From severe acute respiratory syndrome-associated coronavirus to 2019 novel coronavirus outbreak: similarities in the early epidemics and prediction of future trends

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Emerging infectious diseases represent a serious threat for human public health worldwide.[1,2] The 2019 novel coronavirus (2019-nCoV) caused a pneumonia outbreak, which is spreading around the country and has affected 32 provinces and regions of China as of January 27, 2020.[3,4] Countries outside China, including Japan, the United States, Thailand, and South Korea, have also reported cases imported from other countries.[5] With the joint efforts of Chinese scientists, health workers, and related departments, the pathogen causing this epidemic was quickly identified as a new type of coronavirus, 10 days after the first official report. After confirming the pathogen, specific detection methods were rapidly developed, with improvement in etiological diagnosis. As of January 22, 2020, it has been confirmed that the new coronavirus came from wild bats and belonged to group 2b of the beta coronavirus, which includes severe acute respiratory syndrome-associated coronavirus (SARS-CoV).[6] Although 2019-nCoV and SARS-CoV belong to the same sub-group of beta coronaviruses, the similarity at the genome level is only 80%,[7,8] meaning that the new virus is genetically different from SARS-CoV [Supplementary Figure 1A, http://links.lww.com/CM9/A209]. Rapid discovery of the causative agent and development of diagnostic reagents demonstrated that technology has greatly improved in the 17 years since the SARS outbreak. However, no effective anti-viral medication or vaccines are available for this new virus, and many of its aspects remain to be explored. Similar to the SARS outbreak, this outbreak also occurred during the spring festival, the most important of the Chinese traditional festivals, when 3 billion people travel throughout the country.[9] This unexpectedly provides beneficial conditions for the transmission of this highly infectious disease and correspondingly poses great challenges for the prevention and control of the outbreak.

Although technology has greatly improved since the 2003 SARS outbreak, the basic laws and characteristics of the occurrence and development of infectious diseases have not fundamentally changed.[10] Therefore, the epidemic laws and characteristics of the SARS outbreak and the painful lessons we learned in responding to the epidemic are of great value currently and in the future. Due to concerns about controlling the impact of the epidemic and the relatively less developed information exchange tools of that time, the early epidemics and characteristics of the early SARS cases were not reported. However, as we had participated in the epidemiological investigations of early SARS cases in 2003, we had collected important data about the early stages of the outbreak. Using these valuable data, we analyzed the characteristics of the early SARS cases and the progression of the outbreak. By comparing the epidemic situations of the two outbreaks, we found some strikingly similar characteristics and trends, providing lessons for better responses to the present and future epidemics.

On January 2, 2003, a hospital in Heyuan city, Guangdong Province, reported two strange cases of severe pneumonia, which were then transferred to a larger hospital for further treatment. Several days later, seven medical staff members in the department that treated these patients developed symptoms. Retrospective investigation

Access this article online

Quick Response Code:

Website: www.cmj.org

DOI: 10.1097/CM9.0000000000000776

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Chinese Medical Journal 2020;133(9)

Received: 11-02-2020 **Edited by:** Peng Lyu

found that a hospital in Foshan had treated a similar case on November 25, 2002 [Supplementary Figure 2A, http://links.lww.com/CM9/A209]. This patient developed symptoms on November 16, 2002, and subsequently, five family members also developed symptoms. This indicated that SARS-CoV emerged with high human-to-human transmission capability, characterized by familial and medical staff infections.[11,12] An investigation of family clustering identified 35 clusters involving 105 patients, in families with two or more family members in Guangzhou. The largest cluster was derived from a female patient. A total of 91 persons were infected due to visiting or nursing the female patient, and two of these people died[13] [Supplementary Figure 2B, http://links.lww.com/CM9/A209]. This indicated that the super virus spreader emerged at the earliest stage of the outbreak, confirming the high infection capability of the virus.[14,15] Subsequent case investigations also showed that SARS-CoV had the capability to multiply and continuously undergo human-to-human transmission [Supplementary Figure 2C, http://links.lww.com/CM9/A209]; at least four generations of cases were identified from one original patient. Among the clusters of cases, healthcare workers were common victims.[16] As of April 13, 2003, a total of 48 medical institutions had medical staff with SARS-CoV infection, and 33 medical institutions in Guangzhou reported a total of 283 cases. The incidence among medical staff in the respiratory care department of a university affiliated hospital in Guangzhou was 61.7% (29/47), that is, more than half of the medical staff were infected while treating their patients.[17]

As for the 2019-nCoV outbreak, the first patient with unexplained pneumonia was identified on December 12, 2019. On December 31, 2019, 27 cases of viral pneumonia were officially announced; seven of these patients were in a severe condition.[18] Respiratory infectious diseases, including influenza, SARS, and Middle East respiratory syndrome, were screened for and excluded.[19] On January 3, 2020, only 1 week later, a new type of coronavirus was discovered. The identification of pathogenic nucleic acids was completed on January 10,[20] and on January 12, the World Health Organization officially named the new coronavirus the "2019 novel coronavirus." It took less than 10 days from the first official announcement to the identification of the pathogen. In contrast to that of SARS-CoV, the discovery of human-to-human transmission of 2019-nCoV came relatively late. On December 31, 2019, 27 confirmed pneumonia cases were officially reported, no human-to-human transmission case was identified.[18] On January 19, 2020, a cluster of cases, including 15 healthcare workers, were confirmed to have been infected via patients, confirming that 2019-nCoV also has human-to-human transmission capability.[21] Based on these results, it was concluded that 2019-nCoV also has high human-to-human transmission capability. It remains unclear whether earlier cases also showed this capability, and if so, how many victims were not identified. The close contacts of these unidentified patients might act as new infection sources and could become super-spreaders.

The incidence and development process of the SARS outbreak has valuable implications for the 2019-nCoV outbreak. After discovering the earliest case identified on November 16, 2002, the incidence remained low until January 2, 2003. The peak of the incidence was observed between January 3 and February 4, 2003, and the number of cases accounted for 54.7% of the total cases (Wikipedia). According to the case numbers and the developmental characteristics, the SARS epidemic can be roughly divided into four stages: stage 1, from November 16, 2002 to January 31, 2003; stage 2, from February 1 to March 2, 2003; stage 3, from March 3 to April 2; and stage 4, after April 4 [Supplementary Figure 2D, http://links.lww.com/CM9/A209]. Coincidentally, the SARS outbreak duration also coincided with the Chinese spring festival. Each year, the Chinese government launches a 40-day spring festival transport support system, and during this period, billions of people migrate around China. In 2003, the spring festival transport period started from January 17 to February 25, 2003 and coincided with the peak incidence [Supplementary Figure 2D, http://links.lww.com/CM9/A209, purple box]. The spring festival travel period in 2020 started from January 10 to February 18, which coincided with the rapid increase in 2019-nCoV cases between January 10 and 22, 2020 [Supplementary Figure 2D, http://links.lww.com/CM9/A209, red box]. Both outbreaks happened in the winter, when the two provinces have similar climate patterns suitable for virus survival and spread. Temperature and weather are risk factors of natural infectious diseases, and those in Wuhan and Guangzhou seem to be suitable for disease transmission. Given previous trends, this is unlikely to be the incidence peak of this new virus outbreak. The daily counts of 2019-nCoV cases were higher than the daily counts of SARS cases during its peak in 2003, implying a possibly higher number of cumulative cases.[10] We analyzed the transportation between different and large cities. High frequency transportation is mainly distributed among megacities [Supplementary Figure 2E, http://links.lww.com/CM9/A209]. The highest ranked cities include Beijing, Guangzhou, and Shanghai.[22] Wuhan has a population of 10 million and is also a major hub of the spring festival transportation network.[23] The predicted number of passengers traveling during the 2020 spring festival is 3.11 billion, 1.7 times the total number in 2003 (1.82 billion) [Supplementary Figure 2F, http://links.lww.com/CM9/A209]. This large-scale migration has brought favorable conditions for disease spread that are difficult to control.

Because we are now in the early stage of the outbreak, we must be prepared for subsequent larger-scale outbreaks and predict the scale of the outbreak. Since 2019-nCoV is highly similar to SARS-CoV, some important characteristics of SARS-CoV could be used for this prediction. By combining the reported daily counts of 2019-nCoV cases and data from the SARS outbreak, we constructed a logistic model and predicted the incidence of 2019-nCoV over time. During the 2003 SARS outbreak, a total of 8000 cases were reported.[24] With this data and the present situation, we predict that the cumulative number of 2019-nCoV cases might be 60,000 to 70,000. Logistic models were fitted to these data, and the cumulative and daily counts of 2019-nCoV cases were predicted. As shown in Supplementary Figure 1B and 1C, http://links.lww.com/CM9/A209, we also calculated the time needed to reach

the peak of incidence under different scenarios. Setting the upper limit of cumulative incidence (K) to 50,000, 60,000, or 70,000, the end date of incidences will be in 56 days (March 6, 2020), 60 days (March 10, 2020), or 62 days (March 12, 2020), respectively.

Using valuable epidemiological data from the SARS outbreak, we systematically evaluated and compared the characteristics of the 2019-nCoV and SARS-CoV outbreaks. The two outbreaks share many similarities, and the ongoing 2019-nCoV outbreak situation seems to be a repetition of the SARS-CoV outbreak situation. Fortunately, the Chinese government is implementing many efficient measures, including shutting down public transportation in Wuhan and other cities, reducing population migration, and encouraging personal protection such as face mask-wearing. With these measures, case numbers could be reduced significantly. However, due to the lack of awareness regarding the human-to-human transmission capability of 2019-nCoV in the early stages, there is a possibility that super-spreaders exist.[25] These super-spreaders may be distributed in different places and are difficult to track. This represents the most important problem for this outbreak.

Acknowledgements

The authors thank the collaborators who participated in the original investigations during the 2002 to 2003 SARS outbreak.

Funding

This work was supported by grants from the National Key Research and Development Program Projects of China (No. 2017YFD0500305), the National Key Program for Infectious Disease of China (No. 2018ZX10101002-002), the State Key Program of National Natural Science of China (No. U1808202), Guangdong Province Key Area R & D Plan Project (No. 2018B020241002), and the Guangdong Provincial Science and Technology Project (No. 2018B020207013).

Conflicts of interest

None.

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How to cite this article: Chen ZL, Zhang WJ, Lu Y, Guo C, Guo ZM, Liao CH, Zhang X, Zhang Y, Han XH, Li QL, Lu JH. From severe acute respiratory syndrome-associated coronavirus to 2019 novel coronavirus outbreak: similarities in the early epidemics and prediction of future trends. Chin Med J 2020;133:1112–1114. doi: 10.1097/CM9.0000000000000776