COVID-19: epidemiology and preventive measures in Jiangsu province, China

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RESEARCH ARTICLE

COVID-19: epidemiology and preventive measures in Jiangsu province, China

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Abstract

Background: To investigate the epidemiological features of coronavirus disease 2019 (COVID-19) and the prevention measures in Jiangsu Province.

Methods: Information of all novel coronavirus pneumonia confirmed cases in Jiangsu was collected from the official website of Jiangsu Commission of Health. All data were entered into Excel and Python3 for statistical analysis. Epidemiological characteristics of novel coronavirus pneumonia confirmed cases from January 10, 2020 to March 18 in Jiangsu province were retrospectively analyzed. Meanwhile, the preventive measures of Jiangsu Commission of Health and the people's Government of Jiangsu Province were also analyzed.

Results: 631 COVID-19 cases were diagnosed in Jiangsu Province, covering 13 cities in Jiangsu. Before February 1, the confirmed cases were mainly imported cases, and after February 1, community transmission cases became main part of confirmed cases. There were more male patients than females, and most patients were in the group of 30-70 years old, 49 patients (7.8%) with mild symptom and 572 patients (90.6%) with common type accounted for the majority. The cumulative mortality rate was 0% and the cure rate was 100%. Reasonable treatments, timely and effective preventive measures were taken to effectively improve cure rate and to prevent the spread of the epidemic, all measures ensure the health and life safety of the people.

Conclusion: The preventive measures in Jiangsu Province were timely and effective, the epidemic situation in Jiangsu Province had been well controlled.

Keywords: COVID-19; epidemiology; confirmed case; preventive measures; likely-Sigmoid function

Background

Since December 2019, a cluster of pneumonia cases with unknown cause was detected in Wuhan City, Hubei Province, China [1, 2]. A novel coronavirus had been identified in samples obtained from cases and that initial analysis of virus genetic sequence suggested that this was the cause of the outbreak. This virus is referred to as SARS-CoV-2, and the associated disease as COVID-19 (Coronavirus Disease 2019). SARS-CoV-2 belongs to the coronavirus of the genus β , with an envelope, with round or oval virus particles, polymorphic, and the diameter is 40–60nm [3, 4, 5]. The continued human-to-human transmission of SARS-CoV-2

is reported, which can be spread through respiratory droplets and close contact, resulting in a rapid increase of confirmed cases nationwide and even worldwide [6]. On January 30, the epidemic was declared by WHO as 'A Public Health Emergency of International Concern' [7]. Until April 10, 2020, more than 1.56 million cases had been diagnosed globally, with over 95,000 fatalities. Investigating the epidemiological characteristics of COVID-19 is essential for formulating and implementing effective preventive measures. There are few studies on the epidemiology of novel coronary pneumonia in Jiangsu Province. This study analyzed the epidemiological characteristics of all COVID-19 cases occurring in Jiangsu Province until March 18, 2020, in order to provide a basis for the prevention and control of COVID-19.

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Methods

The data source

The data source was based on the official data of Jiangsu Commission of Health (<http://wjw.jiangsu.gov.cn>), from which the confirmed cases and epidemics of COVID-19 cases were counted from January 23 to March 18, 2020. The diagnosis of patients with COVID-19, and the clinical classification of mild, common, severe and critical diseases, the cure standard and the isolation standard were all judged according to 'Novel Coronary Virus Pneumonia Diagnosis and Treatment Program (Trial 6th Edition)'. The diagnosed date or confirmed date of COVID-19 patients in this study was defined as the day before the confirmed date of the official data of Jiangsu Commission of Health.

Methods

Descriptive epidemiological studies were used to retrospectively analyze the data collected above, to describe the distributions, the source of case infection, and clinical outcomes. It is a common analysis method in previous studies to directly define the characteristic date (e.g. the day with largest cured cases of the time series, etc.) as the inflection time-point of the epidemic situation. This kind of method uses empirical judgment among several consecutive days with high values without mathematical description, and cannot explain the fluctuation of data after the inflection point. Therefore, a certain degree of smooth curve fitting from mathematical point of view is necessary, which can remove the influence of data noise, that can find the characteristics of the data trend. Hence, curve fitting was introduced to establish a mathematical description of all the cases-time series based on scaled Sigmoid function (also, likely-Sigmoid, $f(x) = \frac{a}{1+\exp(-k(x-x_0))}$, where, a , k , x_0 are parameters). By this means, the largest-speed and characteristic points of the curves for the number of confirmed and cured cases can be quantified by derivative calculation. These points could be used to describe the trend and changes in the epidemic situation and to objectively evaluate its development.

Statistical analysis

Data time series estimation adopted likely-Sigmoid function fitting. Statistical processing was performed with SPSS 20.0, GraphPad Prism 6.0 and Matlab 2017 were used for picture production, Python3 was used for function fitting, and ESRI ArcMap 10.6 was used for map production.

Result

Characteristics of COVID-19 cases

Until March 18, 2020, a total of 631 confirmed cases were reported, including 191 imported cases (30.27%),

440 second-generation or above transmission cases (69.73%). 240 of 631 cases were reported by age and gender according to available information (Table 1).

Geographical distribution

On January 22, 2020, 5 newly confirmed cases of COVID-19 were first declared by Jiangsu Commission of Health. All 5 patients had records of traveling from Hubei Province, i.e., imported cases. Two of them were confirmed in Nanjing City, and one each was in Suzhou, Yangzhou, and Lianyungang (Figure 1A). On January 26, an imported case was confirmed in Zhenjiang City as its first case. So far, 13 cities across Jiangsu Province had reported confirmed cases of COVID-19 [8, 9], with a total of 47 imported cases. Nanjing, Changzhou and Suzhou had more COVID-19 patients, compared with other cities (Figure 1B). Until March 18, Jiangsu Province had a total of 631 COVID-19 confirmed cases, among which the top three cities for the number of confirmed cases were Nanjing (93 cases, 15%), Suzhou (87 cases, 14%), Xuzhou (79 cases, 12%) (Figure 1 C).

Time distribution

On January 22, Jiangsu Province confirmed 5 patients with novel coronary pneumonia, all of whom had a clear history of contact with Wuhan. On January 27, Jiangsu Commission of Health confirmed the first case of second-generation transmission of novel coronary pneumonia all over Jiangsu province. So far, COVID-19 had followed a community transmission mode, which means the coexisting of imported cases and community transmission cases. The peak period of the epidemic was from January 28 to February 8, and the number of new additions after February 8 showed a downward trend with fluctuating. The number of confirmed cases stopped increasing on February 19, accumulating to totally 631 cases. Through a retrospective study of patients' epidemiologic history, imported cases were predominantly diagnosed before January 29, and the percentage of daily imported cases accounted for more than 67% in daily total cases. Then the number of imported cases began declining and no imported cases were reported after February 3. From that time on, the confirmed cases were all second-generation or above transmission cases in Jiangsu, which means, the onset was typically caused by SARS-CoV-2 after contacting with confirmed cases in the gathering place (Figure 2).

Until March 18, Jiangsu had 631 confirmed COVID-19 patients totally, consisting of 49 mild patients (7.8%), 572 common patients (90.6%), and 10 severe patients (1.6%). From February 18 to March 18, there were no newly confirmed cases in Jiangsu Province,

and on March 13 the confirmed cases in Jiangsu Province were all cured. The cumulative number of severe patients in Jiangsu was 10, and gradually changed mild or common after February 21. The cumulative fatality rate in Jiangsu Province was 0% (Figure 3).

Further analysis based on data driven methodology of cases was carried out. The changing trend of both cumulative confirmed and cured cases number time series indicated a smooth 'slow-fast-slow' speed growth pattern, which had a well-matched property with the classic Sigmoid function ($f(x) = \frac{1}{1+\exp(-x)}$) [10] from the perspective of graphics features. Therefore, this study attempted to fit the time series of cumulative confirmed cases number and the cured cases number with the likely-Sigmoid function to get the closed form math expression respectively. Python module *scipy* and its '*optimize.curve_fit*' tool was utilized for calculation. The cumulative number of confirmed patients in Jiangsu was fitted to: $f(x) = \frac{633}{1+\exp(-0.259(x-15.5))}$, (R-square: 0.9979, RMSE: 10.347); the cumulative number of cured patients was fitted to: $f(x) = \frac{629}{1+\exp(-0.196(x-31.2))}$, (R-square: 0.9983, RMSE:10.422). The 99.79% and 99.83% R-squares showed excellent performance of likely-Sigmoid function to fit the cases number time series. Next in this study, the first and second order derivatives of the fitted function were calculated in order to estimate the key points of the epidemic.

For the functional model of the cumulative number of confirmed cases, the extreme point of the first order derivative of the fitted curve corresponded to the point with the largest growth rate of confirming infection. Via this point, the epidemic could be divided into two stages. The first was the accelerated growth stage, while the second was the decelerated growth stage. The date corresponding to the extreme point of the first order derivative could be regarded as the turning point. Also, the point could be regarded as the inflection point of the epidemic. Applying this method to Jiangsu cumulative confirmed cases data, the first order derivative of the fitted likely-Sigmoid model had an extreme point on February 4, indicating that February 4 was the day with the largest growth speed for newly confirmed cases for the overall trend (Figure 4B). The growth rate of cumulative confirmations number after February 4 had slowed down. As a comparison, the epidemic inflection point of the whole China (except Hubei Province) appeared on February 3, which shows the trend of Jiangsu epidemic development was consistent with the national unified level with one-day late difference (for confirmed cases) (Figure 4A).

For the functional model of the cured patients cumulative number (Figure 4C-D), there were two extreme points of the second order derivative of the fitted

curve, and the epidemic can be divided into three periods, respectively corresponding to the growth acceleration 'increase-decrease-increase' mode. Since it was difficult to define the threshold of fast or slow growth speed artificially, we regard the extreme point of acceleration curve as the dividing point of fast or slow growth rate from the perspective of graphics. So, these three period corresponds to the cases number growth speed increasing slowly first, then fast and then slowly, means a 'low speed-high speed-low speed' pattern. The characteristic points of the growth speed of the cured patients' number were on February 12 and February 26 (Figure 4D), respectively. After February 12, the number of cured patients increased significantly and the growth speed was remarkably higher than before. After February 26, the growth of the cured patients number step into a low-speed period. The same measurement method was used to analyze the situation of non-Hubei regions in China. The results showed that the characteristic points of cumulative cure case number in Jiangsu appeared one day faster than that in the whole country (for cured cases).

Population Distribution

Since the demographic sociological information of cases was not a project that must be announced by the Commission of Health, the basic information of some cases was missing. The distribution of 240 confirmed patients with complete data in 7 cities (Taizhou, Yangzhou, Xuzhou, Nantong, Suzhou [11], Zhenjiang, and Nanjing [12]) was analyzed (Figure 5). Of the 240 confirmed cases, 131 were male (54.58%) and 109 were female (45.42%). The gender ratio of male to female was 1.20 : 1, which means more male infected than female. Of the 240 confirmed cases, 7 cases were younger than 20-year old (2.92%), 23 cases were among 20-30 years old (9.58%), and 5 cases were older than the 80-year-old (2.08%). The number of confirmed cases in 30-80 years old was the largest, 205 cases, accounting for 85.41% of the total number, which was roughly similar to the overall situation in China (30-80 years old group accounted for 86.6%) [13]. The median age of confirmed cases was 47.035(± 1.162) years for males and 47.633(± 16.763) years for females. The youngest patient was a 10-month old male child in Nanjing, and the oldest patient was a 91-year old male in Huaian city.

Transmission route

Based on the complete epidemic history data of 20 confirmed cases from Jiangsu Commission of Health, transmission chains of COVID-19 were classified into four types. Type One was for imported cases who had a clear contact history in Hubei, and then were confirmed a few days after isolation (Figure 6. patient 1,

2), with or without second-generation transmission. Type Two was for clustering cases in a family, in which situation, the infected patients transmitted to their family members (Figure 6. patient 3, 4). Type Three was entertainment aggregation transmission, in which situation, new patients were infected through close contact by the person who carried the virus in a congregation or party (Figure 6. patient 5, 6). The last type was community transmission (Figure 6. patient 7, 8), in which situation, patients were infected by unconscious contact with confirmed COVID-19 patients or asymptomatic infectors, such as staying in the same coach, supermarket, or other public places with infectors.

Discussion

In terms of geographical distribution, until March 18, the cumulative number of confirmed patients in Nanjing, Xuzhou, and Suzhou ranked the top three in Jiangsu. According to the transportation network map of Jiangsu Province (Figure 1D), Nanjing and Xuzhou are the largest road or railway transportation hub in Jiangsu province, and Suzhou has extremely convenient railway and road traffic with Shanghai, the international transportation hub [14, 15]. The above data suggested that the transportation convenience of the region was relative to the number of imported cases. The epidemic prevention work at airports, stations, and railways would have the top priority. The timely first-level response of Jiangsu Province greatly reduced the input of imported cases.

In terms of time distribution, for the 'low-high-low speed' growth mode shown by the cumulative confirmation curve, the characteristic points for the growth speed of the cumulative cured curve were on February 12 and February 26, respectively (Figure 4D). After February 12, the number of cured people increased significantly and the growth speed was high. The continuous increase in the cumulative number of confirmed cases was a possible acceleration factor. Another possible reason is due to optimized treatment plan recommended by 'Novel Coronavirus Infected Pneumonia Diagnosis and Treatment Program (Trial Version 5)' on February 8 [16]. After February 26, the growth speed of the cured patients number slowed down was possibly due to the discharge of mild patients and common patients from the existing patients, the structure of the patients changed, and the proportion of severe patients increased. Meanwhile, Jiangsu Province completed 100% patient cure, which may due to the traditional Chinese medicine widely used and timely consultation taken by provincial expert team — 89% patients were treated by integrated Chinese and western medicine and 100% patients were diagnosed by professional expert team in Nanjing [8].

There were still some limitations in this study. Because the epidemic data were collected from the official websites of the National Commission of Health and Jiangsu Commission of Health, the information provided was limited, since we were not able to get the information of the specific onset time, exposure history, and past history of each case, clinical manifestations, diagnosis and treatment plans, treatment effects and personal basic conditions, etc., we failed to do a more in-depth study on the population distribution, susceptibility factors and so on. At the same time, all the treatment methods and epidemic prevention measures in this study came from the official website of the People's Government of Jiangsu Province and the National Novel Coronavirus Pneumonia Medical Treatment Expert Group, which may exist bias in some degree. Furthermore, in the context of the international outbreak of novel pneumonia, until March 18, 2020, Jiangsu Province had reported none of new case for 27 consecutive days, and no new imported cases had been found. It can be considered that the epidemic in Jiangsu Province was close to disappearing. However, the epidemic prevention work still needed to be highly valued, guarded against the importation of foreign cases.

Jiangsu's preventive measures

After the lockdown of Wuhan was announced on January 23, the People's Government of Jiangsu Province successively initiated the first-level response to public health emergencies according to the 'Emergency Response Plan for Public Health Emergencies in Jiangsu Province' on January 24. It also highlighted the focus of work to four aspects (Figure 7). Firstly, strictly prevented imported epidemics, including strictly managing the agricultural market, doing a good job in the ventilation, disinfection, temperature detection, and health quarantine of personnel-intensive places such as airports, stations, and docks, and public transportation. Secondly, implemented effective medical interventions. The hospital strengthened emergency protocols, and medical personnel improved their own safety protection to effectively ensure early detection, early reporting, early diagnosis, early isolation, and centralized treatment measures. Thirdly, cut off the chain of transmission in time, including requiring residents to reduce going out and wear masks in public places, prohibiting assembly, closing large entertainment venues, tracking and quarantining close contacts. Lastly, actively strive for support and strengthen logistics support.

In conclusion, the analysis of the epidemiological characteristics of novel coronary pneumonia reported by Jiangsu Province until March 18, 2020, and the

analysis of the prevention and control measures during the epidemic can lead to the following conclusions: timely, reasonable and effective epidemic prevention measures, constantly updated treatment methods, rich medical and health resources are indispensable parts of the success of Jiangsu epidemic prevention work.

Conclusion

This study based on 631 confirmed cases of COVID-19 in Jiangsu Province contributes to the epidemiological features of COVID-19 and the prevention measures in Jiangsu Province. It should benefit the control of the disease spread. Conclusion came that the preventive measures in Jiangsu Province were timely and effective, the epidemic situation in Jiangsu Province had been well controlled.

Abbreviations

SARS-CoV-2: Severe acute respiratory syndrome coronavirus 2; COVID-19: Coronavirus disease 2019; WHO: World Health Organization.

Declarations

Acknowledgements

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Author's contributions

YC, JSL and CRY contributed to study design, introducing function fitting methods, mathematical calculation, data analysis and processing, figures plotting, literature search and paper writing. AHZ, ZSA contributed to study design, article quality supervision and overall control. All authors have read and approved the manuscript.

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Availability of data and materials

The data sets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

No application. This study used data set published by government and has no ethical controversy.

Consent to publish

Not applicable.

Competing interests

The authors declare that they have no competing interests to disclose.

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Figure Legends

Figure 1 Geographical distribution of the cumulative confirmed cases number of COVID-19 patients in Jiangsu. A: Geographical distribution map of Jiangsu on Jan. 22; B: Geographical distribution map of Jiangsu on Jan. 26; C: Geographical distribution map of Jiangsu on Feb. 20; D: Jiangsu main road and railway transportation map. Figures were drawn based on ArcGIS Desktop 10.6 (with a stand-alone user license), software link: <https://support.esri.com/en/products/desktop/arcgis-desktop/arcmap/10-6>

Figure 2 The number and source of newly diagnosed cases in Jiangsu Province.

Figure 3 Line chart of cumulative number of confirmed patients.

Figure 4 Cumulative number of confirmed and cured people in China (non-Hubei) and Jiangsu. A: fitting curve of cumulative confirmed cases and its first order derivative in China (except Hubei Province). B: fitting curve of cumulative confirmed cases number and its first order derivative in Jiangsu Province. C: fitting curve of cumulative cured cases number and its second order derivative in China (except Hubei Province). C: fitting curve of cumulative cured cases and its second order derivative in Jiangsu Province.

Figure 5 Age and gender distribution of confirmed patients in Jiangsu Province.

Figure 6 Examples of transmission routes

Figure 7 Schematic diagram of epidemic prevention measures in Jiangsu Province

Tables

Table 1 Characteristics of COVID-19 cases in Jiangsu Province.

Case characteristics		Confirmed cases (n (%))
Total		631 (100)
Age group[#]		
	~ 0	3 (1.25)
	~ 10	4 (1.67)
	~ 20	23 (9.58)
	~ 30	46 (19.17)
	~ 40	52 (21.67)
	~ 50	59 (24.58)
	~ 60	31 (12.92)
	~ 70	17 (7.08)
	≥ 80	5 (2.08)
Gender group		
	Male	131 (30.27)
	Female	109 (69.73)
Source		
	Import	191 (30.27)
	Second-generation or above transmission cases	440 (69.73)
Severity		
	Mild	49 (7.77)
	Common	572 (90.65)
	Severe	10 (1.58)
Time		
	Before 28-Jan	70 (11.09)
	From 29-Jan to 30-Jan	59 (9.35)
	From 31-Jan to 7-Feb	279 (44.22)
	From 8-Feb to 19-Feb	223 (35.34)

[#] Only 240 of total 631 cases were reported by age and gender.

Figures

Figure 1

Geographical distribution of the cumulative confirmed cases number of COVID-19 patients in Jiangsu. A: Geographical distribution map of Jiangsu on Jan. 22; B: Geographical distribution map of Jiangsu on Jan. 26; C: Geographical distribution map of Jiangsu on Feb. 20; D: Jiangsu main road and railway transportation map. Figures were drawn based on ArcGIS Desktop 10.6 (with a stand-alone user license),

software link: <https://support.esri.com/en/products/desktop/arcgisdesktop/arcmap/10-6>. 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 number and source of newly diagnosed cases in Jiangsu Province.

Figure 3

Line chart of cumulative number of confirmed patients.

Figure 4

Cumulative number of confirmed and cured people in China (non-Hubei) and Jiangsu. A: fitting curve of cumulative confirmed cases and its first order derivative in China (except Hubei Province). B: fitting curve of cumulative confirmed cases number and its first order derivative in Jiangsu Province. C: fitting curve of cumulative cured cases number and its second order derivative in China (except Hubei Province). C: fitting curve of cumulative cured cases and its second order derivative in Jiangsu Province.

Figure 5

Age and gander distribution of confirmed patients in Jiangsu Province.

1. Imported cases:

2. Second-generation transmission cases:

2.1 Family aggregation

2.2 Entertainment aggregation

2.3 Unconscious close contact

① M 42
 ① Gender Age □ One day ■ Time from exposure to onset ■ Time from onset to confirmation

Figure 6

Examples of transmission routes

Preventive Measures:

- 1.Hubei Province lockdown
- 2.Jiangsu first-level response
- 3.Traffic quarantine
- 4.Medical isolation close tracking
- 5.Shut down Entertainment place
- 6.Reduce outgoing
- 7.Wear masks
- 8.Stop the party

Figure 7

Schematic diagram of epidemic prevention measures in Jiangsu Province