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Case Fatality Risk of the First Pandemic Wave of Coronavirus Disease 2019 (COVID-19) in China

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(See the Editorial Commentary by Rothenberg on pages e86–e87.)

Background. To assess the case fatality risk (CFR) of COVID-19 in mainland China, stratified by region and clinical category, and estimate key time-to-event intervals.

Methods. We collected individual information and aggregated data on COVID-19 cases from publicly available official sources from 29 December 2019 to 17 April 2020. We accounted for right-censoring to estimate the CFR and explored the risk factors for mortality. We fitted Weibull, gamma, and log-normal distributions to time-to-event data using maximum-likelihood estimation.

Results. We analyzed 82 719 laboratory-confirmed cases reported in mainland China, including 4632 deaths and 77 029 discharges. The estimated CFR was 5.65% (95% confidence interval [CI], 5.50–5.81%) nationally, with the highest estimate in Wuhan (7.71%) and lowest in provinces outside Hubei (0.86%). The fatality risk among critical patients was 3.6 times that of all patients and 0.8–10.3-fold higher than that of mild-to-severe patients. Older age (odds ratio [OR], 1.14 per year; 95% CI, 1.11–1.16) and being male (OR, 1.83; 95% CI, 1.10–3.04) were risk factors for mortality. The times from symptom onset to first healthcare consultation, to laboratory confirmation, and to hospitalization were consistently longer for deceased patients than for those who recovered.

Conclusions. Our CFR estimates based on laboratory-confirmed cases ascertained in mainland China suggest that COVID-19 is more severe than the 2009 H1N1 influenza pandemic in hospitalized patients, particularly in Wuhan. Our study provides a comprehensive picture of the severity of the first wave of the pandemic in China. Our estimates can help inform models and the global response to COVID-19.

Keywords. coronavirus disease 2019; severe acute respiratory syndrome coronavirus 2; case fatality risk; China.

As of 17 April 2020, a total of 82 719 cases of coronavirus disease 2019 (COVID-19) have been reported in mainland China, including 4632 deaths [1, 2]. The first wave of COVID-19 transmission has ended in mainland China, due to implementation of stringent public health interventions [3]. However, as the pandemic continues throughout the world, China faces mounting pressure from travel-related case importations. As of 17 April, a total of 1566 imported cases were reported in 27 (87%, 27/31) Chinese provinces [1, 2]. Coupled with the decline in the public health response and resumption of economic activities, the risk of re-emergence of COVID-19 remains high [4].

The case fatality risk (CFR) is a key metric for clinical severity assessment. It is determined by multiple factors, including the intrinsic virulence of a pathogen, the availability of timely and appropriate treatment, the surge capacity of the healthcare system, and accessibility to medical care. Unbiased and precise estimates of CFR are important to help policymakers balance the socioeconomic impact of interventions against the potential health benefits [5]. The CFR is also a key parameter for mathematical models of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) transmission, which have been widely used throughout the outbreak to compare intervention scenarios.

Estimates of the fatality risk of COVID-19 in China have been highly variable (0.98–18%) [4, 6–13]. These estimates addressed the early stages of the outbreak and suffer from censoring due to time delay between onset and death; they do not include recent updated COVID-19 statistics [14], and they do not account for improved patient care in later stages of the outbreak. More comprehensive estimates of COVID-19 severity could help preparedness for the potential resurgence of a second wave.

Other important quantities for healthcare system planning and modeling include the distribution of time intervals from symptom onset to seeking care, hospitalization, and death or discharge. Several studies have evaluated these time-to-event

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distributions early in the epidemic [15–19]; however, these may have changed as the outbreak progressed.

A seminal report on the epidemiology of COVID-19 in China indicates that mild cases have a 5.1% probability of death, and this probability increases markedly with severity [20]. However, to our knowledge, no study has evaluated CFR stratified by clinical category upon hospital admission. This information is important for prioritization of patients upon hospital admission.

Here, we assessed CFR among laboratory-confirmed COVID-19 cases reported until mid-April 2020 in mainland China, stratified by clinical category and region. We also explored the risk factors associated with fatal outcomes and the key time-to-event intervals in provinces outside Hubei.

METHODS

Case Definitions and Surveillance

The National Health Commission of China (NHC) and the Chinese Center for Disease Control and Prevention (China CDC) launched a surveillance system to record information on COVID-19 cases in late December 2019 (see [21] for details). As the epidemic evolved, a total of 7 versions of case definitions were issued by the NHC [4, 15].

Four clinical categories of patients with laboratory-confirmed COVID-19 have been identified by the NHC, including mild, moderate, severe, and critical patients [21–23]. "Mild patients," introduced in the fifth and sixth versions of the COVID-19 case definition, refers to patients with no radiographic evidence of pneumonia. "Moderate patients," introduced in the fourth version of the case definition, refers to patients with fever, respiratory symptoms, and radiographic evidence of pneumonia. "Severe patients," introduced in the second version, refers to patients with either breathing problems, low oxygen saturation, low PaO_2:FiO_2 (PaO_2 denotes partial pressure of oxygen in arterial blood; FiO_2 denotes fraction of inspired oxygen), or pulmonary imaging showing obvious progress of lesions (>50%) within 24–48 hours. "Critical patients" denotes patients having any respiratory failure or shock and any other organ failure that requires intensive care unit (ICU) admission. This definition was used from the very beginning of the outbreak.

Patients were discharged when they met all of the following criteria: (1) normal body temperature for more than 3 days, (2) significantly improved respiratory symptoms, (3) significantly relieved acute exudative lesions indicated by lung radiographic findings, and (4) negative nucleic acid detection by real-time reverse transcriptase–polymerase chain reaction (RT-PCR) using respiratory specimens on 2 consecutive days, with a sampling interval of 1 or more day [23].

Data Collection

Daily aggregated data (hereafter referred to as the aggregated dataset) on the cumulative number of cases were extracted from the websites of national, provincial, and municipal Health Commissions [1]. Individual records on COVID-19 cases (hereafter referred to as the individual dataset) were collected from 2 official publicly available sources from 29 December 2019 to 17 April 2020, including the following: (1) health authority websites [1] and (2) national and local government-affiliated medias [24]. Individual information was extracted and entered into a structured database comprising demographic characteristics, dates of symptom onset, first healthcare consultation, hospital admission, official announcement (reporting date), as well as outcome (ie, death/discharge and corresponding dates). Each individual record was extracted and entered by 3 coauthors and was cross-checked to ensure data accuracy. Conflicting information was resolved based on the Health Commission data. Details on data collection, completeness, and censoring are provided in Supplementary Tables 1 and 2.

Statistical Analysis

Using individual datasets, we analyzed demographic characteristics, risk factors associated with fatal outcome, and key time-to-event intervals to the provinces outside Hubei, where the majority of individual records were obtained (80.8%, 11 793/14 590). We implemented a multivariate logistic regression model to explore the risk factors associated with death. We included age, sex, economic region [25], time interval from symptom onset to first medical consultation, first hospital admission, and laboratory diagnosis. We categorized China into 3 economic regions (see Supplementary Figure 1) [25].

To estimate the key time-to-event intervals, including symptom onset to first healthcare consultation, hospital admission, laboratory diagnosis, and death or discharge, and from hospital admission to death or discharge, we fitted 3 parametric distributions (Weibull, gamma, and log-normal) to empirical data using maximum-likelihood estimation. We selected the best fit based on the Akaike information criterion.

Using the aggregated dataset as of 17 April, we applied 2 methods to estimate CFR. First, we calculated a crude CFR based on the cumulative number of deaths divided by the cumulative number of cases, ignoring the time lag between symptom onset and death [26]. In a second approach, we adjusted for delays between hospitalization and death to obtain more accurate estimates of CFR, using the method described by Garske et al [27] for pandemic influenza A/H1N1 in 2009. This approach weights cases in the denominator of the CFR based on the distribution of the time interval from hospital admission to death. Recent cases have lower weights since their outcomes are unlikely to be observed (Supplementary Section 2). This approach generates time-stamped CFR estimates using aggregated data.

To estimate CFR by clinical category, we compiled the proportion of cases and deaths in each category and region from different reports [28–30]. We then applied these proportions to our aggregated datasets of cases and deaths using resampling approaches (Supplementary Section 2).

Last, we assessed the impact of importations on the CFRs and key time-to-event intervals in sensitivity analyses. As of 17 April, all 1566 international importations were reported in provinces outside Hubei and no death has been reported among imported cases. Statistical analyses were performed in R (version 3.6.0; R Foundation for Statistical Computing).

Ethics

The study was approved by the Institutional Review Board from the School of Public Health, Fudan University (IRB no. 2020–02–0802). All data were collected from publicly available sources and did not contain any personal information.

RESULTS

As of 17 April 2020, a total of 82 719 laboratory-confirmed cases including 4632 deaths, 77 029 discharged patients, and 1058 patients who were still hospitalized were reported in mainland China (see Supplementary Table 2 for details of each province). Of these, provinces outside Hubei accounted for 14 591 (17.6%, 14 591/82 719) of laboratory-confirmed cases, including 120 deaths (2.6%, 120/4632), 13 535 (17.6%, 13 535/77 029) discharged cases, and 936 (88.5%, 936/1058) patients who were still hospitalized. We collected individual information from publicly available official sources on 11 793 laboratory-confirmed cases detected outside Hubei, accounting for 80.8% (11 793/14 590) of total cases reported, 65.0% (78/120) of deceased patients, and 27.7% (3746/13 533) of recovered patients. Of the 11 793 cases, unresolved patients accounted for 67.6% (7969/11 793) (Table 1). (See Supplementary Figure 3 for an epidemic curve of cases with available individual information.)

The median age of cases outside Hubei was 45 years (range, 4 days–97 years), and 53% (5950/11 321) were male. Those who died were significantly older than those who were discharged (median age, 75 vs 42 years; $P < .001$). Seventy-seven percent (59/77) of deaths occurred in adults aged 65 years or above, and 60% (47/78) were in males (Table 1).

The intervals from symptom onset to first healthcare consultation, from symptom onset to hospitalization, and from symptom onset to laboratory confirmation were consistently longer for deceased patients than for those who recovered. However, disease progression was quicker in individuals who died: overall, the time interval from symptom onset to death was estimated to be 13.9 days (95% confidence interval [CI], 1.9–47.2 days), and the interval from symptom onset to discharge was 20.6 days (95% CI, 8.9–39.8 days) (Table 2).

Based on the total patients reported to the surveillance system, the CFR estimated by Garske's method [27] was somewhat higher than crude CFR estimates (Table 3). The CFR was 5.65% (95% CI, 5.50–5.81%) for mainland China, with the highest estimate in Wuhan (7.71%; 95% CI, 7.48–7.94%) and lowest estimate in the provinces outside Hubei (.86%; 95% CI, .72–1.03%).

In Wuhan, the CFR among critical patients was 86.49% (95% CI, 80.93–92.47%), which was 13-fold higher than that in

Table 1. Demographic Characteristics of COVID-19 Cases Outside Hubei Province in Mainland China, as of 3 April 2020

Characteristics	Died (n = 78)	Discharged (n = 3746)	Unresolved (n = 7969)[a]	All Cases (N = 11 793)
Median age (range), y	75 (25–94)	42 (0.13–97)	46 (0.01–96)	45 (0.01–97)
Age group (years),[b] n (%)				
0–6	0 (0)	85 (2)	84 (1)	169 (2)
7–17	0 (0)	129 (4)	200 (3)	329 (3)
18–24	0 (0)	257 (7)	455 (6)	712 (7)
25–49	4 (5)	1865 (52)	3565 (50)	5434 (50)
50–64	14 (18)	877 (24)	1931 (27)	2822 (26)
≥65	59 (77)	407 (11)	893 (13)	1359 (13)
Missing[c]	1 (1)	126 (3)	841 (11)	968 (8)
Sex, n (%)				
Male	47 (60)	1969 (53)	3934 (52)	5950 (53)
Female	31 (40)	1727 (47)	3613 (48)	5371 (47)
Missing[c]	0 (0)	50 (1)	422 (5)	472 (4)
Region,[d] n (%)				
East	31 (40)	1614 (43)	3351 (42)	4996 (42)
Central	20 (26)	978 (26)	2914 (37)	3912 (33)
West and Northeast	27 (35)	1154 (31)	1704 (21)	2885 (24)

Abbreviation: COVID-19, coronavirus disease 2019.

[a]Including those cases who may have had outcomes (ie, death/discharge), but their information was unavailable from public data sources.

[b]A significant difference was observed among patients who died and those who were discharged ($P < .001$).

[c]The denominator for estimating the proportion of missing data is the total number of COVID-19 cases. Missing data were excluded for calculating the proportion per strata.

[d]A significant difference was observed among patients who died and those who were discharged ($P < .05$). East: Beijing, Tianjin, Hebei, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, and Hainan provinces; Central: Shanxi, Anhui, Jiangxi, Henan, and Hunan provinces; West: Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang; Northeast: Heilongjiang, Jilin, and Liaoning.

Table 2. Key Time-to-Event Intervals of Patients With COVID-19 Outside Hubei Province in Mainland China, as of 3 April 2020

Key time-to-event interval	All (N = 11 793)	Died (n = 78)	Discharged (n = 3746)
Time from symptom onset to first healthcare consultation (days), n	3804	36	1360
Estimates from empirical data	1.0 (.5, 10.2)	2.0 (.5, 9.6)	1.0 (.5, 10.0)
Estimates by fitting	1.6 (.2, 12.4)	1.7 (.2, 15.6)	1.5 (.2, 12.1)
Time from symptom onset to hospital admission (days), n	3381	39	1563
Estimates from empirical data	3.0 (.5, 13.0)	4.0 (.5, 12.5)	3.0 (.5, 13.0)
Estimates by fitting	2.2 (.3, 19.0)	3.5 (.2, 16.0)	2.9 (.2, 13.4)
Time from symptom onset to laboratory confirmation (days), n	6406	41	1890
Estimates from empirical data	5.0 (.5, 16.0)	6.0 (1.0, 14.8)	5.0 (.5, 15.0)
Estimates by fitting	5.0 (.5, 15.9)	5.8 (.8, 15.8)	4.9 (.5, 15.5)
Time from symptom onset to outcome (days), n	2178	46	2132
Estimates from empirical data	20.0 (9.0, 42.0)	13.5 (3.1, 43.8)	20.0 (10.0, 42)
Estimates by fitting	20.4 (8.5, 40.3)	13.9 (1.9, 47.2)	20.6 (8.9, 39.8)
Time from hospital admission to outcome (days), n	2643	60	2583
Estimates from empirical data	16.0 (6.0, 38.9)	9.0 (.7, 37.5)	16.0 (7.0, 39.0)
Estimates by fitting	16.7 (5.8, 36.5)	9.3 (.7, 39.1)	16.4 (7.0, 38.6)

Data are presented as means (95% confidence intervals) unless otherwise indicated.
Abbreviation: COVID-19, coronavirus disease 2019.

provinces outside Hubei (6.07%; 95% CI, 4.52–7.72%). The CFR among critical patients was 6.6-fold higher than that of severe patients, 12.1-fold higher than that of moderate patients, and 41.2-fold higher than that of mild patients. Smaller differences in mortality risk by clinical categories (0.8- to 10.3-fold) were observed in the rest of mainland China (Figure 1).

The CFR in provinces outside Hubei remained stable at around 1.0% after 1 February, as estimated by Garske's method [27]. In Wuhan, the CFR declined rapidly from 88.6% on 28 January to 8.5% on 24 February, and remained stable afterwards. Similar patterns were observed in other regions, where the CFR became stable in late February (Figure 2). Multivariate logistic analysis revealed that increasing age and being male were risk factors for mortality (Table 4; see also Supplementary Table 3 for univariate analysis).

The key time-to-event intervals were shorter for imported cases than that of domestic cases (Supplementary Figure 4). Excluding importations, the CFR in provinces outside Hubei provinces increased to 5.72% (95% CI, 5.57–5.89%), while the CFR in mainland China increased to 0.93% (95% CI, .78–1.11%).

DISCUSSION

We have shown that the CFR was 5.65% in mainland China, with the highest severity in Wuhan (7.71%) and the lowest severity in provinces outside Hubei (0.86%). The CFR increased with clinical severity, which was estimated at 86.49% among critical patients in Wuhan and 6.07% in provinces outside Hubei. Males and older patients were at increased risk of mortality. Both the time from symptom onset to outcome and from hospital admission to outcome was shorter for deceased patients than for those who recovered. These estimates account for delayed outcomes and recent updates in official statistics and could represent the most accurate estimates of COVID-19 severity in China so far.

Our CFR estimate of 0.86% for patients with COVID-19 outside Hubei province is higher than the crude CFRs reported by the World Health Organization and China CDC, which is 0.4–0.7% [20, 26]. This is expected as the crude CFR is an underestimate due to the inevitable delay between symptom onset and death. Another study of patients outside Hubei that accounted for censoring reports an estimate comparable to ours (0.98%) [4, 14]. Our estimate for Wuhan is higher than in prior studies, however (7.71% vs 5.91%) [4, 14], and this is likely explained by

Table 3. Fatality Risk of COVID-19 Among All Reported Cases and Among Severe and Critical Cases

	Number of Cases		Fatality Risk Among All Reported Cases, % (95% CI)	
	Deaths	Total Cases Reported	Crude	Estimated Using Garske's method [27]
Wuhan in Hubei province	3,869	50 333	7.69 (7.46, 7.92)	7.71 (7.48, 7.94)
Outside Wuhan in Hubei province	643	17 795	3.61 (3.35, 3.90)	3.62 (3.35, 3.90)
Provinces outside Hubei	120	14 591	.82 (.69, .99)	.86 (.72, 1.03)
Overall	4632	82 719	5.60 (5.44, 5.76)	5.65 (5.50, 5.81)

Crude was calculated as the cumulative number of deaths divided by the cumulative number of laboratory-confirmed cases.
Abbreviations: CI, confidence interval; COVID-19, coronavirus disease 2019.

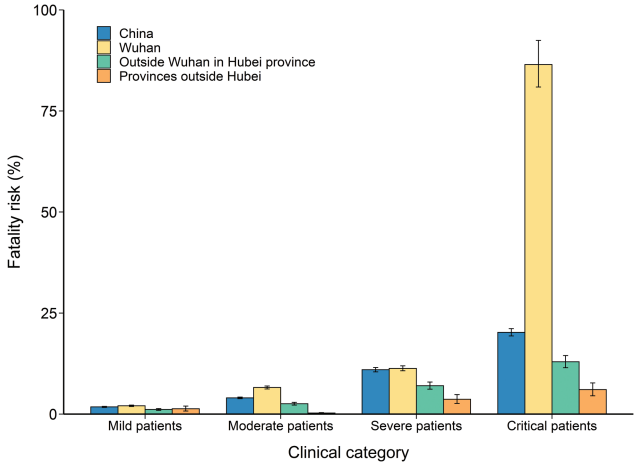

Figure 1. Case fatality risk (mean, 95% confidence interval) by clinical categories (mild, moderate, severe, and critical patients).

our adjustment for censoring and the addition of revised statistics on cases and deaths.

Large variations in CFR were observed between countries [31]. Variations could be explained by differences in the sensitivity of surveillance systems to detect cases at different levels of the severity pyramid, differences in clinical care of severe and critical patients, and age structure and underlying conditions of the population. Accordingly, settings with limited health services, like Iran, report a larger ratio of deaths to cases than other countries [32].

No specialized treatment for patients with COVID-19 has been identified, and the mainstay clinical management has been supportive care. For non–critically ill patients, close follow-up is likely to be sufficient to manage the disease. But critically ill patients are more likely to develop ARDS and require ICU admission [33]. This likely explains our findings that critical patients have a higher fatality risk. The fatality risk in Wuhan and in the broader Hubei province was higher than in the rest of China, probably due to a shortage of health services, and possible difficulties in keeping record of all cases in Wuhan. There was a particular shortage of advanced healthcare facilities for critically ill patients, such as extracorporeal membrane oxygenation.

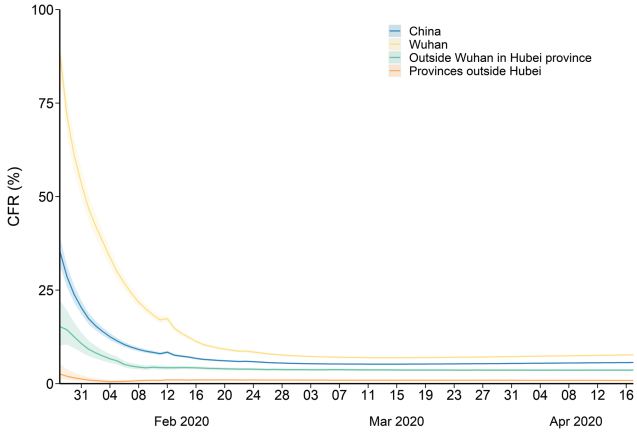

Figure 2. Case fatality risk over time in mainland China (mean, 95% confidence interval). Abbreviations: Apr, April; CFR, case fatality risk; Feb, February; Mar, March.

As the domestic epidemic of COVID-19 was gradually brought under control in mainland China, the government implemented strict quarantine of international arrivals to prevent reintroductions. Care-seeking delays were much shortened among international travelers due to enhanced monitoring and quarantine, possibly explaining the absence of fatal outcomes among imported COVID-19 cases thus far. Reassuringly, due to the small number of imported cases relative to the domestic epidemic, our CFR estimates were not influenced by the inclusion or exclusion of this subpopulation.

Our findings reveal that older individuals and male patients experience higher fatality risk, which is consistent with a seminal report [20, 34]. Additionally, patients with underlying conditions had much higher fatality rates [20, 34]. Our study was unable to address the relative risk of fatal outcome among patients with underlying diseases compared with healthy individuals, because limited information was available from publicly available data sources.

Our CFR estimates outside Hubei province indicate that the severity of SARS-CoV-2 is lower than that of other diseases caused by zoonotic coronaviruses, including Middle East respiratory syndrome (MERS; CFR, 34.4%) [35] and severe acute respiratory syndrome (SARS; CFR, 7% in mainland China and 11% globally) [36]. In contrast, the CFR of COVID-19, particularly in the epicenter of Wuhan, is more severe than that of pandemic 2009 influenza A(H1N1) virus hospitalizations (CFR of 1.4% in Asia) [37].

Outside Hubei, close contacts of laboratory-confirmed cases were kept in quarantine for 14 days. Local hospitals tested patients with respiratory symptoms and those with epidemiological links to Hubei province or to other patients with COVID-19. Surprisingly, only a small number of mild cases were captured. In our aggregated dataset for Guangdong province, for instance, only 8.2% of reported cases were mild, while the majority (80.1%) had moderate disease severity with the presence of pneumonia. Chest X-ray confirmed pneumonia is a threshold for hospital admission in China, and thus our CFR estimates could approximately represent the fatality risk among hospitalized cases. Thresholds for hospitalization may vary among countries due to different clinical practices and health service capacity.

Notably, the definition of suspected cases eligible for laboratory testing was broadened on 27 January to include milder patients. This would bias our sample towards more clinically severe cases before 27 January, as reflected by the very high CFR estimate before that date (89%). In addition to improvement in

Table 4. Risk Factors Associated With Fatal Outcome Among Patients With COVID-19

Variables	OR (95% CI)	*Z* Value	*P* Value
Age, per year increase	1.14 (1.11–1.16)	12.12	<.001
Sex			
Female	Ref	…	
Male	1.83 (1.10–3.04)	2.32	.020
Unknown	0 (0–Inf)	−0.02	.983
Economic regions[a]			
East	Ref	…	
Central	1.41 (.74–2.70)	1.05	.294
West and Northeast	1.38 (.78–2.46)	1.10	.271
Time from symptom onset to first healthcare consultation			
≤2 days	Ref	…	
>2 days	1.27 (.55–2.90)	0.56	.577
Unknown	.47 (.21–1.05)	−1.84	.065
Time from symptom onset to hospital admission			
≤3 days	Ref	…	
>3 days	1.12 (.47–2.67)	0.25	.805
Unknown	.64 (.27–1.51)	−1.02	.307
Time from symptom onset to laboratory confirmation			
≤6 days	Ref	…	
>6 days	1.30 (.58–2.90)	0.63	.527
Unknown	2.79 (1.13–6.90)	2.22	.027

Abbreviations: CI, confidence interval; COVID-19, coronavirus disease 2019; inf, infinite; OR, odds ratio; Ref, reference; …, not applicable.
[a]East: Beijing, Tianjin, Hebei, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, and Hainan provinces; Central: Shanxi, Anhui, Jiangxi, Henan, and Hunan provinces; West: Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang; Northeast: Heilongjiang, Jilin, and Liaoning.

therapeutic capacity, the shift in surveillance definition could partially explain the declining trend of CFR in February and beyond. A robust estimate of CFR can be obtained after 23 February since 90% of deaths occurred within 26 days of hospitalization; these later estimates should be considered more reliable.

Our study has some limitations. First, reliable individual records were retrieved from publicly available official sources; however, records were scarce for Hubei because this province did not release complete individual information, and thus we were unable to estimate key time-to-event intervals in Hubei using maximum-likelihood estimation.

Second, to estimate the CFR stratified by clinical category in provinces outside Hubei, the proportions of patients in each clinical category were obtained from Guangdong data [30]. Geographically comprehensive information was not available. However, the proportion of severe and critical cases was similar in Guangdong province and provinces outside Hubei (10.9% vs 11.3%), supporting the representativeness of our data.

Third, assessment of clinical severity in Hubei, especially in the epicenter of the outbreak in Wuhan, is challenging because disease severity may be increased by bottlenecks in local healthcare capacity. Complete and accurate documentation of causes of death during such a large outbreak is challenging. To correct for late reporting, omissions, and misreporting of COVID-19 cases during the outbreak, Wuhan authorities conducted a comprehensive and systematic verification between late March and middle April, adding a substantial amount of cases and deaths. We cannot rule out, however, the potential misclassification of COVID-19 deaths. To the best of our knowledge, these data represent direct deaths from COVID-19 in otherwise healthy patients, as well as deaths among patients with comorbidities and a diagnosis of COVID-19. Even outside of a pandemic situation, ascertainment of cause of death is complicated; further analyses of vital statistics using excess mortality approaches will be important to resolve the direct and indirect contribution of COVID-19 to mortality.

CONCLUSIONS

In conclusion, our estimates of CFR among laboratory-confirmed cases suggest that COVID-19 is not as severe as SARS and MERS, but more severe than the pandemic 2009 H1N1 virus among hospitalized patients. The fatality risk of COVID-19 cases is higher in Wuhan, among males, and in older ages. Our findings can inform the response to the ongoing COVID-19 pandemic, provide useful parameters to model the effect of interventions on morbidity and mortality, and assist preparedness for a potential resurgence of the epidemic in China.

Supplementary Data

Supplementary materials are available at *Clinical Infectious Diseases* online. Consisting of data provided by the authors to benefit the reader, the posted materials are not copyedited and are the sole responsibility of the authors, so questions or comments should be addressed to the corresponding author.

Notes

Author contributions. H. Y. conceived, designed, and supervised the study. W. W., J. L., Y. C., H. Y., Y. Z., Q. Q., H. G., Xianglin W., L. W., and K. S. participated in data collection. X. D., J. Y., X. W., Jiaxin Z., Z. C, Juanjuan Z., and Y. W. analyzed the data and prepared the figures. J. Y. prepared the first draft of the manuscript. X. D., P. W., M. A., B. J. C., C. V., and H. Y. commented on the data and its interpretation and revised the content critically. All authors contributed to review and revision and approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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