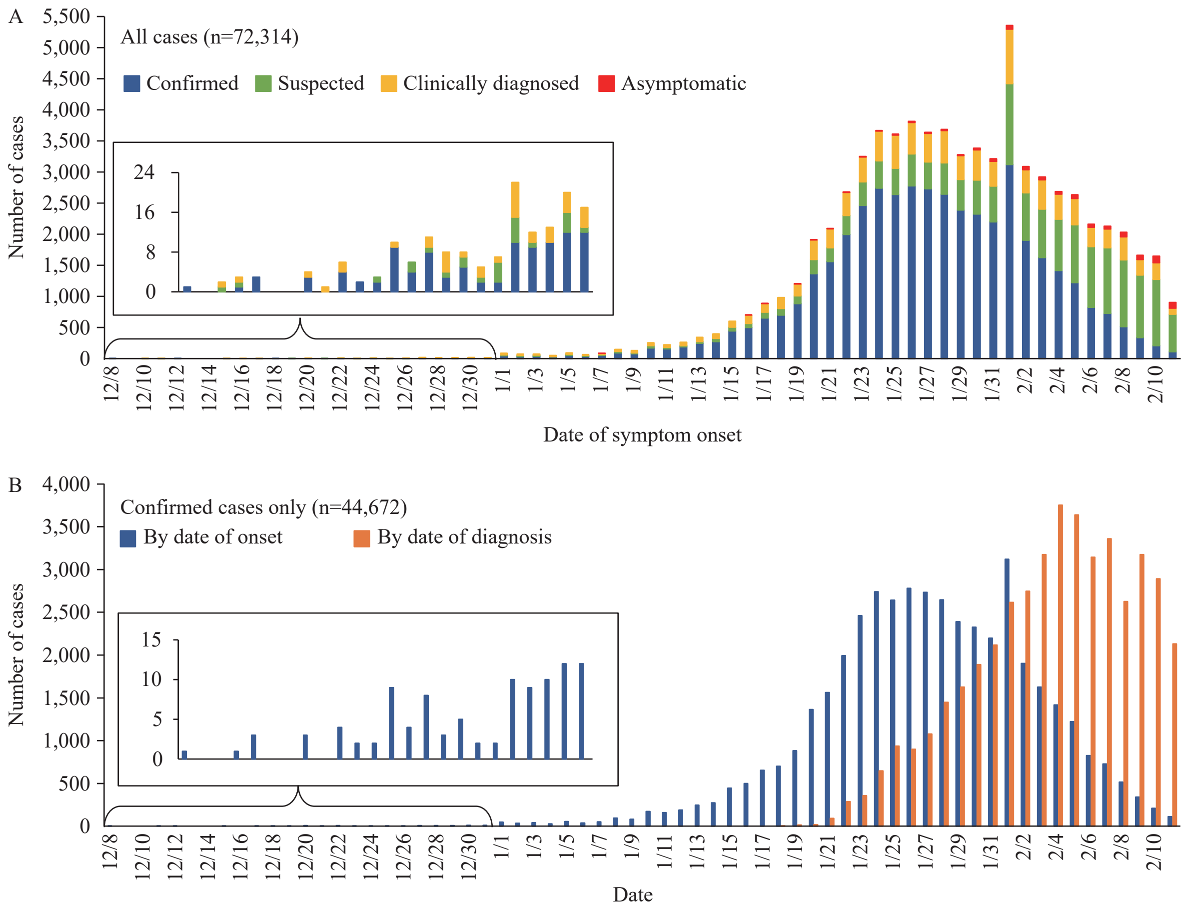

FIGURE 3. Epidemiological curves of COVID-19 in China through February 11, 2020. (A) the epidemiological curve shows the progression of illness in the outbreak over time from December 8, 2019 to February 11, 2020. A total of 72,314 cases are shown and confirmed cases (blue) are compared to suspected cases (green), clinically diagnosed cases (yellow), and asymptomatic cases (red). The inset shows a zoomed-in view of all days in December, when total daily count remained below 24 cases; (B) the epidemiological curve shows the progression of illness in the outbreak over time from December 8, 2019 to February 11, 2020 for confirmed cases only (blue). The number of cases diagnosed each day is also shown for confirmed cases only (orange). The inset shows a zoomed-in view of all days in December, when total daily count remained below 15 cases.

Subgroup Findings

Figure 4 shows the COVID-19 epidemic curve with the number of cases plotted by date of onset of symptoms from December 18, 2019 to February 11, 2020 for two subgroups—confirmed cases found outside of Hubei Province (Figure 4A) and all cases among health workers nationwide (Figure 4B). Peak timing of onset of symptoms among cases outside of Hubei Province occurred on January 27. Most of these cases (85.8%) reported having recently resided in or visited Wuhan or having had close contact with an infected individual from Wuhan. Peak timing of onset of symptoms among health worker cases occurred on February 1. In the 422 medical facilities serving COVID-19 patients, a total of 3,019 health workers have been infected (1,716 confirmed cases), and 5 have died.

Confirmed cases, case severity, and case fatality rates among health workers in different areas of China and different time periods are presented in Table 2. A total of 1,080 confirmed cases among health workers have been found in Wuhan, accounting for 64.0% of

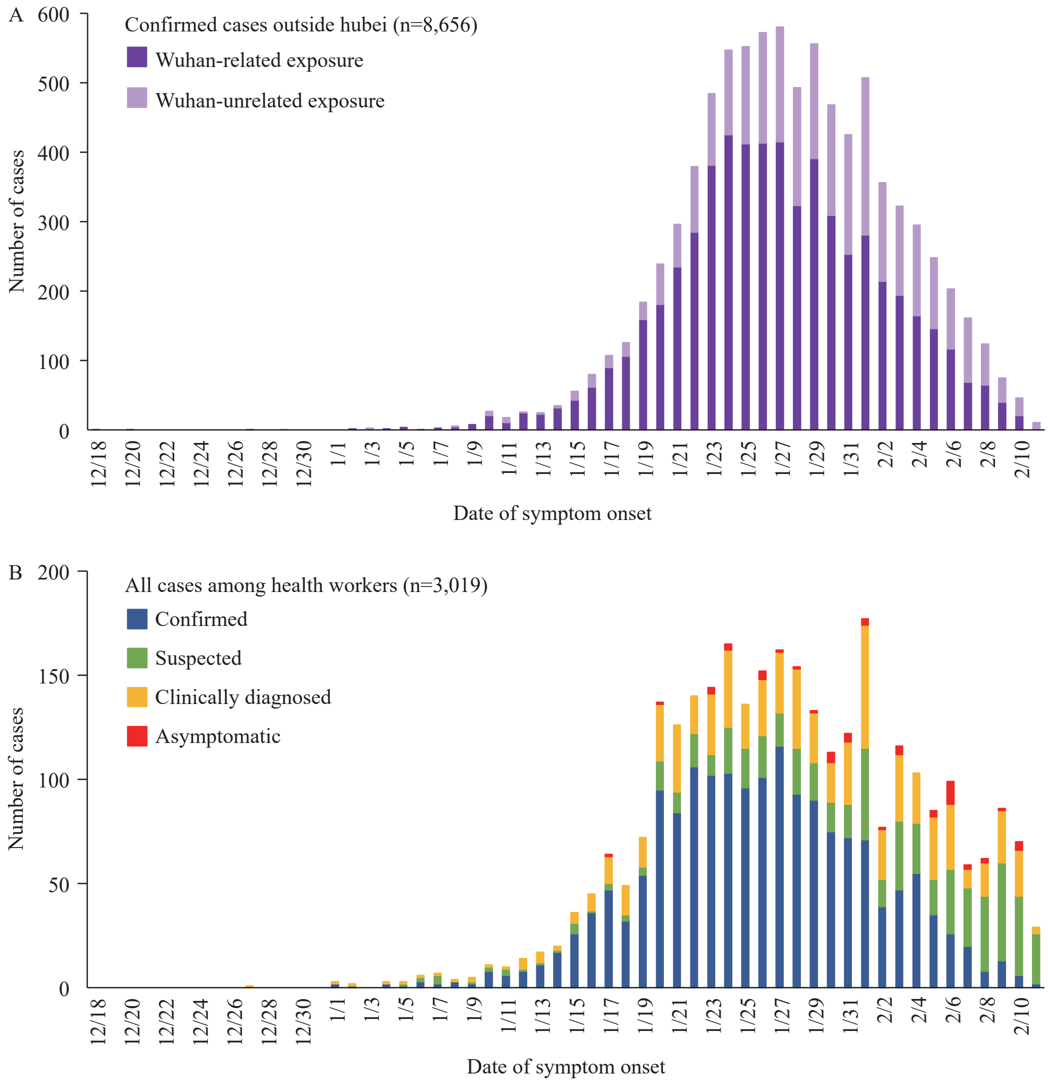

FIGURE 4. Subgroup epidemiological curves of COVID-19 in China through February 11, 2020. (A) subgroup analysis of confirmed cases discovered outside of Hubei Province only. The epidemiological curve shows the progression of illness in the outbreak over time from the onset of symptoms of the first case outside Hubei Province on December 18, 2019 through the end of February 11, 2020. Total confirmed cases outside Hubei Province, and Wuhan-related exposure (dark purple) versus Wuhan-unrelated exposure (light purple), are shown; (B) subgroup analysis of all cases among health workers only. The epidemiological curve shows the progression of illness in the outbreak over time from the onset of symptoms of the first health worker case on December 27, 2019 through the end of February 11, 2020. Total cases among health workers and confirmed (blue) versus suspected (green), clinically diagnosed (yellow), and asymptomatic (red) cases are shown.

national total. An additional 394 health worker cases (23.3%) were found in Hubei Province (excluding Wuhan), and 214 cases (12.7%) were found in the other 30 PLADs. The proportion of health worker cases that were severe or critical was 17.7% in Wuhan, 10.4% in Hubei Province, 7.0% in the remaining 30 PLADs, and 14.6% overall. The proportion of health worker cases in Wuhan classified as severe or critical declined from 38.9% in early January to 12.7% in early February. In China overall, the severe or critical cases among health workers also declined—from 45.0% in early January to 8.7% in early February.

Discussion

A main finding of this characterization and exploratory analysis of the first 72,314 cases of COVID-19 found in China in the 40 days between first recognition of the outbreak of pneumonia with unknown etiology on December 31, 2019 to the end of the study period on February 11, 2020 is that this novel coronavirus is highly contagious. It has spread extremely rapidly from a single city to the entire country within only about 30 days. Moreover, it has achieved such far-reaching effects even in the face of extreme response measures including the complete shutdown and isolation of whole cities, cancellation of Chinese New Year celebrations, prohibition of attendance at school and work, massive mobilization of health and public health personnel as well as military medical units, and rapid construction of entire hospitals.

In light of this rapid spread, it is fortunate that COVID-19 has been mild for 81% of patients and has a very low overall case fatality rate of 2.3%. Among the 1,023 deaths, a majority have been ≥60 years of age and/or have had pre-existing, comorbid conditions such as hypertension, cardiovascular disease, and diabetes. Moreover, the case fatality rate is unsurprisingly highest among critical cases at 49%, and no deaths have occurred among those with mild or even severe symptoms (Table 1).

A major contribution of our study is a first description of the COVID-19 epidemic curves. We interpret the overall curve (Figure 3A) as having a mixed outbreak pattern—the data appear to indicate a continuous common source pattern of spread in December and then from early January through February 11, 2020, the data appear to have a propagated source pattern. This mixed outbreak time trend is consistent with the working theory that perhaps several zoonotic events occurred at Huanan Seafood Wholesale Market in Wuhan allowed 2019-nCoV to be transmitted from a still-unknown animal into humans and, due to its high mutation and recombination rates, it adapted to become capable of and then increasingly efficient at human-to-human transmission (*3*,*8*).

The early days of the outbreak have been reminiscent of SARS and MERS, and indeed, the discovery that the causative agent was a closely-related, never-before-described coronavirus predicted potential for nosocomial transmission and so-called "super-spreader" events (*8*). Unfortunately, 2019-nCoV did indeed infect health workers in China via nosocomial transmission. Here we offer a first description of the 1,716 confirmed cases among health workers. Overall, they also display a likely mixed outbreak pattern—perhaps the data are characterized by a point source curve beginning in late December 2019, which

TABLE 2. Confirmed cases, case severity, and case fatality rates among health workers in different areas of China by time period.

Period (by date of onset)	Wuhan			Hubei (outside Wuhan)			China (outside Hubei)			China (overall)		
	Confirmed cases, N	Severe + critical, N (%)	Deaths, N (CFR*, %)	Confirmed cases, N	Severe + critical, N (%)	Deaths, N (CFR*, %)	Confirmed cases, N	Severe + critical, N (%)	Deaths, N (CFR*, %)	Confirmed cases, N	Severe + critical, N (%)	Deaths, N (CFR*, %)
Before Dec 31, 2019	0	0	0	0	0	0	0	0	0	0	0	0
Jan 1–10, 2020	18	7 (38.9)	1 (5.6)	1	1 (100)	0	1	1 (100)	0	20	9 (45.0)	1 (5.0)
Jan 11–20, 2020	233	52 (22.3)	1 (0.4)	48	8 (16.7)	0	29	1 (3.4)	0	310	61 (19.7)	1 (0.3)
Jan 21–31, 2020	656	110 (16.8)	0	250	29 (11.6)	2 (0.8)	130	10 (7.7)	0	1,036	149 (14.4)	2 (0.2)
After Feb 1, 2020	173	22 (12.7)	1 (0.6)	95	3 (3.2)	0	54	3 (5.6)	0	322	28 (8.7)	1 (0.3)
Total	1,080	191 (17.7)	3 (0.3)	394	41 (10.4)	2 (0.5)	214	15 (7.0)	0	1,688	247 (14.6)	5 (0.3)

Abreviation: CFR, case-fatality rate.
* CFR presented here was calculated as number of deaths (numerator) divided by total number of confirmed cases in the row (denominator), expressed as a percent.

was eclipsed by a higher magnitude continuous source curve beginning on January 20, 2020. To date, there is no evidence of a super-spreader event occurring in any of the Chinese health facilities serving COVID-19 patients. However, we do not know whether this is due to the nature of the virus itself or whether these events have been successfully prevented.

It is these authors' sincere hope and intent that this new analysis, on what has become a "public health emergency of international concern," (*12*) helps to inform health and public health workers preparing for or perhaps already experiencing COVID-19 in their populations. This study provides important insight into several crucial open questions on this epidemic and how to design strategies to effectively control it (*3*). For instance, the downward trend in the overall epidemic curve suggests that perhaps isolation of whole cities, broadcast of critical information (e.g., promoting hand washing, mask wearing, and care seeking) with high frequency through multiple channels, and mobilization of a multi-sector rapid response teams is helping to curb the epidemic.

China's response is certainly an echo of lessons learned during SARS and is a tribute to the work China and other low- and middle-income countries have been doing, with the much-needed help of international partners, over the past few decades to build infectious disease surveillance systems and public health infrastructure capable of catching outbreaks early and responding swiftly using evidence-based best practices. The 2019-nCoV and other coronaviruses may continue to adapt over time to become more virulent (*3*), and zoonosis is not going to stop. We must remain vigilant, hone our skills, fund our defenses, and practice our responses, and we must help our neighbors to do the same.

The very large number of cases included in our study was a major strength. Nevertheless, our study did have some important limitations. Firstly, a large proportion of cases included in our analysis (37%) were not confirmed by nucleic acid testing since this process is slow, labor intensive, and requires specialized equipment and skilled technicians. Yet all 72,314 cases were at least diagnosed clinically and investigated by trained epidemiologists. Secondly, some records did have missing data for a few important variables of interest—Wuhan-related exposure, comorbid conditions, and case severity—which limits our ability to draw conclusions from the data.

In conclusion, the present descriptive, exploratory analysis of the first 72,314 cases of COVID-19 reported through February 11, 2020 offers important new information to the international community on the epidemic in China. In particular, this analysis chronicles the extremely rapid spread of the novel coronavirus despite extreme efforts to contain it. However, important questions remain including identification of the animal reservoir, determination of infectiousness period, identification of transmission routes, and effective treatment and prevention methods including further test development, drug development, and vaccine development (*3*–*4*,*8*–*9*). As an international community, we must all be responsible partners in surveillance, communication, response, research, and implementation of evidence-based public health and clinical practice. The massive vigorous actions taken by the Chinese government have slowed down the epidemic in China and curbed spread to the rest of the world. Although the epidemic appears to be in decline in the lead up to February 11, 2020, we may yet face more challenges. Huge numbers of people will soon be returning to work and school after the extended New Year holiday. We need to prepare for a possible rebound of the COVID-19 epidemic in the coming weeks and months.

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In order to share the results of epidemiological characteristics of COVID-19 domestically and internationally, the Chinese Versionis jointly published on the *Chinese Journal of Epidemiology*.

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Notes from the Field

Isolation of 2019-nCoV from a Stool Specimen of a Laboratory-Confirmed Case of the Coronavirus Disease 2019 (COVID-19)

Yong Zhang[1,&]; Cao Chen[1,&]; Shuangli Zhu[1]; Chang Shu[2]; Dongyan Wang[1]; Jingdong Song[1]; Yang Song[1]; Wei Zhen[1]; Zijian Feng[3]; Guizhen Wu[1]; Jun Xu[2,#]; Wenbo Xu[1,#]

The novel coronavirus (2019-nCoV) is spreading very fast in Hubei Province of China. As of February 14, 2020, 51,986 confirmed cases (including laboratory-confirmed cases and clinically-confirmed cases) were reported in Hubei Province, and 1,318 of them died. Respiratory droplets and contact transmission are considered to be the most important routes of transmission of 2019-nCoV, but do not fully account for the occurrence of all coronavirus disease 2019 (COVID-19) cases, previously known as novel coronavirus pneumonia (NCP), and the reasons for the rapid spread of this virus (*1*).

In Biosafety Level 3 (BSL-3) Laboratory of the National Institute for Viral Disease Control and Prevention, Vero cells were used for viral isolation from stool samples of COVID-19 patients sent by Heilongjiang CDC. A 2019-nCoV strain was isolated from a stool specimen of a laboratory-confirmed COVID-19 severe pneumonia case, who experienced onset on January 16, 2020 and was sampled on February 1, 2020. The interval between sampling and onset was 15 days. The full-length genome sequence indicated that the virus had high-nucleotide similarity (99.98%) to that of the first isolated novel coronavirus isolated from Wuhan, China (Figure 1). In the Vero cells, viral particles with typical morphology of a

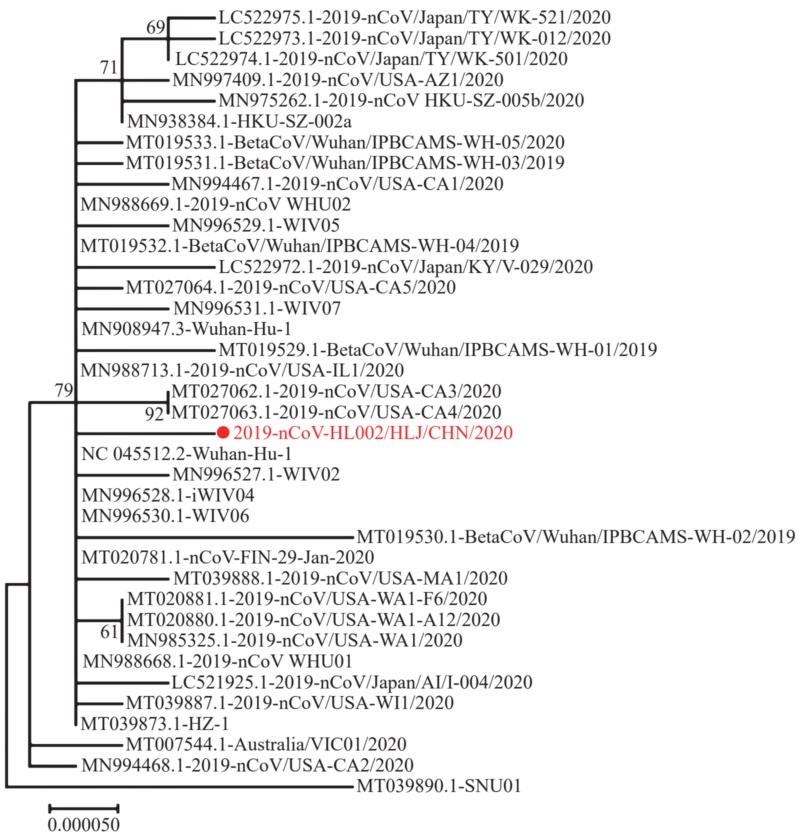

FIGURE 1. Phylogenetic tree based on the full-length genome sequences of 2019-nCoV. The sequence represented by the red circle is the Heilongjiang sequence in this study.

coronavirus could be observed under the electron microscope (Figure 2).

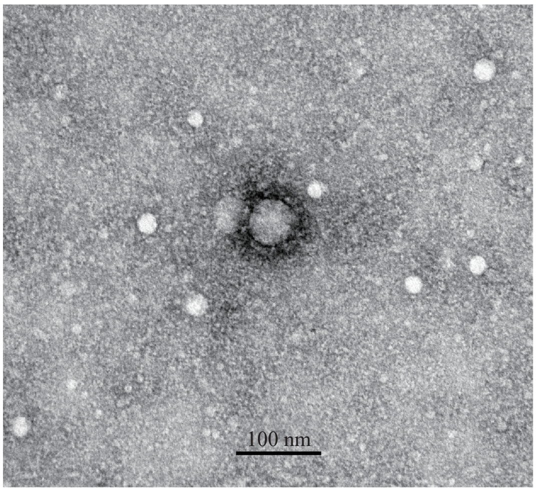

FIGURE 2. A virus particle with typical morphology of coronavirus was observed using electron microscopy after inoculating stool suspension into Vero cells.

These results confirm that COVID-19 patients have live virus in stool specimens, which is a new finding in the transmission routes of 2019-nCoV. In addition to close contact and contact with respiratory secretions of patients, the virus can also be transmitted through the potential fecal-oral route. This means that stool samples may contaminate hands, food, water, etc., and may cause infection by invading the oral cavity, respiratory mucosa, conjunctiva, etc. This virus has many routes of transmission, which can partially explain its strong transmission and fast transmission speed. This study also verified that the nucleic acids of 2019-nCoV can be detected from stool samples (*2*).

This finding has important public health significance. Suggestions to strengthen the control of fecal oral transmission of 2019-nCoV include strengthening health publicity and education; maintaining environmental health and personal hygiene; drinking boiled water, avoiding raw food consumption, and implementing separate meal systems in epidemic areas; frequently washing hands and disinfecting of surfaces of objects in households, toilets, public places, and transportation vehicles; and disinfecting the excreta and environment of patients in medical facilities to prevent water and food contamination from patients' stool samples.

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Notes from the Field

Investigation of a Cluster of 2019 Novel Coronavirus Disease (COVID-19) with Possible Transmission During the Incubation Period — Shenyang City, China, 2020

Ping Wang[1]; Zhiyong Lian[1]; Ye Chen[1]; Ying Qi[1]; Huijie Chen[1]; Xiangdong An[1,#]

Background

In December of 2019, a novel coronavirus (2019-nCoV) emerged in Wuhan China, which was later named COVID-19 (*1*). It quickly spread and as of February 11, 2020, there were 38,800 laboratory-confirmed cases, 16,067 suspected cases, and 1,113 attributable deaths that have affected all provincial-level administrative divisions (PLADs) of Mainland China (*2*).

The first confirmed COVID-19 case in Shenyang City, the capital of Liaoning Province, occurred on January 22, 2020, with a total of 9 confirmed cases by January 29, 2020. Of these cases, 4 were clustered in one family. Shenyang CDC immediately launched an investigation to determine routes of transmission, scale of the outbreak, and evidence for epidemic control.

Methods and Case Finding

This investigation focused on cases that were clustered. In-person interviews were conducted with a detailed questionnaire. Using the China CDC guideline definitions for suspected and confirmed COVID-19 cases, the following criteria was used.

A suspected case was defined in a person fulfilling at least 1 from items 1–4 that revealed exposure history, 2 from items 5–7 that revealed clinical symptoms, or with items 5, 6, and 7 if there was no exposure history (*3*).

1. History of travel to or being a resident of Wuhan, areas surrounding Wuhan, or any other places where COVID-19 patients were reported.
2. Contact history with COVID-19 confirmed case(s).
3. Contact history with a patient with fever or respiratory symptoms who came from Wuhan, areas surrounding Wuhan, or other places where COVID-19 patients were reported.
4. Be one of the fever or respiratory symptom cluster cases.
5. Fever and/or respiratory symptoms.
6. Radiographic evidence of pneumonia.
7. Low or normal white-cell count or low lymphocyte count.

A confirmed case was defined as a suspected case with respiratory or blood specimens that tested positive for the COVID-19 by RT-PCR or with a genetic sequence highly homologous to COVID-19.

We did face to face interviews with all confirmed cases to understand their activities during the previous 14 days before onset of symptoms. All close contacts were advised to isolate themselves at home for 14 days with daily check-ins by local CDC staff and body temperature readings were required two times a day. If a contact developed fever or respiratory symptoms, they would immediately be sent to the hospital for testing by RT-PCR testing.

Results

History of the primary case:

January 17: A 21-year old student from Shenyang (Patient A) travelled to Wuhan with 5 classmates on January 17 and returned on January 20 by air while wearing masks. Her father picked her up at the airport at 3: 30 pm via personal car, where both wore masks, to return home, and no one wore masks at home.

January 20 Evening: Patient A had dinner with her boyfriend, who later became Patient D, at 8 pm for 3 hours in a fast-food restaurant.

January 21: Patient A participated in a family dinner with seven other relatives including her father, mother, grandfather, grandmother, uncle, aunt, and cousin. All those at the dinner were later quarantined at home for 14 days. Besides her parents, the other five family members who attended the dinner showed no symptoms and their throat swabs tested negative for COVID-19 using RT-PCR.

January 22: Patient A had a party with 11 friends for

6 hours including her boyfriend. They were later quarantined at home for 14 days.

January 23: Patient A became symptomatic around 4 pm with no previous symptoms. She then began having nasal congestion, runny nose, fatigue, headache, and fever (37.3 ℃). Her fever increased to 38.7 ℃ that night. Her father (Patient B) also had a fever that started at 6 pm the same day.

January 24: Patient A and B went to the hospital together where both tested positive for COVID-19 by RT-PCR. They were diagnosed as confirmed cases and isolated at hospital.

January 25: The mother (Patient C) of Patient A was under self-isolation at home, experienced onset of fever, and was laboratory confirmed with COVID-19 on January 26.

January 27: Patient A's boyfriend experienced onset of fever and was confirmed with COVID-19 on January 28. They only met twice at restaurant on 20 and 22, respectively. Among the four total cases in this cluster, only Patient A had traveled outside of Shenyang or had traveled to Wuhan, and none of the other three patients had traveled or had contact with another confirmed case (Table 1).

Among the 11 friends who had the party with patient A, one friend, who sat next to patient A at the party, developed fever (37.9 ℃), sore throat and productive cough on Jan 25. However, her two successive throat swabs showed negative RT-PCR results for COVID-19. The other 10 friends showed no symptoms and their throat swabs all showed negative RT-PCR results for COVID-19 after 14 days quarantine.

Of the five other classmates that had traveled to Wuhan with Patient A, none developed symptoms during the 14 days of self-quarantine. Their throat swabs tested negative by RT-PCR for COVID-19. Everyone in the group who traveled to Wuhan bought duck snacks, a Hubei-Province delicacy, for their families and no further cases were found among those who ate the snacks. Figure 1 showed the epi curve of the 4 cases (Figure 1).

From the 4 cases, 43 contacts were identified, and all contacts were quarantined at home for 14 days and showed no symptoms. Patients were immediately isolated at the hospital when they were confirmed.

Among the 169 passengers and 14 crew who were on the flight returning from Wuhan to Shenyang with Patient A, another confirmed case of COVID-19 was found among the passengers. This passenger became febrile on January 25 and was COVID-19 confirmed on January 28 in Jiamusi, Heilongjiang Province. After arriving in Shenyang by air he traveled by train to Changchun on January 20. His 3 family members were infected in the several days following his return home. This passenger was seated 13 rows apart from Patient

TABLE 1. The cluster of COVID-19 cases by age, sex, onset of symptoms, laboratory confirmation, and travel history in Shenyang, China, 2020.

Case	Sex	Relationship to patient A	Age	Onset of symptoms	Laboratory confirmation	Date of diagnosis	Travel history
A	Female	Self	21	January 23	Confirmed	January 24	Flight to Wuhan 1/17 Return 1/20
B	Male	Father	44	January 23	Confirmed	January 24	No travel
C	Female	Mother	45	January 25	Confirmed	January 26	No travel
D	Male	Boyfriend	21	January 27	Confirmed	January 28	No travel

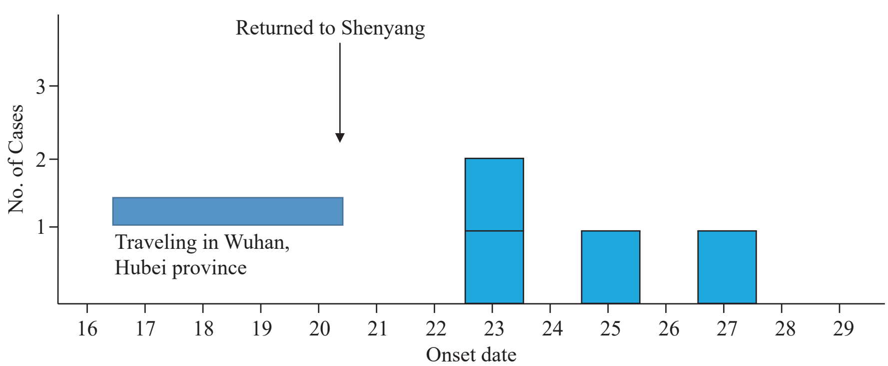

FIGURE 1. The epi curve of a cluster of COVID-19 cases of in Shenyang, China, 2020.

A, did not know Patient A. The passenger said that he did not show any symptoms on the plane.

Discussion

Transmission of COVID-19 is thought to primarily be from patients with overt symptoms (coughing, sneezing, runny nose, fever, and contaminated hands). Spread of coronavirus during incubation period is considered quite possible given the transmission factors of other coronaviruses (*4*).

Based on the results of the cluster investigation, we concluded that Patient A likely transmitted COVID-19 to 3 close contacts during her incubation period. Patient A was home 3 days before onset of symptoms, which occurred on the same day her father, Patient B, experienced onset of fever symptoms and the day before both were laboratory-confirmed with COVID-19. Patient C, the mother, was exposed to Patient A five days before onset of symptoms. Patient D, boyfriend, had symptoms five or seven days after exposure to Patient A. If COVID-19 can be transmitted in the incubation period, as possibly indicated in this investigation, then epidemic control will be more difficult (*5*).

Currently, close contact recommendations focus on those who had contact with cases after development of symptoms and 2 days before development of symptoms, which is in accordance with the national close contact guidelines for COVID-19 in China. More of an evidence base is needed to evaluate transmission during incubation period and its importance and contribution to the COVID-2019 epidemic.

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Commentary

A Strong Public Health System: Essential for Health and Economic Progress

Tom Frieden[#]

Public health has been defined as "*the science and art of preventing disease, prolonging life, and promoting health through the organized efforts and informed choices of society, organizations, public and private communities, and individuals*" (*1*).

Public health, and not medical care, has been responsible for most of the health gains in the world during the past century. Public health initiatives such as clean water and sanitation, vaccination, tobacco control, motor vehicle and workplace safety, and improved nutrition led to 80% of the gain in U.S. life expectancy in the 20th century (*2*). Globally, public health accomplishments such as smallpox (*3*) and polio eradication (*4*), and immunization (*5*) have saved millions of lives.

The U.S. CDC, created in 1946, has become an epicenter of public health knowledge and practice (*6–7*). China CDC is a much younger organization, created in 2002. The following year, the SARS outbreak killed 774 people worldwide, including 349 in China. In response, China's government made substantial investments to strengthen China CDC (*8*). I was privileged to serve as director of the U.S. CDC from 2009–2017, and have seen firsthand, through visits and regular communication, how dedicated China CDC leadership and staff are.

The most effective public health units at local, city, state/provincial, national, and global levels have at least 5 key components (*7,9*). These include:

Sufficient funding. The U.S CDC's annual budget is more than U.S. $12 billion (*10*), which is nearly U.S. $40 per person.

Sufficient number and quality of staff to detect, investigate, stop, and prevent health threats, including robust laboratory and disease investigation capacity. The U.S. CDC has approximately 14,000 regular full-time staff and another 10,000 contract staff focused on all aspects of health promotion and disease prevention, from infectious diseases and environmental health to noncommunicable diseases and injuries (Table 1). In virtually any area of health, some of the world's top experts are working at the U.S. CDC. In addition, in the United States, state, city, and local public health agencies employ more than 200,000 additional people. Furthermore, the U.S. CDC is able to pay top health experts competitive salaries above the standard government pay scale (*11*).

Close connections with other public health and health care entities. The U.S. CDC sends billions of dollars a year – 60% of its budget – to state and city health departments to assist with specific programs. These are in the form of "cooperative agreements" and include specific requirements for the local area and commitments of the U.S. CDC. U.S. CDC also sends 1,000 staff to embed with state, city, and local health departments for periods of 2 years or more. These local agencies have a wide range of capacities, some on par or superior to those at U.S. CDC, and others which need extensive technical and financial support. The essential importance of the U.S. CDC has been not just providing reference and technical leadership, but also upgrading skills and capacities of state and local public health, where competence can determine whether an emerging health threat is found and stopped rapidly.

Technical independence in the context of political support. The U.S. CDC is a federal agency just two steps removed from the President, with considerable latitude to act independently. CDC's technical expertise is respected both within and outside of government, both in the U.S. and globally. As U.S. CDC director, I briefed President Barack Obama on critical health issues. This direct access to the highest level of government gives U.S. CDC authority and ensures that public health is prioritized at a national level.

Effective communication. The U.S. CDC communicates frequently and effectively with the public, doctors, the media, and policy-makers. It produces the *MMWR*, a weekly epidemiological digest widely respected as a definitive resource worldwide. In times of crisis, it follows the risk communication principle: "Be first, be right, be credible".

China has a history of excellent public health

TABLE 1. Number and proportion of United States Centers for Disease Control and Prevention staffing in different public health areas.

Unit	Staff	Percentage
National Center for Emerging and Zoonotic Infectious Diseases	1,296	11%
Center for Global Health	1,263	11%
National Center for HIV, Viral Hepatitis, Sexually Transmitted Diseases, and Tuberculosis Prevention	1,204	10%
National Institute for Occupational Safety and Health	1,073	9%
National Center for Chronic Disease Prevention and Health Promotion	828	7%
National Center for Environmental Health/Agency for Toxic Substances and Disease Registry	701	6%
National Center for Immunization and Respiratory Diseases	683	6%
Center for Preparedness and Response	485	4%
National Center for Injury Prevention and Control	407	4%
National Center for Birth Defects and Developmental Disabilities	202	2%
Scientific services including the National Center for Health Statistics	1,336	12%
Cross-cutting including support to states, tribes, localities, and territories	1,993	17%
Total	11,471	

Note: Includes authorized full-time equivalent positions but does not include approximately 10,000 individuals for whom the unit-wise breakdown is not available. These include contractors, fellows, locally employed staff in global offices, and other categories. https://www.cdc.gov/budget/documents/fy2021/FY-2021-CDC-congressional-justification.pdf and https://www.cdc.gov/budget/documents/fy2021/FY-2021-ATSDR-congressional-justification.pdf.

practice. The country has reduced maternal and infant mortality rates and improved life expectancy over the past half century (*12*). There has been great progress controlling and even eliminating many formerly endemic infectious diseases (*13*). China faces new challenges with the emergence of new infectious diseases such as COVID-19, increasing antimicrobial resistance worldwide, and the increase in noncommunicable diseases, driven in part by high smoking rates among men, high sodium consumption, and air pollution (*14*). The Healthy China 2030 policy established a plan to achieve the UN Sustainable Development Goals (SDGs) and address these important health issues (*15*).

Epidemic prevention and control requires both hard work and deep expertise. Infectious disease cases need to be detected, investigated, treated, and monitored, with contacts traced and checked and epidemiological trends analyzed to identify prevention strategies. Every country needs capacity to prevent, detect, and effectively respond to disease outbreaks – and the larger the country, the more resources are needed.

China has made extraordinary efforts to understand and contain COVID-19. China's public health system became much stronger after SARS. Those of us working in global public health hope that, just as SARS led China to step up the function and investment in China CDC, the current effort will trigger another exponential leap in public health capacity in China.

Compared with the strongest public health systems in the world, China has great strengths, including community mobilization. In other areas, China's public health system has the potential to increase its contributions to China's growth and development. This will not only better protect the health of the Chinese people, but also have a ripple effect regionally and throughout the world.

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Dr. Tom Frieden (MD, MPH) is the former director of the US Centers for Disease Control and Prevention, and commissioner of the New York City Health Department. He is currently president and CEO of Resolve to Save Lives, a global non-profit initiative of Vital Strategies, working with countries to prevent 100 million deaths and make the world safer from epidemics. Vital Strategies is officially registered as an international non-governmental organization in China, with headquarters in Shandong Province.

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