International Journal of Infectious Diseases 96 (2020) 284–287

Contents lists available at ScienceDirect

International Journal of Infectious Diseases

journal homepage: www.elsevier.com/locate/ijid

Quantifying the improvement in confirmation efficiency of the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) during the early phase of the outbreak in Hong Kong in 2020

Jinjun Ran[a,1], Shi Zhao[b,c,1,*], Zian Zhuang[d], Marc K.C. Chong[b,c], Yongli Cai[e], Peihua Cao[f], Kai Wang[g], Yijun Lou[d], Weiming Wang[e], Daozhou Gao[h], Lin Yang[i], Daihai He[d,*], Maggie H. Wang[b,c]

[a] School of Public Health, Li Ka Shing Faculty of Medicine, University of Hong Kong, Hong Kong, China
[b] JC School of Public Health and Primary Care, Chinese University of Hong Kong, Hong Kong, China
[c] Shenzhen Research Institute of Chinese University of Hong Kong, Shenzhen, China
[d] Department of Applied Mathematics, Hong Kong Polytechnic University, Hong Kong, China
[e] School of Mathematics and Statistics, Huaiyin Normal University, Huaian, China
[f] Clinical Research Centre, Zhujiang Hospital, Southern Medical University, Guangzhou, Guangdong, China
[g] Department of Medical Engineering and Technology, Xinjiang Medical University, Urumqi, China
[h] Department of Mathematics, Shanghai Normal University, Shanghai, China
[i] School of Nursing, Hong Kong Polytechnic University, Hong Kong, China

ARTICLE INFO

Article history:
Received 18 February 2020
Received in revised form 2 May 2020
Accepted 3 May 2020

Keywords:
COVID-19
confirmation efficiency
early outbreak
Hong Kong.

ABSTRACT

Backgrounds: The emerging virus, severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), caused a large outbreak of coronavirus disease, COVID-19, in Wuhan, China, since December 2019. COVID-19 soon spread to other regions of China and overseas. In Hong Kong, local mitigation measures were implemented since the first imported case was confirmed on January 23, 2020. Here we evaluated the temporal variation of detection delay from symptoms onset to laboratory confirmation of SARS-CoV-2 in Hong Kong.

Methods: A regression model is adopted to quantify the association between the SARS-CoV-2 detection delay and calendar time. The association is tested and further validated by a Cox proportional hazard model.

Findings: The estimated median detection delay was 9.5 days (95%CI: 6.5 – 11.5) in the second half of January, reduced to 6.0 days (95%CI: 5.5 – 9.5) in the first half of February 2020. We estimate that SARS-CoV-2 detection efficiency improved at a daily rate of 5.40% (95%CI: 2.54 – 8.33) in Hong Kong.

Conclusions: The detection efficiency of SARS-CoV-2 was likely being improved substantially in Hong Kong since the first imported case was detected. Sustaining enforcement in timely detection and other effective control measures are recommended to prevent the SARS-CoV-2 infection.

1. Backgrounds

The deadly coronavirus disease (COVID-19), caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2, formerly 2019-nCoV), has emerged in Wuhan, China, in December 2019 (WHO, 2020). COVID-19 cases were soon exported to other Chinese cities and overseas, mainly owing to the traffic surge near the Chinese Lunar New Year (Bogoch et al., 2020; Wu et al., 2020). The first imported cases in Hong Kong were confirmed and reported on January 23, 2020, see Fig. 1(a). Since then, the government of Hong Kong has implemented a series of control and prevention measures for COVID-19, including enhanced border

* Corresponding authors.
E-mail addresses: jimran@connect.hku.hk (J. Ran), zhaoshi.cmsa@gmail.com (S. Zhao), larry.zhuang@polyu.edu.hk (Z. Zhuang), marc@cuhk.edu.hk (M.K.C. Chong), yonglicai@hytc.edu.cn (Y. Cai), cphcc@smu.edu.cn (P. Cao), wangkaimath@sina.com (K. Wang), yijun.lou@polyu.edu.hk (Y. Lou), weimingwang2003@163.com (W. Wang), dzgao@shnu.edu.cn (D. Gao), l.yang@polyu.edu.hk (L. Yang), daihai.he@polyu.edu.hk (D. He), maggiew@cuhk.edu.hk (M.H. Wang).

[1] JR and SZ contribute equally, and thus they are joint first authors.

https://doi.org/10.1016/j.ijid.2020.05.015
1201-9712/

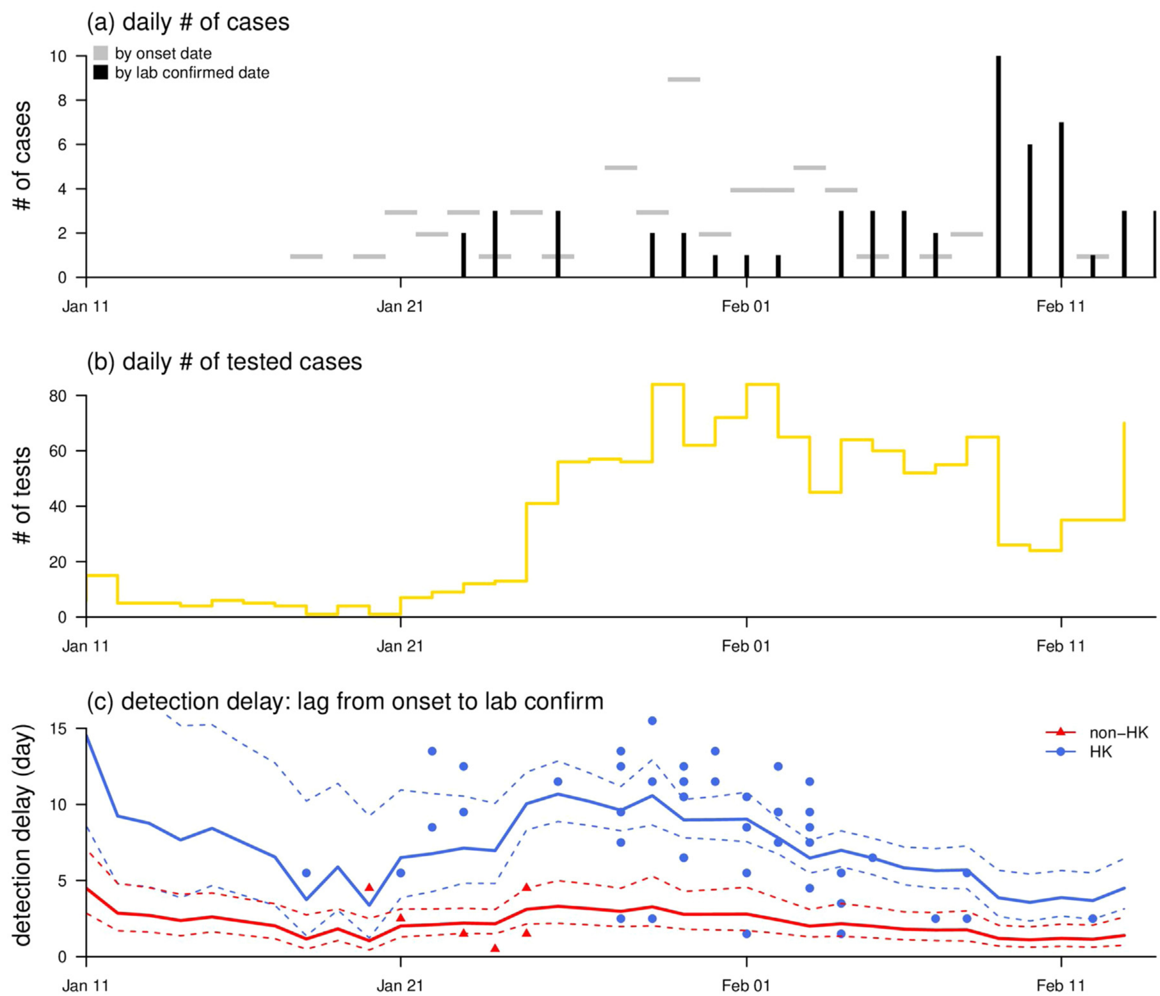

Fig. 1. The daily SARS-CoV-2 cases time series in (a), and count of tested cases (b) and the association between detection delay (τ) and time in (c). Panel (a) shows the time series of the daily number of SARS-CoV-2 cases aggregated by the date of onset (grey horizontal bars) and by the laboratory-confirmed date (black vertical bars). Panel (b) shows the time series of the daily number of tested cases. Panel (c) shows the detection delays (τ) of the cases who are Hong Kong residence (blue dots) and of the cases who are not Hong Kong residence (red triangles) vary over the calendar date. The bold curves are the fitting results of the regression in Eqn (1), and the dashed curves are the 95% confidence interval (95%CI).

screening and traffic restrictions (summary, in press; CHP, in press). The official news related to the COVID-19 outbreak was first released by the CHP on December 31, 2019. Outbreak-related news reports have been released daily since January 2 and updated at least twice per day since January 23, 2020 (CHP, in press). After the first week of February, COVID-19 was controlled at 1 incidence onset from February 9 to the present (as of February 15), 2020.

In this study, we quantify the improving rate of detection efficiency of SARS-CoV-2 in Hong Kong.

2. Data and methods

The follow-up data of individual patients were collected via the official website of the Centre for Health Protection (CHP) of Hong Kong (summary, in press). All cases were laboratory-confirmed following the case definition, referring to the official diagnostic protocol released by WHO (WHO, in press).

The case detection efficiency is the reciprocal of detection delay, denoted by τ. The detection delay (τ) is measured by the time interval between the date of COVID-19 symptoms onset and the date of laboratory confirmation. For the i-th patient, the detection delay is denoted by $\tau_{i,t}$, where t denotes symptoms onset on the t-th day.

Thus, the time evolution of the detection delay is formulated by a regression model in Eqn (1).

$$\mathbf{E}[\log(\tau_{i,t})] = \beta \cdot t + \beta_1 \cdot \log(n_{t,t+\tau}) + \beta_2 \cdot \mathrm{isHK}_i + \beta_0, \quad (1)$$

where $\mathbf{E}[\cdot]$ represents the expectation. The 'isHK$_i$' is an indicator that is 1 if the i-th patient is a Hong Kong resident but 0 otherwise. The $\langle n \rangle_{t,t+\tau}$ denotes the average number of cases being tested between the t-th and $(t+\tau)$-th days, and thus it accounts for the effect of time-varying working load. The β is the regression coefficient for the onset time variable t. The β quantifies the rate of change in the detection delay. Since a shorter detection delay means a higher detection efficiency, we expect a negative estimate of β for an improving detection efficiency over time. The $[\exp(-\beta) - 1] \times 100\%$ quantifies the percentage improvement in the detection efficiency per day in Hong Kong. We fit the model by a Gamma-distributed likelihood framework. The 95% confidence interval (95%CI) of β is calculated by using its mean estimate plus and minus its standard deviation (SD) multiplied by the Student's t quantile.

Validation analysis is conducted by using the Cox proportional hazard (PH) model defined as $S(\tau) = S_0(\tau) \cdot \exp[\alpha \cdot t + \alpha_1 \cdot \log\left(\langle n \rangle_{t,t+\tau}\right) + \alpha_2 \cdot \mathrm{isHK} + \alpha_0]$, which has a similar form as

Table 1
Summary of the events and control measures during the early phase of the COVID-19 outbreak in Hong Kong (HK).

Date or period	Event type	Details
January 17 -	control measure	Temperature check of all inbound travellers at borders
January 19	Fact	First COVID-19 case in HK symptom onset
January 21 -	control measure	COVID-19 reporting system in operation
January 24 -	control measure	Testing for all suspected, confirmed cases and close contacts Isolation and quarantine
January 25 -	control measure	Activate the 'Emergency' level of response plan against the outbreak
January 23 -	fact and control measure	Local schools' holiday, and school closure
January 25 - January 28	Fact	Chinese lunar new year holiday
January 26 -	control measure	Cancellation of major gathering events, and closure of parks
January 27 -	control measure	Flight suspension between HK and Wuhan Boarder restriction for non-HK residents with travel history to Hubei
January 30 -	control measure	Close 6 border-control points
February 4 -	control measure	Close 4 additional border-control points
February 9 -	control measure	Quarantine for all individuals coming from mainland China

Eqn (1). The $S(\cdot)$ is the survival function, and the $S_0(\cdot)$ is the baseline survival function. Similarly, the α is the regression coefficient for t in the hazard function, and thus $\exp(\alpha)$ is the hazard ratio (HR). In contrast to β, we expect a positive estimate of α for an improving detection efficiency over time. For validation, we exam the signs of the estimated α and β, and their statistical significance levels.

3. Results and discussion

Fig. 1(a) shows the epidemic curve of all 56 COVID-19 cases as of February 15, 2020, in Hong Kong. We reported that the onset cases peaked on January 30, and the confirmed cases peaked on February 9, 2020. The daily number of tests started increasing rapidly from January 23 until the end of January, see Fig. 1(b). The estimated median detection delay was 9.5 days (95%CI: $6.5-11.5$) in the second half of January, and this number was reduced to 6.0 days (95%CI: $5.5-9.5$) in the first half of February 2020. These estimates indicate the enhancement of infection screening and public interventions for the prevention and control of SARS-CoV-2.

The fitting results of Eqn (1) are shown in Fig. 1(c); and the Nagelkerke's pseudo-R-squared is 0.38. The non-resident cases are likely to be detected earlier than the resident cases even though there were only 5 non-Hong Kong resident cases. We estimate that SARS-CoV-2 detection efficiency improves 5.40% per day (95%CI: $2.54-8.33$) in Hong Kong. The estimates of α and β are consistent in signs, i.e., α is positive, and β is negative, and statistical significance levels, i.e., both are significant with p-values < 0.05, which validate our estimates. Therefore, we report that the SARS-CoV-2 infection detection efficiency was likely being improved substantially and significantly since January 23, 2020, when the first imported case was detected in Hong Kong.

Due to the unavailability of data, our findings are restricted to the early phase of the COVID-19 outbreak in Hong Kong. However, our analytical approach can be extended to a more complex context. In Table 1, the events and control measures during the early outbreak are summarized. Most of the control measures aimed at strengthening the testing efforts, i.e., number of tests and testing efficiency, and reducing the size of the outbreak. Though the control measures would partially affect the testing efforts, we have accounted for these effects by adjusting the $\langle n \rangle_{t,t+\tau}$ term in the models. Hence, our estimates should quantify the temporal improvement in detection efficiency.

We note that the sustaining enforcement in timely detection and other effective control measures are recommended in response to reduce the risk associated with SARS-CoV-2.

Declarations

Ethics approval and consent to participate

The follow-up data of individual patients were collected via the public domain (summary, in press), and thus neither ethical approval nor individual consent was required.

Availability of data and materials

All data and materials used in this work were publicly available via (summary, in press).

Consent for publication

Not applicable.

Funding

DH was supported by the General Research Fund (Grant Number 15205119) of the Research Grants Council (RGC) of Hong Kong, China, and an Alibaba (China) - Hong Kong Polytechnic University Collaborative Research project (0031768). WW was supported by the National Natural Science Foundation of China (Grant Number 61672013) and Huaian Key Laboratory for Infectious Diseases Control and Prevention (Grant Number HAP201704), Huaian, Jiangsu, China.

Competing Interests

DH was supported by an Alibaba-Hong Kong Polytechnic University Collaborative Research project. Other authors declared no competing interests.

Disclaimer

The funding agencies had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; or decision to submit the manuscript for publication.

Conflict of Interests

The authors declared no competing interests.

Authors' Contributions

SZ conceived the study, carried out the analysis. JR and SZ drafted the first manuscript. All authors discussed the results, critically read and revised the manuscript, and gave final approval for publication.

Acknowledgments

None.

References

'Pneumonia of unknown cause – China,' Emergencies preparedness, response, Disease outbreak news, World Health Organization (WHO) [https://www.who.int/csr/don/05-january-2020-pneumonia-of-unkown-cause-china/en/]

Bogoch II, Watts A, Thomas-Bachli A, Huber C, Kraemer MU, Khan K. Pneumonia of unknown etiology in Wuhan, China: potential for international spread via commercial air travel. Journal of Travel Medicine 2020;, doi:http://dx.doi.org/10.1093/jtm/taaa1008.

Wu JT, Leung K, Leung GM:. Nowcasting and forecasting the potential domestic and international spread of the 2019-nCoV outbreak originating in Wuhan, China: a modelling study. The Lancet 2020;.

Summary of data and outbreak situation of the Severe Respiratory Disease associated with a Novel Infectious Agent, Centre for Health Protection, the government of Hong Kong. [https://www.chp.gov.hk/en/features/102465.html]

The collection of Press Releases by the Centre for Health Protection (CHP) of Hong Kong. [https://www.chp.gov.hk/en/media/116/index.html]

Laboratory testing for 2019 novel coronavirus (2019-nCoV) in suspected human cases, World Health Organization (WHO) [https://www.who.int/health-topics/coronavirus/laboratory-diagnostics-for-novel-coronavirus]