Lockdown contained the spread of 2019 novel coronavirus disease in Huangshi city, China: Early epidemiological findings

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Summary

The epidemic scale of COVID-19 has increased rapidly worldwide. Lockdown and nonpharmaceutical interventions effectively contained the progression of COVID-19 in Huangshi city, China. Feb 1 (day 9 of lockdown) was identified as the “turning point” as the epidemic faded soon.

Abstract

Background To control the spread of 2019 novel coronavirus disease (COVID-19), China sealed Wuhan on Jan 23, 2020 and soon expanded lockdown to other twelve cities in Hubei province. We aimed to describe the epidemiological characteristics in one of the cities and highlight the effect of current implemented lockdown and nonpharmaceutical interventions.

Methods We retrieved data of reported cases in Huangshi and Wuhan from publicly available disease databases. Local epidemiological data on suspected or confirmed cases in Huangshi were collected through field investigation. Epidemic curves were constructed with data on reported and observed cases.

Results The accumulated confirmed COVID-19 cases and fatality in Huangshi were reported to be 1015 and 3.74% respectively, compared with 50006 and 5.08% in Wuhan till Mar 27, 2020. Right after Jan 24, the epidemic curve based on observed cases in Huangshi became flattened. Feb 1, 2020 was identified as the "turning point" as the epidemic in Huangshi faded soon afterwards. COVID-19 epidemic was characterized by mild cases in Huangshi, accounting for 82.66% of total cases. Moreover, 50 asymptomatic infections were identified in adults and children. Besides, we found confirmed cases in 19 familial clusters and 21 health care workers, supporting inter-human transmission.

Conclusions Our study reported the temporal dynamics and characteristics of the COVID-19 epidemic in Huangshi city, China, across the unprecedented intervention. Such new epidemiological inference might provide further guidance on current lockdown measures in high-risk cities and, subsequently, help improve public health intervention strategies against the pandemic on the country and global levels.

Introduction

In December 2019, several cases of pneumonia of unknown etiology occurred in Wuhan city, Hubei province, China [1]. On Jan 7, 2020, a novel coronavirus was identified by the Chinese Center for Disease Control and Prevention (CDC) from the throat swab sample of a patient. It was named 2019 novel coronavirus (2019-nCoV) by World Health Organization (WHO)[2], and subsequently severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) by the Coronavirus Study Group (CSG) of the International Committee on Taxonomy of Viruses [3]. Preliminary studies have suggested that SARS-CoV-2 is more infectious but less deadly than the severe acute respiratory syndrome (SARS) and the Middle East respiratory syndrome (MERS) [4-8]. The disease has rapidly spread from Wuhan to other areas in China and other 190 countries in the world [9]. Many countries are facing the challenges in controlling its spread.

Wuhan is the capital of Hubei province with more than 11 million residents and is connected to other cities via high-speed railways and frequent domestic and international airline flights. In the early days of this outbreak, a total of 389 confirmed cases reported in Wuhan on Jan 22, 2020, there was much uncertainty in the epidemic scale. However, it was estimated that there would be over 3 billion passenger journeys within as well as in and out of China between Jan 10 and Feb 18, around the Spring Festival (CGTN, 2020) [10]. As of Jan 23, 2020, Chinese government initiated an unprecedented public health intervention to confine the epidemic by shutting down all transportation in and out of Wuhan (i.e. a modern form of quarantine) [11]. It was estimated that the number of newly confirmed cases would reach its peak at 8 (6-10) days after the lockdown initiation and that the quarantining might last for two weeks [12]. However, the real-world evidence for the impact of such interventions has not been thoroughly examined. The outbound travel restriction still remains effective in Wuhan when this article is written (Mar 28, 2020).

Huangshi city, with population 2.7 million, is located in the south-east of Hubei Province, bordering Wuhan. Given their geographical and economical connection, Wuhan and Huangshi are officially recognized as “sister cities”. Lockdown of Huangshi meant to curb the import of COVID-19 cases from Wuhan, as well as the export of cases to other cities. The lockdown intervention, same as that in Wuhan, has lasted for two months (between Jan 24

and Mar 23, 2020) in Huangshi. At present, little is known regarding the COVID-19 epidemic in other cities near Wuhan. We conducted this study to describe epidemiological features of the novel coronavirus spread in Huangshi, and to highlight the effect of the lockdown intervention.

Methods

Data source

We retrieved and merged data of reported cases in Huangshi and Wuhan from publicly available disease databases of Hubei Provincial Health Committee (http://wjw.hubei.gov.cn/). Local epidemiological data on suspected and confirmed cases in Huangshi were collected through field investigation by epidemiologists from local CDC together with trained health care workers from the hospitals. Standardized forms were designed to interview with the patients, their relatives and close contacts. Data used in the present analyses include age, gender, geographic location, dates of symptoms onset, contact history with suspicious persons or environment, and clinical syndromes.

Data collection and analysis of these cases were determined by the municipal Health Commission to be part of an outbreak investigation. The study was thus deemed exempt from institutional review board approval.

Infection control measures

As of 10:00 AM Beijing time, Jan 23, 2020, Wuhan shut down all public transportation, including the airport, railway station, bus and subway services. Closure of travel to and from the Huangshi was implemented starting 10:00 AM, Jan 24, 2020. In addition, Huangshi on Jan 25, 2020 addressed a wide range of nonpharmaceutical interventions (NPI) regarding surveillance, detection and containment measures

(http://www.hbdaye.gov.cn/xwzx/dyyw/202001/t20200128_597815.html). First, real-time syndromic surveillance was used for individuals seeking care at clinics or hospitals to detect the onset of the illness. Second, health screening and quarantine were applied for incoming travelers. Third, voluntary personal social isolation (such as staying at home) and compulsory facial masks outdoors were indicated for all residents, followed by monitoring and reporting. Last, factories, businesses, schools and other institutions were closed during the outbreak. The community workers, together with volunteers, dedicated to ensure the effective NPI implementation. As the epidemic situation goes stable, Huangshi on Mar 13, 2020 announced resuming work and production in an orderly manner.

Case definitions

These diagnostic criteria were based on the WHO interim guidance [2] and the recommendation by the Chinese National Health Commission (http://www.gov.cn/zhuanti/2020-02/05/content_5474791.htm).

A confirmed case was defined as one both (1) fulfilled two clinical criteria plus one epidemiological clue, or all three clinical criteria, and (2) had the throat-swab specimens tested positive for SARS-CoV-2 using real-time RT-PCR assay. Clinical criteria of manifestations: (ⅰ) fever and/or acute respiratory illness; (ⅱ) radiographic evidence of pneumonia; (ⅲ) low or normal white-cell count or low lymphocyte count. Epidemiological clues: (ⅰ) history of travel to or residence in Wuhan city within 14 days prior to symptom onset; (ⅱ) close contact with a confirmed or probable case of COVID-19 within 14 days prior to symptom onset; (ⅲ) close contact with persons who had fever or acute respiratory illness and were from Wuhan city or local community with case-reported, within 14 days prior to symptom onset; (ⅳ) a cluster of persons with similar symptoms was identified. The laboratory protocol for SARS-CoV-2 real-time RT-PCR assay was described previously [4]. The tests were screened by local CDC and confirmed by Hubei provincial CDC.

Confirmed cases were classified into four clinical syndromes: (1) uncomplicated illness, e.g. cold-like upper respiratory illness; (2) mild pneumonia, i.e. mild radiographic evidence of pneumonia; (3) severe pneumonia, plus one of severe respiratory distress, respiratory rate

>30 breaths/min, or SpO_2 <90% on room air; (4) critically illness, complicated with septic shock or acute respiratory distress syndrome (ARDS) needing mechanical ventilation.

From Feb 12, 2020, the clinically diagnosed patients in Hubei province (not applicable for other provinces in China) who fulfilled one epidemiological clue and had radiographic evidence of pneumonia were classified as confirmed cases, regardless of the PCR results.

Statistical analysis

All Continuous variables were analyzed with student t tests and categorical variables with chi-square or Fisher's exact tests. A *P*-value of <0.05 was considered as the level of significance. The epidemic curves were constructed on reported or observed cases. Stata software (version 14.0, StataCorp, USA) was used for statistical analysis. The maps were performed using ArcGIS software (version 10.6, Esri, USA).

Results

The accumulated number of confirmed cases with COVID-19 in Huangshi and Wuhan were reported to be 1015 and 50006 respectively till Mar 27, 2020 (Fig. 1A). In Huangshi, 57% (575/1015) of the total cases were in the main city, following by its two satellite cities Daye (24%) and Yangxin (16%). Patients in Huangshi showed slightly lower case fatality of 3.74% (38/1015), compared with 5.08% (2538/50006) in Wuhan (*P*=0.055).

Based on the reported data by the official government, we constructed the epidemic curves of confirmed and fatal cases with COVID-19 in Wuhan and Huangshi from Jan 10 to Mar 27, 2020 (Fig. 1B, 1C). The exponential increase in the number of reported cases was observed in Wuhan. The abrupt increase on Feb 12 was attributed to the diagnosis criteria modification (Fig. 1B). In contrast, the threat of a sustained epidemic in Huangshi is less likely (Fig. 1C).

Given that there was delay for the laboratory test and diagnosis procedure, we also constructed the epidemic curve for Huangshi based on symptoms onset. The first case of

COVID-19 in Huangshi was observed on Jan 2. The onset day of epidemic was Jan 10, defined as the first day of ascending phase leading to the peak. Right after Jan 24 (day 1 of lockdown), the epidemic curve became flattened, suggesting that the lockdown intervention slowed the progression of the epidemic. Feb 1, 2020 (day 9 of lockdown) was identified as the "turning point" as the epidemic in Huangshi faded soon afterwards. There have been no new cases observed since Feb 26, 2020 (Fig. 1D).

Demographic and clinical characteristics of the 1015 confirmed COVID-19 cases, 93.62% (997) of whom were SARS-CoV-2 RNA positive, are shown in Table 1. They were consisted of 509 males and 504 females, aged from 1 month through 92 years (mean 49.01, median 49). The novel coronavirus infection predominated in the young and mature adult age groups (18-44 group, 37.04%; 45-64 group, 42.07%). There were eight cases in infants (0-3 years) and six cases in pregnant women. The proportion of health care worker (HCW) cases was 2.07% (21/1015). Those patients who had a history of visit to or residence in Wuhan city within 14 days prior to symptom onset were defined as probably imported cases. The percentages of imported cases in patients with symptom onset before Jan 24, 2020 and patients onset afterwards were 63.07% and 31.94% respectively (P<0.001). COVID-19 epidemic was characterized by mild cases (uncomplicated illness or mild pneumonia) in Huangshi, accounting for 82.66% of total cases. The percentage of uncomplicated illness in cases with symptoms onset on/after Jan 24, 2020 were significantly higher than that in cases with earlier onset (46.48% vs. 23.30%, P<0.001). There was no significant difference between cases with onset before Jan 24, 2020 and those afterwards in terms of age, gender and fatality rate.

Nineteen familial clusters of confirmed cases have been found, shown in Figure 2. Four clusters were comprised of imported cases and local cases. The other fifteen clusters were all local cases, suggesting secondary or tertiary transmission. Based on the dates of illness onset of cases in these clusters, we estimated that the serial interval distribution was 6.5±6.3 days (mean ± SD).

Moreover, asymptomatic infections have been identified not only in 41 adults but also in 9 children. They had epidemiological clues for COVID-19 contact and the throat-swab tested positive for SARS-CoV-2 RNA. After quarantined for at least 14 days, all the persons had no signs of illness.

Discussion

As observed during this pandemic, the novel coronavirus virus could spread globally before the epidemic peaks locally [9]. One week before WHO's declaration of the global public health emergency of international concern (PHEIC), Chinese government launched the remarkable lockdown intervention in high-risk cities, the first such quarantine in its history. To the best of our knowledge, this report for the first time described the epidemiological features of the COVID-19 outbreak in a city in China, other than Wuhan, across the implemented lockdown intervention. The relationship detected in our analysis strongly suggests that the aggressive public health intervention resulted in flattened epidemic curves and a trend toward better overall outcomes.

Why were Huangshi and other eleven cities closed down besides Wuhan? There had been concerns that the synchrony level of COVID-19 epidemics in Hubei's 13 cities might be high enough to view Hubei province as "single epidemiological unit" [13]. However, our study revealed considerable differences in the timing and magnitude of COVID-19 epidemics between Huangshi and Wuhan cities. The basic reproduction number (R_0) of COVID-19 was estimated to be as high as 3.11-6.49 [12, 14]. It turned out that the rapidity of the growth of cases in Wuhan was much greater than that observed in outbreaks of either SARS or MERS-CoV [15, 16]. The lockdown intervention resulted in the limited outbreak in Huangshi, as well as containment of the export of cases. Some mathematical models suggested that the lockdown strategy applied early may significantly reduce disease transmission by up to 70% [12].

Most researchers believe that Wuhan is the epicenter of COVID-19 outbreak, with patient zero suspected to have originated there. Yet, how this novel coronavirus arrived in Wuhan remains unclear. The primary reservoirs for SARS-CoV and MERS-CoV were bats while the intermediary sources were civet cats and camels respectively [17]. The genomic sequencing results showed that 2019-nCoV was closely related (with 88% identity) to two bat-derived SARS-like coronaviruses, but more distant from SARS-CoV (79%) and MERS-CoV (50%) [18]. In addition, the epidemiological association between 66% (27/41) of the initial infected patients with Huanan wet market [4], suggests that the novel coronavirus may be related to sale of wild animal as game food. Consistent with previous reports, we found laboratory-

confirmed cases in 19 familial clusters and 21 health care workers, supporting human-to-human transmission.

It is worth noting that COVID-19 was characterized by mild cases (uncomplicated illness plus mild pneumonia) in Huangshi, accounting for 82.66% of total confirmed cases, higher than previous reports on cases in Wuhan [6]. In addition, 50 asymptomatic infections were identified through screening. This might be explained by both a decreased virulence throughout the successive transmission, like SARS-CoV [19], and under-reporting bias in early cases in Wuhan. Undetected asymptomatic or mild cases may also be a factor in the apparent decrease in the case fatality rate over time. If asymptomatic or mildly symptomatic but infectious cases constituted an important fraction of the total infection, R_0 might be higher than estimated because detecting and isolating these cases would be "extremely challenging" [20, 21].

A practical issue requiring further study is when such lockdown intervention could be relaxed. Without an effective vaccine, these cities remain vulnerable against imported cases with infection. In the event of a severe pandemic, such as 1918 influenza, cities will likely need to maintain lockdown for longer than 2-8 weeks [22]. Actually, Huangshi city reported no new cases since it lift lockdown on Mar 23, 2020.

Admittedly, this study has several limitations. First, only one city with COVID-19 was included. It would be better to include as many cities as possible in Hubei, and in other provinces in China to get a more comprehensive insight of COVID-19 epidemic. Second, more detailed information, such as genomic sequencing outcomes and the overall people's response to NPI measures, was unavailable at the time of analysis. However, the data in this study permit an early assessment of the epidemiological characteristics of COVID-19 in Huangshi, China. Last, under-reporting bias is also a natural limitation of this study, as some asymptomatic or mild cases might be missed.

In conclusion, our study reported the temporal dynamics and characteristics of the COVID-19 epidemic in Huangshi city, China, across the implemented lockdown intervention. Such new findings might provide further guidance on current lockdown intervention in high-risk cities and, subsequently, improve public health strategies against the pandemic on the country and global levels.

Note

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Table 1. Demographic and clinical characteristics of confirmed COVID-19 cases in Huangshi

Characteristics	Symptom onset		Total (n=1015)
	before Jan 24 (n=176)	on/after Jan 24 (n=839)	
Age (years)[a]	48 (21-85)	50 (0-92)	49 (0-92)
≤17	0	19 (2.26%)	19 (1.87%)
18–44	75 (42.61%)	301 (35.88%)	376 (37.04%)
45–64	79 (44.89%)	348 (41.48%)	427 (42.07%)
≥65	22 (12.50%)	171 (20.38%)	193 (19.01%)
Male	87 (49.43%)	422 (50.30%)	509 (50.15%)
Imported case[b]	111 (63.07%)	268 (31.94%)	379 (37.34%)
Pregnant women	0	6 (0.68%)	6 (0.59%)
Clinical syndrome			
Uncomplicated illness[c]	41 (23.30%)	390 (46.48%)	431 (42.46%)
Mild pneumonia	104 (59.09%)	304 (36.23%)	408 (40.20%)
Severe pneumonia	23 (13.07%)	84 (10.01%)	107 (10.54%)
Critical illness	8 (4.55%)	61 (7.27%)	69 (6.80%)
Fatality	4 (2.27%)	34 (4.05%)	38 (3.74%)
Health care worker	4 (2.27%)	17 (2.03%)	21 (2.07%)

a: median (range)

b: Imported cases were defined as those who had a history of visit to or residence in Wuhan city within 14 days prior to symptoms onset. Chi-square test P <0.001

c, Percentage of uncomplicated illness. Chi-square test P <0.001

FIGURE LEGENDS

Figure 1. Epidemic curves of reported and observed cases with COVID-19 in Wuhan and Huangshi. (A) The accumulated number of confirmed and fatal cases with COVID-19 in Wuhan and Huangshi till Mar 27, 2020; (B) New confirmed and fatal cases in Wuhan between Jan 10 and Mar 27, 2020; (C) New confirmed and fatal cases with COVID-19 in Huangshi between Jan 10 and Mar 27, 2020; (D) New observed cases with COVID-19 in Huangshi between Jan 2 and Mar 1, 2020

Figure 2. Timeline of nineteen familial clusters of COVID-19 in Huangshi. The date of diagnosis (eg. 2.4, Feb 4, 2020), gender (M or F, male or female), age (y or m, years or months), relationship to the index case (eg. son or mother), imported case or not (Wuhan or local) were used to denote main characteristics of the patient.

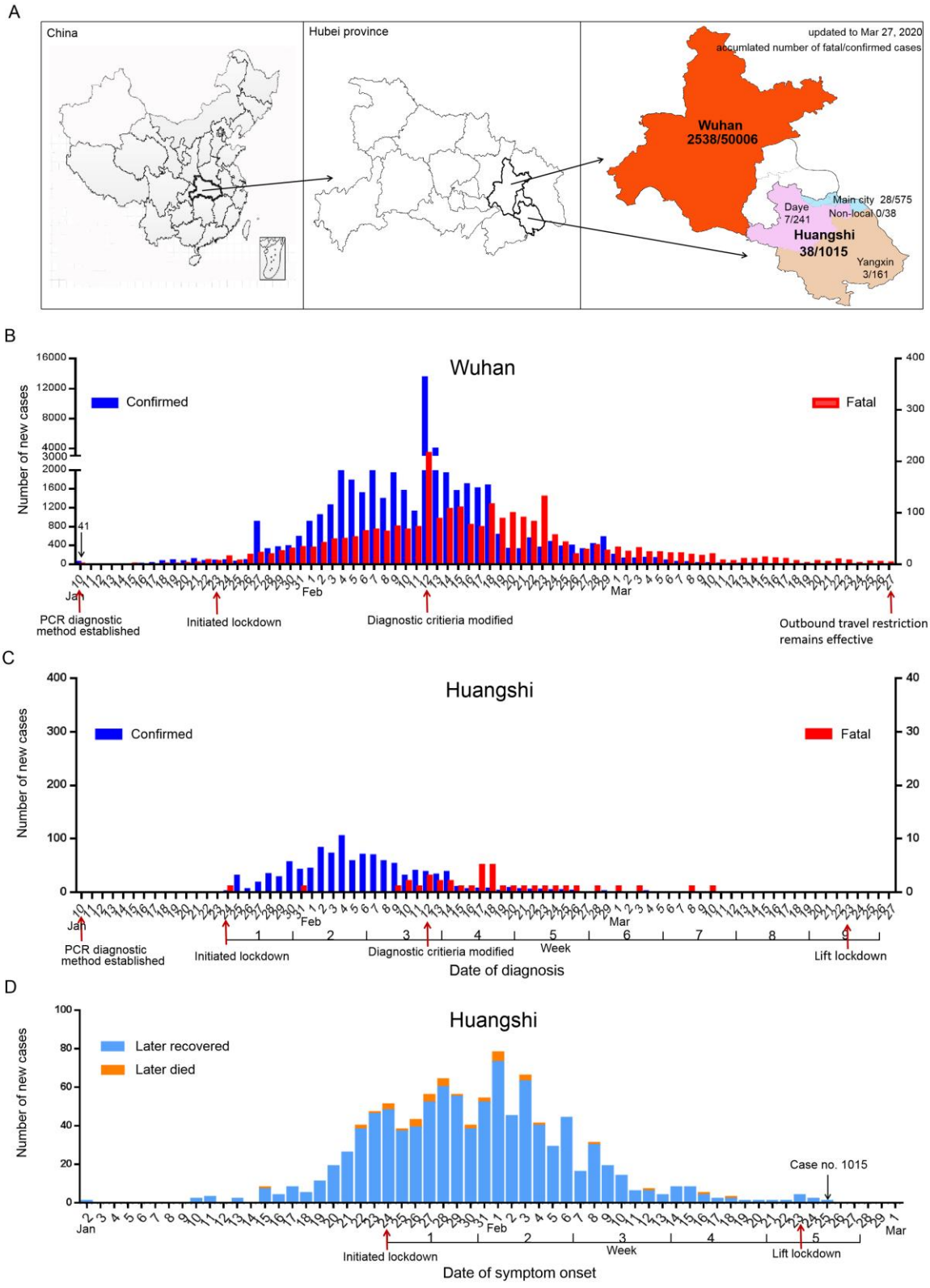
A
China
Hubei province
updated to Mar 27, 2020
accumlated number of fatal/confirmed cases
Wuhan
2538/50006
Daye
7/241
Main city 28/575
Non-local 0/38
Huangshi
38/1015
Yangxin
3/161
B
Wuhan
Confirmed
Fatal
Number of new cases
41
PCR diagnostic method established
Initiated lockdown
Diagnostic critieria modified
Outbound travel restriction remains effective
C
Huangshi
Confirmed
Fatal
Number of new cases
PCR diagnostic method established
Initiated lockdown
Diagnostic critieria modified
Lift lockdown
Week
Date of diagnosis
D
Huangshi
Later recovered
Later died
Number of new cases
Case no. 1015
Initiated lockdown
Lift lockdown
Week
Date of symptom onset

Figure 1

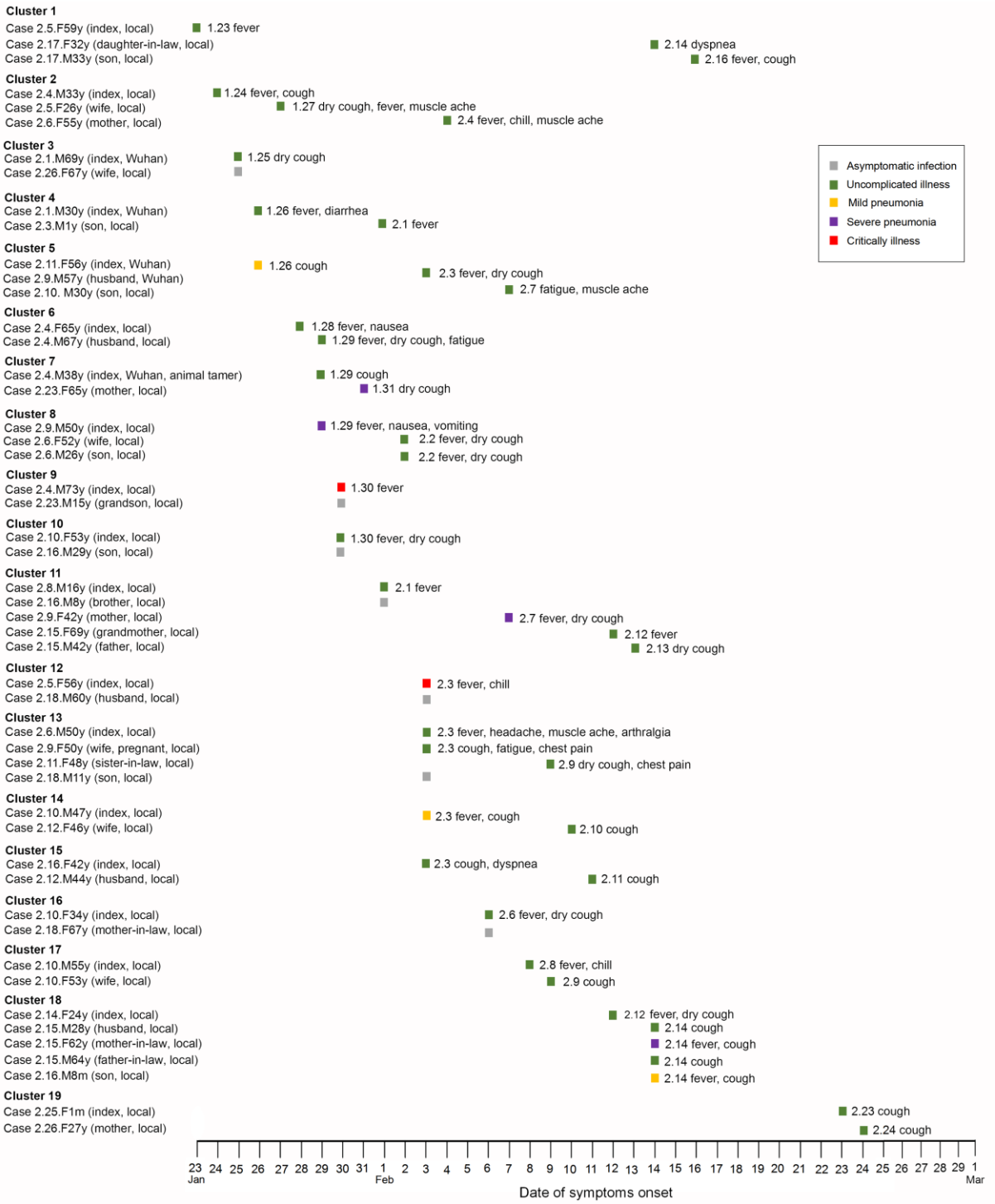
Cluster 1
Case 2.5.F59y (index, local)
Case 2.17.F32y (daughter-in-law, local)
Case 2.17.M33y (son, local)
1.23 fever
2.14 dyspnea
2.16 fever, cough
Cluster 2
Case 2.4.M33y (index, local)
Case 2.5.F26y (wife, local)
Case 2.6.F55y (mother, local)
1.24 fever, cough
1.27 dry cough, fever, muscle ache
2.4 fever, chill, muscle ache
Cluster 3
Case 2.1.M69y (index, Wuhan)
Case 2.26.F67y (wife, local)
1.25 dry cough
Asymptomatic infection
Uncomplicated illness
Mild pneumonia
Severe pneumonia
Critically illness
Cluster 4
Case 2.1.M30y (index, Wuhan)
Case 2.3.M1y (son, local)
1.26 fever, diarrhea
2.1 fever
Cluster 5
Case 2.11.F56y (index, Wuhan)
Case 2.9.M57y (husband, Wuhan)
Case 2.10. M30y (son, local)
1.26 cough
2.3 fever, dry cough
2.7 fatigue, muscle ache
Cluster 6
Case 2.4.F65y (index, local)
Case 2.4.M67y (husband, local)
1.28 fever, nausea
1.29 fever, dry cough, fatigue
Cluster 7
Case 2.4.M38y (index, Wuhan, animal tamer)
Case 2.23.F65y (mother, local)
1.29 cough
1.31 dry cough
Cluster 8
Case 2.9.M50y (index, local)
Case 2.6.F52y (wife, local)
Case 2.6.M26y (son, local)
1.29 fever, nausea, vomiting
2.2 fever, dry cough
2.2 fever, dry cough
Cluster 9
Case 2.4.M73y (index, local)
Case 2.23.M15y (grandson, local)
1.30 fever
Cluster 10
Case 2.10.F53y (index, local)
Case 2.16.M29y (son, local)
1.30 fever, dry cough
Cluster 11
Case 2.8.M16y (index, local)
Case 2.16.M8y (brother, local)
Case 2.9.F42y (mother, local)
Case 2.15.F69y (grandmother, local)
Case 2.15.M42y (father, local)
2.1 fever
2.7 fever, dry cough
2.12 fever
2.13 dry cough
Cluster 12
Case 2.5.F56y (index, local)
Case 2.18.M60y (husband, local)
2.3 fever, chill
Cluster 13
Case 2.6.M50y (index, local)
Case 2.9.F50y (wife, pregnant, local)
Case 2.11.F48y (sister-in-law, local)
Case 2.18.M11y (son, local)
2.3 fever, headache, muscle ache, arthralgia
2.3 cough, fatigue, chest pain
2.9 dry cough, chest pain
Cluster 14
Case 2.10.M47y (index, local)
Case 2.12.F46y (wife, local)
2.3 fever, cough
2.10 cough
Cluster 15
Case 2.16.F42y (index, local)
Case 2.12.M44y (husband, local)
2.3 cough, dyspnea
2.11 cough
Cluster 16
Case 2.10.F34y (index, local)
Case 2.18.F67y (mother-in-law, local)
2.6 fever, dry cough
Cluster 17
Case 2.10.M55y (index, local)
Case 2.10.F53y (wife, local)
2.8 fever, chill
2.9 cough
Cluster 18
Case 2.14.F24y (index, local)
Case 2.15.M28y (husband, local)
Case 2.15.F62y (mother-in-law, local)
Case 2.15.M64y (father-in-law, local)
Case 2.16.M8m (son, local)
2.12 fever, dry cough
2.14 cough
2.14 fever, cough
2.14 cough
2.14 fever, cough
Cluster 19
Case 2.25.F1m (index, local)
Case 2.26.F27y (mother, local)
2.23 cough
2.24 cough
23 24 25 26 27 28 29 30 31 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 1
Jan
Feb
Mar
Date of symptoms onset

Figure 2