Early signs of geographic spread of COVID-19: lessons learnt from outbreaks in Wuhan 2020 and Nanjing 2021

Shan Xuea,b, Yiwen Huac, Yanhui Leia,b, Lingcai Konda, Menghan Zhouc, Lijun Fanb and Wei Duc,*

aState Key Laboratory of Resources and Environmental Information System, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China; bUniversity of Chinese Academy of Science, Beijing 10049, China; cKey Laboratory of Environmental Medicine Engineering, Ministry of Education; School of Public Health, Southeast University, Nanjing 210009, Jiangsu, China; dDepartment of Mathematics and Physics, North China Electric Power University, Baoding 071003, China

*Corresponding author: Tel: +86 (25) 8327 2303; E-mail: duwei@seu.edu.cn

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Background: Knowing the spatiotemporal pattern of the early geographic spread of coronavirus disease 2019 (COVID-19) would inform the preparedness for a possible recurrence of COVID-19.

Methods: We ascertained the number of confirmed cases during the early spread of COVID-19 during the Wuhan outbreak in 2020 and the Nanjing outbreak in 2021.

Results: We observed a speeding-up pattern of geographic spread, in particular to cities of no particular orientation then outflowing to commercial cities during the first month of both the Wuhan and Nanjing outbreaks.

Conclusion: Re-emergence of COVID-19 indicates it is becoming endemic, with new outbreaks and a risk of increased transmission remaining a challenge to local public health institutions. Social distancing and lockdowns should continue in response to any potential widespread and focal outbreaks.

Keywords: city clustering, COVID-19, geographic spread.

Introduction

The coronavirus disease 2019 (COVID-19) pandemic showed rapid human-to-human transmission risk and raised concerns within the world health community. The majority of municipalities around the world have activated emergency responses in regards to the COVID-19 pandemic, including community-based health checkpoints and social distancing. However, the COVID Delta variant has presented an opportunity to rethink responses to avoid its spread. Because the early stage of COVID-19 case spread demonstrated a spatial distribution, identification of hotspot cities vulnerable to an outbreak could lead to increased preparedness for containment and control. In this study we measured the spatial clustering in cities to visualise the early spread of COVID-19 for the Wuhan outbreak in 2020 and the Nanjing outbreak 2021. Findings will inform countermeasures to mitigate the risk of outbreak re-emergence in China as well as other places with similar settings.

Methods

To understand the spatiotemporal pattern in the early spread of COVID-19, we ascertained the daily number of confirmed cases during the early period of the Wuhan and Nanjing outbreaks from every provincial health commission in mainland China. We further categorised the types of cities into eight groups (including comprehensive cities with administrative functions, mining cities, manufacturing cities, and tourist destination cities with industrial and commercial functions) based on selected variables (including manufacturing; construction; transport, storage, postal and telecommunications; scientific research, polytechnic services and geological prospecting; business; government and social organizations; mining and quarrying; and tourism) representing the functions of sectors in a city from the Chinese Statistical Yearbook 2015. The variables indicated the number of employees in a sector as a proportion of all employees in a city and k-means cluster analysis was used for
We selected the number of clusters using the largest cubic clustering criterion. Since the clustering method cannot manifest all the characteristic features for every city category, Nelson’s method was applied to determine the main function for each category, as recommended by Wang et al. Specifically for each categorisation variable, the arithmetic mean and standard deviation (SD) were calculated and a variable 1 SD above the mean value was defined as the dominant function for the city category. A similar modelling approach was employed in other settings. We used the Python 3.7 matplotlib package (https://www.python.org) to plot the early geographic spread of confirmed cases over the study period (codes provided in the supplementary material). The city category was colour-coded and plotted on a daily basis to highlight the pattern of geographic spread over time in the early stage of COVID-19 outbreaks (Figure 1).

Figure 1. Early geographic spread of COVID-19 during the outbreaks in (A) Nanjing (2021) and (B) Wuhan (2020).
Results

Figure 1A shows the early spread of the Nanjing outbreak in 2021 to comprehensive cities without orientation, then manufacturing cities and commercial cities with industrial functions, all of which have smaller residential population sizes compared with the receiving cities from the Wuhan outbreak in 2020. Figure 1B shows the early spread of the Wuhan outbreak in 2020 to comprehensive cities without orientation, then commercial cities and those having a substantial population size or having an established transportation network, such as Beijing, Shanghai, and Guangzhou, due in part to the 2021 Spring Festival travel rush with likely movement to these destinations.6

Discussion

On 23 January 2020, the COVID-19 outbreak prompted the lockdown of Wuhan for the purpose of containing and mitigating the risk of geographic spread. During the early spread of COVID-19 prior to the 2021 Spring Festival, an increasing number of confirmed cases were reported in a circle of 68 small cities nested within the Wuhan land transport network, around 600 km distance to Wuhan. This substantial contribution in geographic spread remained constant without being affected by the lockdown of Wuhan, possibly reflecting a reservoir of imported cases prior to the lockdown of Wuhan. The finding of the early spread of the Wuhan outbreak in 2020 also implied the lack of a collaboration mechanism for multiple local governments to identify essential resources and responsibilities during the early spread of COVID-19. Learning from the successful strategies implemented in 2020, countermeasures built on an existing interdepartmental collaboration mechanism during the Nanjing outbreak in 2021 were more precise, including partial lockdown, multiple rounds of nucleic acid amplification tests for screening, quarantine of high-risk populations, fast track of assistance with therapeutic and rehabilitation care and rapid follow-up vaccination. Nevertheless, these hotspot cities from early spread of both outbreaks (Figure 1A and B), with only 1.5-y between them, clearly showed a similar fast-penetrating pattern and required implementation of public health countermeasures, such as social distancing, as early as possible.

Cities at high-risk of COVID-19 outbreaks in 2020 and 2021 demonstrated a similar pattern of easy access to Wuhan and Nanjing by rail, road, or air, and this pattern became clearer over time during the early spread of COVID-19. Compliance with lockdown rules appeared a somewhat robust strategy to contain the geographic spread. While the world is still fighting COVID-19 variants for recovery from the pandemic,9 globally adopting a suite of comprehensive countermeasures in response to an elevated risk of spread,10 consensus on lifting travel restrictions has not been achieved. In case of a likely COVID-19 re-emergence in relation to any large-scale population movements, such as the Spring Festival travel rush in China, summer holiday vacations and any other human migration elsewhere in the world, it is arguably necessary to avoid early lifting of restrictions on domestic and international travel and to implement community-based health checkpoints where appropriate.

The observed early spread of COVID-19 outbreaks in 2020 and 2021 indicated that the global travel, transport and logistics industry sectors as well as social care sector were exposed to a high risk of viral transmission, for example, through transportation depots or educational institutions where a lot of people gather for a common purpose or labour-intensive processes with large numbers of shift workers in the same location. However, evidence on the exact frequency of exposure, modes of transmission and level of immunity in these settings was limited. Given that the transmissibility of COVID-19 has increased from the original variant (approximately 2.2) to the Delta variant (approximately 6), it is likely that the real-world effectiveness of vaccination would have been impaired, especially under circumstances of waning immunity over time. Therefore, countermeasures including lockdowns, social distancing and masks should be reinstated or continued where appropriate, especially among vulnerable populations like children and the elderly, considering that vaccines do not prevent transmission. As the public health authorities continue the current risk mitigation strategies in response to the emergence of COVID-19 variants, greater investment, including expansion of vaccinations, regular medical screening and surveillance for staff in the focal industry sectors is clearly an option that should be considered.

Conclusions

Continuing efforts are warranted to reinforce appropriate public health countermeasures when facing the COVID-19 variants. While the observed variation in geographic spread requires further investigation to elucidate the driving mechanisms, precautionary actions should be adopted in the absence of complete scientific evidence of risk. Future effort should not only target vaccination and travel restrictions, but also improvement of clinical care and human behavioural change.

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References
1 Munster VJ, Koopmans M, van Doremalen N, et al. A novel coronavirus emerging in China—key questions for impact assessment. N Engl J Med. 2020;382(8):692–4.
2 Mawani M, Li C. Coronavirus disease (COVID-19); lessons learnt from international response and advice to the Georgia government. Innovation. 2020;1(2):100025.
3 Shen M, Peng Z, Xiao Y, et al. Modeling the epidemic trend of the 2019 novel coronavirus outbreak in China. Innovation. 2020;1(3):100048.
4 Zhang L, Tao Y, Zhuang G, et al. Characteristics analysis and implications on the COVID-19 reopening of Victoria, Australia. Innovation. 2020;1(3):100049.
5 Wang JF, Liu XH, Peng L, et al. Cities evolution tree and applications to predicting urban growth. Popul Environ. 2012;33(2–3):186–201.
6 Liao Y, Wang J, Chen G, et al. Clustering of disability caused by unintentional injury among 15 to 60 years old: a challenge in rapidly developing countries. Geospatial Health. 2013;8(1):13–22.
7 Zhou Y, Poon J, Yang Y. China’s CO₂ emission intensity and its drivers: an evolutionary Geo-Tree approach. Resour Conserv Recy. 2021;171(4):105630.
8 Hu Y, Kong L, Yao T, et al. Does lock-down of Wuhan effectively restrict early geographic spread of novel coronavirus epidemic during chunyun in China? A spatial model study. BMC Public Health. 2021;21:825.
9 Carvalho K, Vicente JP, Jakovljevic M, et al. Analysis and forecasting incidence, intensive care unit admissions, and projected mortality attributable to COVID-19 in Portugal, the UK, Germany, Italy, and France: predictions for 4 weeks ahead. Bioengineering. 2021;8(6):84.
10 Reshetnikov V, Mitrokhin O, Shepetovskaya N, et al. Organizational measures aiming to combat COVID-19 in the Russian Federation: the first experience. Expert Rev Pharmacoecon Outcomes Res. 2020;20(6):571–6.