Impact of Long-Term Air Pollution on the Case Fatality Rate of COVID-19

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Research

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Abstract

Background There is preliminary evidence of the long-term exposure to air pollution will affect the outcome of patients with COVID-19. More information is needed about relationship between long-term exposure to air pollution and case fatality rate (CFR) of patients with COVID-19.

Methods In this study, we have collected the data of Air Quality Index (AQI), PM_{2.5}, PM₁₀, SO₂, NO₂ and O₃ from 14 representative cities in China in the past 5 years, and calculated the case fatality rate of COVID-19 in the corresponding city. First, we explored correlation relationship between CFR and long-term air quality indicators. Then, we try to point out the air pollutants that affect the level of CFR and evaluated their predictive value.

Results We have observed a positive correlation between the CFR and AQI (1-year, 3-year, 5-year), PM_{2.5} (1-year, 3-year, 5-year), and PM₁₀ (1-year, 3-year, 5-year). Meanwhile, AQI (3-year, 5-year) and PM_{2.5} (1-year, 3-year, 5-year) were significantly higher in the high CFR group. Moderate predictive value of air pollution indicator to CFR such as AQI (1-year, 3-year, 5-year), PM_{2.5} (1-year, 3-year, 5-year) have been found.

Conclusions Our results indicate that long-term exposure to the environment with severe air pollution is associated with CFR of COVID-19. Air pollutants such as PM_{2.5} may have potential ability to predict the CFR of COVID-19.

Background

The novel coronavirus (COVID-19) was first reported in Wuhan, China in December 2019 [1, 2], then spread rapidly worldwide. It was declared as pandemic by the World Health Organization (WHO) in March 2020[3]. Recently, China is keeping the virus within a controllable range and social order gradually resuming normal. However, other countries and regions around the world are still being threatened by this virus, and the number of confirmed cases and deaths is increasing tremendously. According to the data from WHO, the mortality rate of this epidemic varies in different countries. Now, COVID-19 is a huge obstacle to the world economy and people's normal life. There is no doubt that exploring the relevant factors that affect the mortality rate of the COVID-19 is urgent and vital. It will improve the confidence and means of doctors to treat the virus and reduce the public's terror.

Previous studies found that the morbidity and mortality of COVID-19 was related to individual characteristics, such as gender, age, hypertension, diabetes, and obesity [4–8]. In addition, as one of the triggers of respiratory and systemic inflammatory responses, air pollution should also be noted. The primary visceral target organ of COVID-19 virus and air pollution is also the lung. Previous studies have demonstrated that air pollution increased the incidence of airway inflammation and lung diseases [9, 10]. Recent research proved that short-term exposure to air pollution will increase the risk of COVID-19 infection [11–13]. The impact of air pollution has a chronic cumulative process on people. Until now, there are only a few relevant research on the relationship between the long-term air pollution and the outcome of patients with COVID-19, and no consistent conclusions[14, 15]. We speculate that long-term exposure to air pollution will affect the case fatality rate (CFR) of patients with COVID-19. Therefore, we attempted to explore this relationship in 14 cities in China.

Materials And Methods

Data collection

Inclusion criteria: (I) The city is a capital city or a municipality directly under the Central Government; (II) Until April 28th, 2020, the number of confirmed cases of COVID-19 is not less than 100 in the city; (III) The air quality data of the city is available on the China Air Quality Online Monitoring and Analysis Platform (<https://www.aqistudy.cn>).

The number of confirmed cases, deaths and discharges during the epidemic period in the city were recorded from the official websites of national or urban Health Commissions (<http://www.nhc.gov.cn>). In addition, the CFR of COVID-19 were calculated during the current epidemic in the city (Case Fatality Rate = number of deaths / (number of deaths + number of discharges)).

Data of Air Quality Index (AQI), PM_{2.5}, PM₁₀, SO₂, NO₂ and O₃ in the same period of the city were collected, and the average values in the past 1 year, 3 years and 5 years were calculated respectively.

Statistical analysis

SPSS 25.0 was used to perform all statistical analyses. Shapiro-Wilk test was used to check whether indicator conforms to the normal distribution. A simple scatter plot was used to illustrate the relationship between air quality indicators of 1 year, 3 years, and 5 years and the CFR. The Pearson correlation test was performed for normally distributed variables, otherwise the Spearman test was used. According to the CFR of China (except Hubei Province), the cohort was divided into a low CFR group (CFR < 0.86%; n = 6) and a high CFR group (CFR > 0.86%; n = 8). All continuous variables were presented as mean ± standard deviation and compared with the independent-samples *t* test for normally distributed variables. In addition, ROC curve was further determined. An alpha level of 0.05 was considered statistically significant.

Results

In this study, there were 14 cities included in China (Fig. 1, Table 1) and 4247 cured cases of COVID-19 patients were enrolled. 47 COVID-19 cases died and the overall CFR was 1.09%. The average daily concentrations of AQI, PM_{2.5}, PM₁₀, SO₂, NO₂ and O₃ in the past 5 years were 84.17, 47.80 µg/m³, 75.88 µg/m³, 12.36 µg/m³, 41.81 µg/m³ and 90.59 µg/m³, respectively (Table 1 and Supplementary Table 1). The trend of several air pollution indicators in 14 cities over the past five years are shown in Figs. 2a-2 f.

Correlation test between CFR and long-term air quality indicators

As shown in Fig. 3 and Table 2, there was a moderate positive correlation between the city's case fatality rate and AQI (1-year, 3-year, 5-year), PM_{2.5} (1-year, 3-year, 5-year), and PM₁₀ (1-year, 3-year, 5-year). The city's CFR of COVID-19 increased with the rise of long-term AQI, PM_{2.5} and PM₁₀. However, there was weak correlation between CFR and SO₂, NO₂ and O₃.

Comparison of air quality between high CFR group and low CFR group

As of April 28th, 2020, 13962 cases were cured in China (except Hubei Province), with a total of 121 deaths. The national CFR (except Hubei Province) was 0.86%. According to this index, our cohort was divided into a low CFR group (CFR ≤ 0.86%; n = 6) and a high CFR group (CFR > 0.86%; n = 8). The list and geographical distribution of each group was shown in Fig. 1.

Compared with low CFR group, AQI (3-year, 5-year) and PM_{2.5} (1-year, 3-year, 5-year) were significantly higher in high CFR group (Table 3). However, there was no significant difference in the PM₁₀, SO₂, NO₂, and O₃ between high CFR group and low CFR group ($P > 0.05$).

($P < 0.05$)

Predictive Value Of Various Indicators For CFR

ROC curve was used to analysis the predictive value of air pollutants to CFR. The ROC curve showed area under the curve of AQI (1-year, 3-year, 5-year); PM_{2.5} (1-year, 3-year, 5-year) were 0.688, 0.81, 0.854; 0.823, 0.833, 0.896, respectively. However, AQI (1-year, 3-year) did not reach statistical difference. The cut-off values of AQI (5-year); PM_{2.5} (1-year, 3-year, 5-year) were 86.98; 39.58 µg/m³, 37.67 µg/m³, 51.57 µg/m³, respectively (Table 4 and Fig. 4).

Discussion

In this multi-city study, we try to estimate the association between long-term exposures to key ambient air pollutants and COVID-19 CFR, and calculate their predictive values. We observed that AQI, PM_{2.5} and PM₁₀, but NO₂ and O₃, have showed significant positive correlation with CFR. Meanwhile, compared with low CFR group, AQI and PM_{2.5} were significantly higher in high CFR group. Furthermore, after analysis the predictive value of air pollution indicator to CFR by ROC curve, Long-term PM_{2.5} may be the potential one. These findings help for understanding the different severe COVID-19 outcomes between various region. As for this pandemic, stronger healthcare and public attention should be focus on these vulnerable populations, who has suffered from long-term severe air pollution.

Studies have showed that environment play an important role on the transmission and outcomes of some major pandemic and epidemic, namely Severe Acute Respiratory Syndrome (SARS) [16], H1N1 influenza [17]. The role of the atmospheric environment in COVID-19 was not completely clear [18]. Frontera [19] mentioned that the outbreak of COVID-19 may have an potential inevitable association with climatic conditions and air pollutants. After that, Large number of scholars find that air pollutants are substantially associated with an increased risk of COVID-19 [11, 13, 20–22]. For example, according to Zhu's study of 120 city in China, COVID-19 infection is closely related to the short-term exposure to PM_{2.5}, PM₁₀, CO, NO₂ and O₃ [11]. However, the evidences of COVID-19 outcomes and Long-term air pollutants is insufficient. So, the results of our research have important significance. We observed significant positive associations between long-term PM_{2.5} levels and COVID-19 CFR. It's well known that PM_{2.5} affect the airways and the cardiovascular system, it can penetrate deep into lung tissue, causing immune and inflammation response [23–25]. Long-time exposure has been correlated with increased risks of chronic diseases, including chronic obstructive pulmonary disease (COPD) that can develop into lung cancer [26, 27]. In addition, short-term exposure to PM_{2.5} is robust associate with increased mortality from various cardiopulmonary diseases, from a nationwide analysis in 272 chinese cities [28]. Considering that COVID-19 and respiratory system are closely related, there is ample reason to believe that PM_{2.5}, on the basis of eliciting immune or inflammatory response, will affect the CFR of COVID-19.

It's inevitably to figure out that NO₂, which was null associations with severe outcomes of COVID-19 in our research, should also be taken seriously. Ogen [29] found that long-term exposure to NO₂ may be an important cause of death with COVID-19 in Italy and Spain. At the same time, Liang and Shi [14] conducted a cross-sectional nationwide study to estimate the association between long-term county-level exposures to NO₂, PM_{2.5} and O₃ and county-level COVID-19 case-fatality and mortality rates in the US, and found that Long-term exposure to NO₂ may enhance susceptibility to severe COVID-19 outcomes. However, all of those studies come from Europe or the USA. As the first nationwide study in

China to estimate the relationship between long-term exposure to air pollutants and COVID-19 CFR, the regional and ethnic differences should not be ignored.

In our study, in the 14 cities, most air pollutants such as NO₂, PM_{2.5} and PM₁₀ have gradually decreased over the past five years, as the Fig. 3 shown. This is attributed to the increased awareness of environmental protection. However, considering that the impact of air pollutants on people's lives is through eliciting immune or/and inflammatory responses. Long-term air pollutants have a cumulative effect(which is inevitable), and most of the current studies on air pollution and COVID-19 focus on short-term air pollution, which is inappropriate and incomplete for this aspect of research.

It could not be ignored that there were still some deficiencies in this study. Firstly, factors and ethnic characteristics that may affect the case fatality rate were not included such as population density, medical level, government policies, Secondly, although our study provided a reference for studying the relationship between long-term air pollution and CFR, our study was limited to China and further research is needed. Thirdly, as this was a retrospective cohort study with a relatively smaller sample size, the sampling error was hard to avoid.

Conclusion

Long-term exposure to the environment with severe air pollution is associated with CFR of COVID-19. Air quality indicators such as PM_{2.5} may have potential ability to predict the CFR of COVID-19.

Abbreviations

CFR=Case Fatality Rate; AQI=Air Quality Index; COPD=Chronic Obstructive Pulmonary Disease; WHO=World Health Organization; COVID-19=Corona Virus Disease 2019

Declarations

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Authors' contributions

YFQ conceived of the design of the study. CKH and QLL performed and collected the data and contributed to the design of the study. XYY and HW prepared and revised the manuscript. All authors read and approved the final content of the manuscript.

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Availability of data and materials

Not applicable.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

No conflict of interest exists in the manuscript.

References

1. Huang C, Wang Y, Li X, Ren L, Zhao J, Hu Y, et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. *Lancet*. 2020;395(10223):497–506. doi:10.1016/s0140-6736(20)30183-5. PubMed PMID: 31986264; PubMed Central PMCID: PMC7159299. Epub 2020/01/28.

2. Li Q, Guan X, Wu P, Wang X, Zhou L, Tong Y, et al. Early Transmission Dynamics in Wuhan, China, of Novel Coronavirus-Infected Pneumonia. *N Engl J Med*. 2020;382(13):1199–207. doi:10.1056/NEJMoa2001316. PubMed PMID: 31995857; PubMed Central PMCID: PMC7121484. Epub 2020/01/30.
3. WHO Declares COVID-19 a Pandemic
10.23750/abm.v91i1.9397
Cucinotta D, Vanelli M. WHO Declares COVID-19 a Pandemic. *Acta Biomed*. 2020;91(1):157 – 60. Epub 2020/03/20. doi: 10.23750/abm.v91i1.9397. PubMed PMID: 32191675.
4. 10.1002/jmv.25757
Li LQ, Huang T, Wang YQ, Wang ZP, Liang Y, Huang TB, et al. COVID-19 patients' clinical characteristics, discharge rate, and fatality rate of meta-analysis. *Journal of medical virology*. 2020. Epub 2020/03/13. doi: 10.1002/jmv.25757. PubMed PMID: 32162702.
5. Zhou F, Yu T, Du R, Fan G, Liu Y, Liu Z, et al. Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: a retrospective cohort study. *Lancet*. 2020;395(10229):1054–62. doi:10.1016/s0140-6736(20)30566-3. PubMed PMID: 32171076. Epub 2020/03/15.
6. 10.20452/pamw.15272
Lippi G, Wong J, Henry BM. Hypertension and its severity or mortality in Coronavirus Disease 2019 (COVID-19): a pooled analysis. *Polish archives of internal medicine*. 2020. Epub 2020/04/02. doi: 10.20452/pamw.15272. PubMed PMID: 32231171.
7. 10.1001/jama.2020.4683
Onder G, Rezza G, Brusaferro S. Case-Fatality Rate and Characteristics of Patients Dying in Relation to COVID-19 in Italy. *Jama*. 2020. Epub 2020/03/24. doi: 10.1001/jama.2020.4683. PubMed PMID: 32203977.
8. Guan WJ, Ni ZY, Hu Y, Liang WH, Ou CQ, He JX, et al. Clinical Characteristics of Coronavirus Disease 2019 in China. *N Engl J Med*. 2020;382(18):1708–20. doi:10.1056/NEJMoa2002032. PubMed PMID: 32109013; PubMed Central PMCID: PMC7092819. Epub 2020/02/29.
9. Pun VC, Kazemiparkouhi F, Manjourides J, Suh HH. Long-Term. PM2.5 Exposure and Respiratory, Cancer, and Cardiovascular Mortality in Older US Adults. *Am J Epidemiol*. 2017;186(8):961–9. doi:10.1093/aje/kwx166. PubMed PMID: 28541385; PubMed Central PMCID: PMC6915823. Epub 2017/05/26.
10. Tian Y, Wu Y, Liu H, Si Y, Wu Y, Wang X, et al. The impact of ambient ozone pollution on pneumonia: A nationwide time-series analysis. *Environment international*. 2020;136:105498. doi:10.1016/j.envint.2020.105498. PubMed PMID: 31991238. Epub 2020/01/29.
11. Zhu Y, Xie J, Huang F, Cao L. Association between short-term exposure to air pollution and COVID-19 infection: Evidence from China. *Sci Total Environ*. 2020;727:138704. doi:10.1016/j.scitotenv.2020.138704. PubMed PMID: 32315904; PubMed Central PMCID: PMC7159846. Epub 2020/04/22.
12. 10.3390/ijerph17114047
Adhikari A, Yin J. Short-Term Effects of Ambient Ozone, PM(2.5,) and Meteorological Factors on COVID-19 Confirmed Cases and Deaths in Queens, New York. *International journal of environmental research and public health*. 2020;17(11). Epub 2020/06/11. doi: 10.3390/ijerph17114047. PubMed PMID: 32517125; PubMed Central PMCID: PMC7312351.
13. Zhang Z, Xue T, Jin X. Effects of meteorological conditions and air pollution on COVID-19 transmission: Evidence from 219 Chinese cities. *Sci Total Environ*. 2020;741:140244. doi:10.1016/j.scitotenv.2020.140244. PubMed PMID: 32592975. Epub 2020/06/28.
14. Liang D, Shi L, Zhao J, Liu P, Schwartz J, Gao S, et al. Urban Air Pollution May Enhance COVID-19 Case-Fatality and Mortality Rates in the United States. *medRxiv: the preprint server for health sciences*. 2020. Epub 2020/06/09. doi: 10.1101/2020.05.04.20090746. PubMed PMID: 32511493; PubMed Central PMCID: PMC7273261.
15. 10.1101/2020.04.05.20054502
Wu X, Nethery RC, Sabath BM, Braun D, Dominici F. Exposure to air pollution and COVID-19 mortality in the United States: A nationwide cross-sectional study. *medRxiv: the preprint server for health sciences*. 2020. Epub 2020/06/09. doi: 10.1101/2020.04.05.20054502. PubMed PMID: 32511651; PubMed Central PMCID: PMC7277007.
16. Cui Y, Zhang ZF, Froines J, Zhao J, Wang H, Yu SZ, et al. Air pollution and case fatality of SARS in the People's Republic of China: an ecologic study. *Environ Health*. 2003;2(1):15. doi:10.1186/1476-069X-2-15. PubMed PMID: 14629774; PubMed Central PMCID: PMC293432. Epub 2003/11/25.
17. Morales KF, Paget J, Spreeuwenberg P. Possible explanations for why some countries were harder hit by the pandemic influenza virus in 2009 - a global mortality impact modeling study. *BMC Infect Dis*. 2017;17(1):642. doi:10.1186/s12879-017-2730-0. PubMed PMID: 28946870; PubMed Central PMCID: PMC5613504. Epub 2017/09/28.
18. Martelletti L, Martelletti P. Air Pollution and the Novel Covid-19 Disease: a Putative Disease Risk Factor. *SN comprehensive clinical medicine*. 2020:1–5. Epub 2020/04/17. doi: 10.1007/s42399-020-00274-4. PubMed PMID: 32296757; PubMed Central PMCID: PMC7156797.
19. 10.1016/j.jinf.2020.03.045

- Frontera A, Martin C, Vlachos K, Sgubin G. Regional air pollution persistence links to COVID-19 infection zoning. *The Journal of infection*. 2020. Epub 2020/04/14. doi: 10.1016/j.jinf.2020.03.045. PubMed PMID: 32283151; PubMed Central PMCID: PMC7151372.
20. 10.3390/ijerph17124487
Comunian S, Dongo D, Milani C, Palestini P. Air Pollution and Covid-19: The Role of Particulate Matter in the Spread and Increase of Covid-19's Morbidity and Mortality. *International journal of environmental research and public health*. 2020;17(12). Epub 2020/06/26. doi: 10.3390/ijerph17124487. PubMed PMID: 32580440; PubMed Central PMCID: PMC7345938.
21. :278 – 82
10.1016/j.ijid.2020.05.076
Epub 2020/06/06 PubMed PMID: 32502664; PubMed Central PMCID: PMC7266595
Li H, Xu XL, Dai DW, Huang ZY, Ma Z, Guan YJ. Air pollution and temperature are associated with increased COVID-19 incidence: A time series study. *Int J Infect Dis*. 2020;97:278 – 82. Epub 2020/06/06. doi:10.1016/j.ijid.2020.05.076. PubMed PMID: 32502664; PubMed Central PMCID: PMC7266595.
22. 10.1016/j.envpol.2020.114732
Fattorini D, Regoli F. Role of the chronic air pollution levels in the Covid-19 outbreak risk in Italy. *Environmental pollution (Barking, Essex: 1987)*. 2020;264:114732. Epub 2020/05/11. doi: 10.1016/j.envpol.2020.114732. PubMed PMID: 32387671; PubMed Central PMCID: PMC7198142.
23. Zhao J, Gao Z, Tian Z, Xie Y, Xin F, Jiang R, et al. The biological effects of individual-level PM(2.5) exposure on systemic immunity and inflammatory response in traffic policemen. *Occup Environ Med*. 2013;70(6):426–31. doi:10.1136/oemed-2012-100864. PubMed PMID: 23322918. Epub 2013/01/17.
24. Calderon-Garciduenas L, Vojdani A, Blaurock-Busch E, Busch Y, Friedle A, Franco-Lira M, et al. Air pollution and children: neural and tight junction antibodies and combustion metals, the role of barrier breakdown and brain immunity in neurodegeneration. *J Alzheimers Dis*. 2015;43(3):1039–58. Epub 2014/08/26. doi: 10.3233/JAD-141365. PubMed PMID: 25147109.
25. Cieniewicz J, Jaspers I. Air pollution and respiratory viral infection. *Inhalation toxicology*. 2007;19(14):1135–46. Epub 2007/11/08. doi: 10.1080/08958370701665434. PubMed PMID: 17987465.
26. Landrigan PJ, Fuller R, Acosta NJR, Adeyi O, Arnold R, Basu NN, et al. The Lancet Commission on pollution and health. *Lancet*. 2018;391(10119):462–512. doi:10.1016/S0140-6736(17)32345-0. PubMed PMID: 29056410. Epub 2017/10/24.
27. Hayes RB, Lim C, Zhang Y, Cromar K, Shao Y, Reynolds HR, et al. PM2.5 air pollution and cause-specific cardiovascular disease mortality. *Int J Epidemiol*. 2020;49(1):25–35. doi:10.1093/ije/dyz114. PubMed PMID: 31289812; PubMed Central PMCID: PMC7124502. Epub 2019/07/11.
28. 10.1164/rccm.201609-1862OC
Chen R, Yin P, Meng X, Liu C, Wang L, Xu X, et al. Fine Particulate Air Pollution and Daily Mortality. A Nationwide Analysis in 272 Chinese Cities. *Am J Respir Crit Care Med*. 2017;196(1):73–81. Epub 2017/03/02. doi: 10.1164/rccm.201609-1862OC. PubMed PMID: 28248546.
29. Ogen Y. Assessing nitrogen dioxide (NO2) levels as a contributing factor to coronavirus (COVID-19) fatality. *The Science of the total environment*. 2020;726:138605. Epub 2020/04/18. doi: 10.1016/j.scitotenv.2020.138605. PubMed PMID: 32302812; PubMed Central PMCID: PMC7151460.

Tables

Table 1
Descriptive Statistics on COVID-19 Case Fatality Rate and Long-term Air Pollution Indicators(AQI, PM2.5, NO2)in 14 Representative Cities of China

cities	Total Cured	Total Death	Case Fatality Rate(%)	AQI(1-year)	AQI(3-year)	AQI(5-year)	PM2.5(1-year) ug/m ³	PM2.5(3-year) ug/m ³	PM2.5(5-year) ug/m ³	NO2(1-year) ug/m ³	NO2(3-year) ug/m ³	NO2(5-year) ug/m ³
Total	4247	47	1.09	79.28 ± 23.68	80.60 ± 23.79	84.17 ± 27.03	39.45 ± 21.47	42.26 ± 22.08	47.80 ± 25.81	36.40 ± 10.96	39.53 ± 11.82	41.81 ± 12.82
Hangzhou	181	0	0.00	75.75 ± 48.18	77.61 ± 33.77	80.92 ± 36.52	32.91 ± 8.45	37.47 ± 13.15	42.87 ± 16.02	38.42 ± 11.87	40.33 ± 11.89	42.55 ± 11.53
Nanchang	230	0	0.00	70.50 ± 12.01	67.61 ± 12.62	69.92 ± 14.35	35.33 ± 11.71	33.47 ± 13.93	37.18 ± 14.05	32.08 ± 11.04	33.19 ± 10.30	32.9 ± 11.95
Guangzhou	479	1	0.21	73.75 ± 17.44	71.47 ± 13.45	71.12 ± 12.59	27.75 ± 8.96	30.67 ± 10.30	33.17 ± 9.99	42.5 ± 10.88	45.08 ± 9.73	46.1 ± 10.70
Hefei	173	1	0.57	78.67 ± 11.91	82.58 ± 17.71	85.6 ± 20.21	38.83 ± 13.16	45.03 ± 18.96	51.2 ± 21.41	39.17 ± 11.34	41.72 ± 11.93	42.55 ± 12.25
Shenzhen	445	3	0.67	57.42 ± 18.38	53.58 ± 13.76	53.63 ± 13.23	23.25 ± 8.80	24.39 ± 8.87	25.55 ± 8.66	24.67 ± 6.46	26.22 ± 5.30	28.65 ± 5.94
Changsha	240	2	0.83	78.83 ± 15.89	79.22 ± 19.38	80.6 ± 19.24	42.75 ± 16.16	45.81 ± 21.20	49.27 ± 20.54	30.58 ± 10.43	32.67 ± 10.72	24.63 ± 10.71
Chongqing	573	6	1.04	67.83 ± 14.19	71.69 ± 14.44	74.02 ± 14.80	35.33 ± 13.23	37.86 ± 15.53	43.32 ± 16.58	36.83 ± 6.90	40.03 ± 7.17	42.28 ± 7.38
Shanghai	581	7	1.19	70 ± 9.52	74.19 ± 13.36	77.4 ± 13.90	32.42 ± 9.97	34.86 ± 10.56	39.37 ± 13.01	37.92 ± 10.41	40.11 ± 11.41	41.67 ± 11.71
Tianjin	182	3	1.62	97.67 ± 21.46	97.36 ± 17.82	99.8 ± 22.29	49.67 ± 18.87	51.53 ± 16.29	58.77 ± 22.34	40.00 ± 12.37	42.69 ± 11.97	44.33 ± 14.23
Beijing	536	9	1.65	84.42 ± 17.93	88.53 ± 18.71	99.05 ± 25.98	40.33 ± 11.15	45.56 ± 12.12	57.25 ± 25.16	33.00 ± 8.79	37.64 ± 9.31	42.03 ± 12.59
Chengdu	163	3	1.81	74.5 ± 15.81	81.06 ± 18.93	88.35 ± 23.05	40.92 ± 17.74	44.64 ± 19.24	51.27 ± 23.75	38.30 ± 7.27	43.61 ± 9.33	47.53 ± 10.24
Harbin	195	4	2.01	77.33 ± 45.18	78.42 ± 33.77	82.17 ± 36.52	48.25 ± 43.99	47.14 ± 34.93	51.87 ± 36.87	32.08 ± 11.07	36.69 ± 8.65	39.32 ± 12.31
Xi'an	117	3	2.50	99.25 ± 29.32	103.64 ± 32.23	107.75 ± 37.50	54.25 ± 34.19	57.31 ± 34.95	63.07 ± 39.32	43.75 ± 10.72	49.72 ± 13.23	50.83 ± 13.53
Zhengzhou	152	5	3.18	104 ± 21.83	101.39 ± 25.86	108.12 ± 30.13	52 ± 28.62	55.89 ± 28.12	65.07 ± 33.26	40.25 ± 9.87	45.69 ± 11.40	49.93 ± 12.75
“(1-year)” is the abbreviation of “Average in the past year”; “(3-year)” is the abbreviation of “Average in the past 3 years”; “(5-year)” is the abbreviation of “Average in the past 5 years”												

Table 2
Correlation Test Results of Various Air Pollution Indicators and Case Fatality Rate

Variables	Correlation coefficient	P value
AQI (1-year)	R = 0.712	0.004*
AQI (3-year)	R = 0.733	0.003*
AQI (5-year)	R = 0.759	0.002*
PM2.5 (1-year, ug/m ³)	R = 0.790	0.001*
PM2.5 (3-year, ug/m ³)	R = 0.733	0.001*
PM2.5 (5-year, ug/m ³)	R = 0.785	0.001*
PM10 (1-year, ug/m ³)	R = 0.686	0.007*
PM10 (3-year, ug/m ³)	R = 0.744	0.002*
PM10 (5-year, ug/m ³)	R = 0.686	0.007*
SO ₂ (1-year, ug/m ³)	rs = 0.328	0.252
SO ₂ (3-year, ug/m ³)	R = 0.469	0.091
SO ₂ (5-year, ug/m ³)	R = 0.559	0.038*
NO ₂ (1-year, ug/m ³)	R = 0.280	0.332
NO ₂ (3-year, ug/m ³)	R = 0.471	0.089
NO ₂ (5-year, ug/m ³)	R = 0.523	0.055
O ₃ (1-year, ug/m ³)	R = -0.074	0.800
O ₃ (3-year, ug/m ³)	R = 0.200	0.493
O ₃ (5-year, ug/m ³)	R = 0.129	0.659
* indicates that this data is statistically significant ; “ (1-year)” is the abbreviation of “Average in the past year”; “ (3-year)” is the abbreviation of “Average in the past 3 years”; “ (5-year)” is the abbreviation of “Average in the past 5 years”; R is the result of Pearson correlation test; rs is the result of Spearman correlation test.		

Table 3
Independent Sample *t* Test Results of Various Air Pollution Indicators between High CFR Group and Low CFR Group

Variables	Low CFR group	High CFR group	t value	Pvalue
AQI (1-year)	72.49 ± 8.021	84.28 ± 14.196	1.832	0.092
AQI (3-year)	72.01 ± 10.530	87.04 ± 12.541	2.368	0.036*
AQI (5-year)	73.63 ± 11.533	92.08 ± 13.442	2.694	0.020*
PM2.5 (1-year, ug/m ³)	33.47 ± 7.152	44.15 ± 8.030	2.575	0.024*
PM2.5 (3-year, ug/m ³)	36.14 ± 8.360	46.85 ± 7.966	2.438	0.031*
PM2.5 (5-year, ug/m ³)	39.87 ± 9.828	53.75 ± 9.085	2.733	0.018*
PM10 (1-year, ug/m ³)	56.15 ± 9.383	68.39 ± 17.208	1.565	0.144
PM10 (3-year, ug/m ³)	57.81 ± 10.492	74.64 ± 17.454	2.084	0.059
PM10 (5-year, ug/m ³)	66.04 ± 16.174	85.34 ± 20.209	1.855	0.088
SO ₂ (1-year, ug/m ³)	6.68 ± 1.220	8.42 ± 3.842	1.059	0.311
SO ₂ (3-year, ug/m ³)	8.23 ± 1.315	10.44 ± 4.034	1.280	0.225
SO ₂ (5-year, ug/m ³)	10.46 ± 2.320	13.78 ± 5.013	1.497	0.160
NO ₂ (1-year, ug/m ³)	34.57 ± 2.702	34.77 ± 1.358	-1.143	0.275
NO ₂ (3-year, ug/m ³)	36.54 ± 2.868	42.02 ± 1.529	-1.811	0.095
NO ₂ (5-year, ug/m ³)	36.23 ± 3.561	44.74 ± 1.489	-2.205	0.065
O ₃ (1-year, ug/m ³)	100.92 ± 3.820	93.41 ± 14.008	-1.446	0.185
O ₃ (3-year, ug/m ³)	92.66 ± 4.259	92.72 ± 11.835	0.015	0.988
O ₃ (5-year, ug/m ³)	90.65 ± 3.574	90.54 ± 12.019	-0.024	0.982
* indicates that this data is statistically significant; "(1-year)" is the abbreviation of "Average in the past year"; "(3-year)" is the abbreviation of "Average in the past 3 years"; "(5-year)" is the abbreviation of "Average in the past 5 years";				

Table 4
ROC Curve Analysis of Case Fatality Rate

Variables	Cut-off value	AUC	Pvalue
AQI (1-year)	NA	0.688	0.245
AQI (3-year)	NA	0.813	0.053
AQI (5-year)	86.98	0.854	0.028*
PM2.5 (1-year, ug/m ³)	39.58	0.823	0.045*
PM2.5 (3-year, ug/m ³)	37.67	0.833	0.039*
PM2.5 (5-year, ug/m ³)	51.57	0.896	0.014*
* indicates that this data is statistically significant; "(1-year)" is the abbreviation of "Average in the past year"; "(3-year)" is the abbreviation of "Average in the past 3 years"; "(5-year)" is the abbreviation of "Average in the past 5 years";			

Figures

Figure 1

Geographic patterns of COVID-19 CFR in the 14 cities in China till April 28th, 2020. CFR: Case Fatality Rate Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

Figure 2

The changes of air quality indicators in these 14 cities over the past 5 years. (a) AQI; (b) PM2.5; (c) PM10; (d) SO2; (e) NO2; (f) O3; AQI: Air Quality Index

Figure 3

Scatterplots show the relationships between CFR and air quality indicators. a-c) Air quality score in the past 1-year, 3-year, and 5-year, respectively; d-f) AQI in the past 1-year, 3-year, and 5-year, respectively; g-i) PM2.5 in the past 1-year, 3-year, and 5-year, respectively. CFR: Case Fatality Rate, AQI: Air Quality Index

Figure 4

ROC curves show the ability of air quality indicators to predict CFR. a-c) Air quality score in the past 1-year, 3-year, and 5-year, respectively; d-f) AQI in the past 1-year, 3-year, and 5-year, respectively; g-i) PM2.5 in the past 1-year, 3-year, and 5-year, respectively. CFR: Case Fatality Rate, AQI: Air Quality Index

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [SupplementaryTable1.doc](#)