Coronavirus Pandemic

Epidemiological characteristics of COVID-19 in Shenzhen, China: comparison between imported and local cases

Zhihui Li[1] *, Jin Wang[1] *, Jingyi Huang[2], Jiahai Lu[1]

[1] Department of Epidemiology, School of Public Health, Sun Yat-sen University, Guangzhou, Guangdong Province, China
[2] Songgang People's Hospital of Bao'an District, Shenzhen, Guangdong Province, China

* Authors contributed equally to this work

Abstract

Introduction: An unprecedented outbreak of the novel coronavirus disease (COVID-19) has swept across the globe since the end of 2019. Shenzhen confirmed its first imported case from Wuhan on 19 January 2020. However, little is known regarding the epidemiological characteristics of COVID-19 in these imported cities.

Methodology: Data of all 417 confirmed cases diagnosed in Shenzhen before 29 February were collected. The epidemiological characteristics of imported and local cases were compared. The resilience to COVID-19 was evaluated by discharge density.

Results: All ten districts reported COVID-19 cases by 29 February, including 331 imported and 86 local cases. The Pearson linear correlation model showed the number of confirmed cases ($r = 0.990$, $p < 0.001$) as well as incidence of COVID-19 ($r = 0.766$, $p = 0.010$) was positively correlated with the gross domestic product of district. Family clusters were more commonly found in local cases. Imported patients had earlier onset ($p < 0.001$) and diagnosis ($p < 0.001$), but longer interval from onset to admission ($p = 0.030$), diagnosis ($p = 0.003$) and discharge ($p = 0.016$). Older and severe cases had lower discharge density (0.024 and 0.018, respectively); while cases with subclinical symptoms exhibited higher discharge density (0.052).

Conclusions: COVID-19 patients were predominantly imported cases in Shenzhen and the spatial distribution was closely related to district GDP. Imported and local cases differed in the intervals from onset to admission, diagnosis and discharge. Moreover, family-based transmission should not be ignored, especially in local cases.

Introduction

An unprecedented outbreak of the novel coronavirus disease (COVID-19) has swept across the globe since the end of 2019. As of 29 February 2020, the cumulative number of confirmed cases had reached 79,824 in China, with 2,870 deaths (case fatality rate of 3.6%), including 66,907 confirmed cases and 2,761 deaths in Hubei Province. The COVID-19 is considered to be caused by severe acute respiratory syndrome coronavirus (SARS-CoV-2) from bats [1-3]. The SARS-CoV-2 is the seventh known coronavirus that can infect humans, and it can be transmitted from human to human via droplets or close contacts [4,5].

The outbreak of COVID-19 coincided with the eve of the traditional Chinese Spring Festival. Hundreds of millions of residents visited their relatives and friends, leading to sharply increased transportation and potential risk of rapid transmission between cities [6]. Local transmission chains may have started in other domestic cities through the index cases imported from Hubei Province. After the outbreak, Chinese authorities have taken unprecedented measures to control the source of infection, including screening of high-risk populations, prompt identification and reporting of suspicious cases, and rapid diagnosis of cases, which effectively suppress the spread of transmission [7]. However, little is known regarding the local epidemiological characteristics of COVID-19 in the imported cities. And also, what is the difference between the imported and local cases, for instance time delays, remains unclear.

Shenzhen is located in the south of China. It is a national economic centre and an international city, with developed economy and convenient transportation. The city covers an area of 1997.47 km², consisting of 10 administrative districts. Shenzhen has a permanent population of 4.5 million as well as domestic migrants of 8.5 million, which has led to a large number of imported cases in Shenzhen. Indeed, Shenzhen reported

its first imported case on 19 January 2020. In this study, we analysed the spatial and temporal distribution of all 417 confirmed cases in Shenzhen before 29 February to describe the epidemiological characteristics of COVID-19 for further understanding the transmission of SARS-CoV-2 in imported cities.

Methodology

Data Source

Soon after SARS-CoV-2 was identified as the etiological pathogen of the pneumonia outbreak, the disease was classified as Class B infectious disease and managed as Class A [8,9]. Confirmed patients are required to be reported within 24 hours to the National Notifiable Infectious Disease Surveillance System, according to the standard protocol issued by the National Health Commission of the People's Republic of China (NHCC). The information of each COVID-19 case was input into the data system by local hospitals and CDC personnel, who investigated and collected possible exposure history. Each case had a fixed number in the data system in accordance with the order of diagnosis. All case records contained unique personal ID number, so cases were not duplicated in the system.

We collected the COVID-19 epidemic data released from the official website of Shenzhen Health Committee (http://wjw.sz.gov.cn/) and the Shenzhen Centre for Disease Control and Prevention (http://www.szcdc.net/). The relevant data were collected for analysis after removing all personally identifiable information.

Variables

Case data included basic demographic information, date of symptom onset, date of arrival at Shenzhen, date of admission, date of diagnosis, date of discharge, epidemiological history, the severity of disease, and outcome. Patients were diagnosed based on clinical symptoms and/or a history of exposure and positive results from viral nucleic acid tests, according to the Diagnosis and Treatment Program of 2019 New Coronavirus Pneumonia issued by the National Health Commission of China [10,11]. Non-severe infected patients were defined as those without pneumonia or mild pneumonia; Severe cases were defined as those presented dyspnoea, respiratory rate ≥ 30/min, blood oxygen saturation $\leq 93\%$, PaO2/FiO2 ratio < 300, and pulmonary infiltration $> 50\%$ within 24–48 hours; or those cases with respiratory failure, septic shock and/or multiple organ dysfunction/failure.

The date of symptom onset was defined as the date on which a case began to develop symptoms such as fever or cough according to self-report data in the epidemiological investigation. Wuhan-related exposure referred to a history that patients recently lived or travelled in Wuhan, or had close contact with a person who had been to Wuhan. Family cluster was defined as two or more confirmed cases in one family within 14 days, with possibility of interpersonal transmission via close contact or exposure to the same source. Patients were divided into two groups, namely imported and local cases. Imported case was defined as a case in which infection resulted from exposure outside Shenzhen as evidenced by travel history and symptom onset occurring within 14 days. Local cases included patients without any recent travel history as well as those with symptom onset occurring 14 days after arrival at Shenzhen.

Statistical Analysis

For spatio-temporal analysis, the number of confirmed cases was plotted according to the date of symptom onset, date of diagnosis, and date of discharge, respectively. The cumulative numbers of cases before specific time points (19 January 2020, 31 January 2020, 7 February 2020 and 29 February 2020) were mapped by ESRI ArcMap 10.4.1 Software according to the geographic location, respectively.

Person days were calculated by subtracting day of admission from day of discharge or termination of observation (25 February 2020). Discharge density was calculated by dividing the cumulative person days of confirmed cases for observation by the number of patients discharged before 25 February 2020.

Statistical analysis was performed using SPSS 25.0. Quantitative variables were expressed as means $\pm$ standard deviation (SD) or medians and percentiles (twenty-fifth percentile, seventy-fifth percentile). Categorical variables were reported as numbers and percentages. The proportions were compared using the chi-squared test. Comparisons of continuous variables between the groups were performed using independent t-test for normally distributed data, and the Mann-Whitney U test or Kruskal-Wallis H test for data not normally distributed. Bonferroni adjustment was used for multiple pairwise comparisons between subgroups. The scatter plot was created with the number of confirmed cases and incidence of COVID-19. Correlations of gross domestic product (GDP) with number of confirmed cases and incidence were analysed using the Pearson linear correlation model. $p < 0.05$ was considered statistically significant.

Figure 1. Spatial distribution of confirmed COVID-19 cases in Shenzhen.
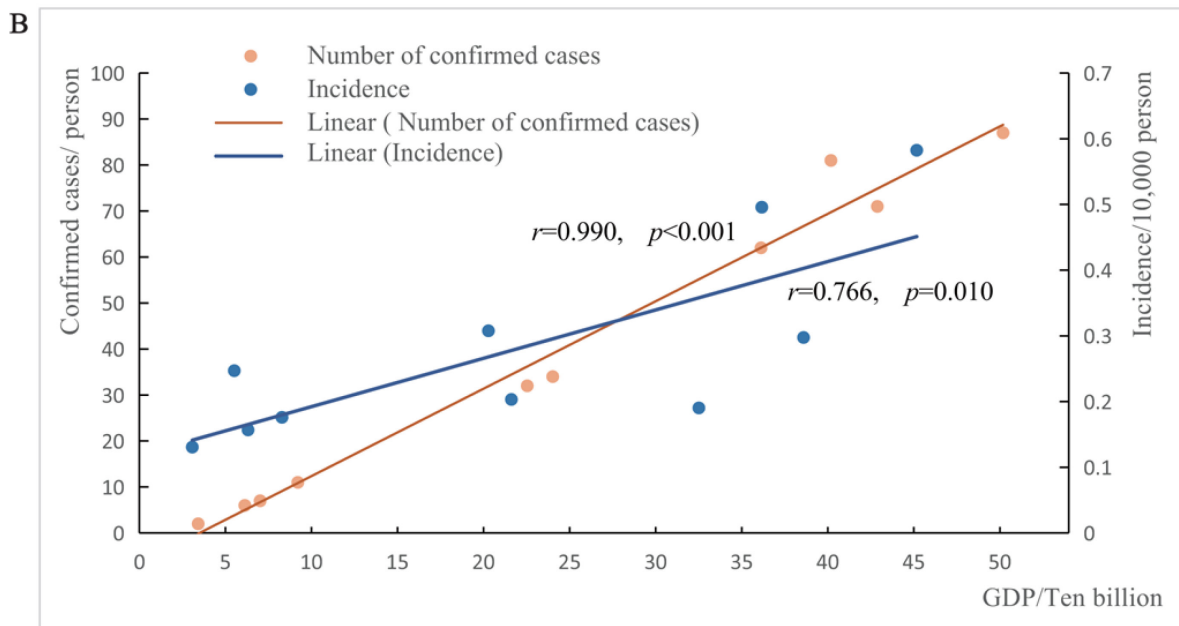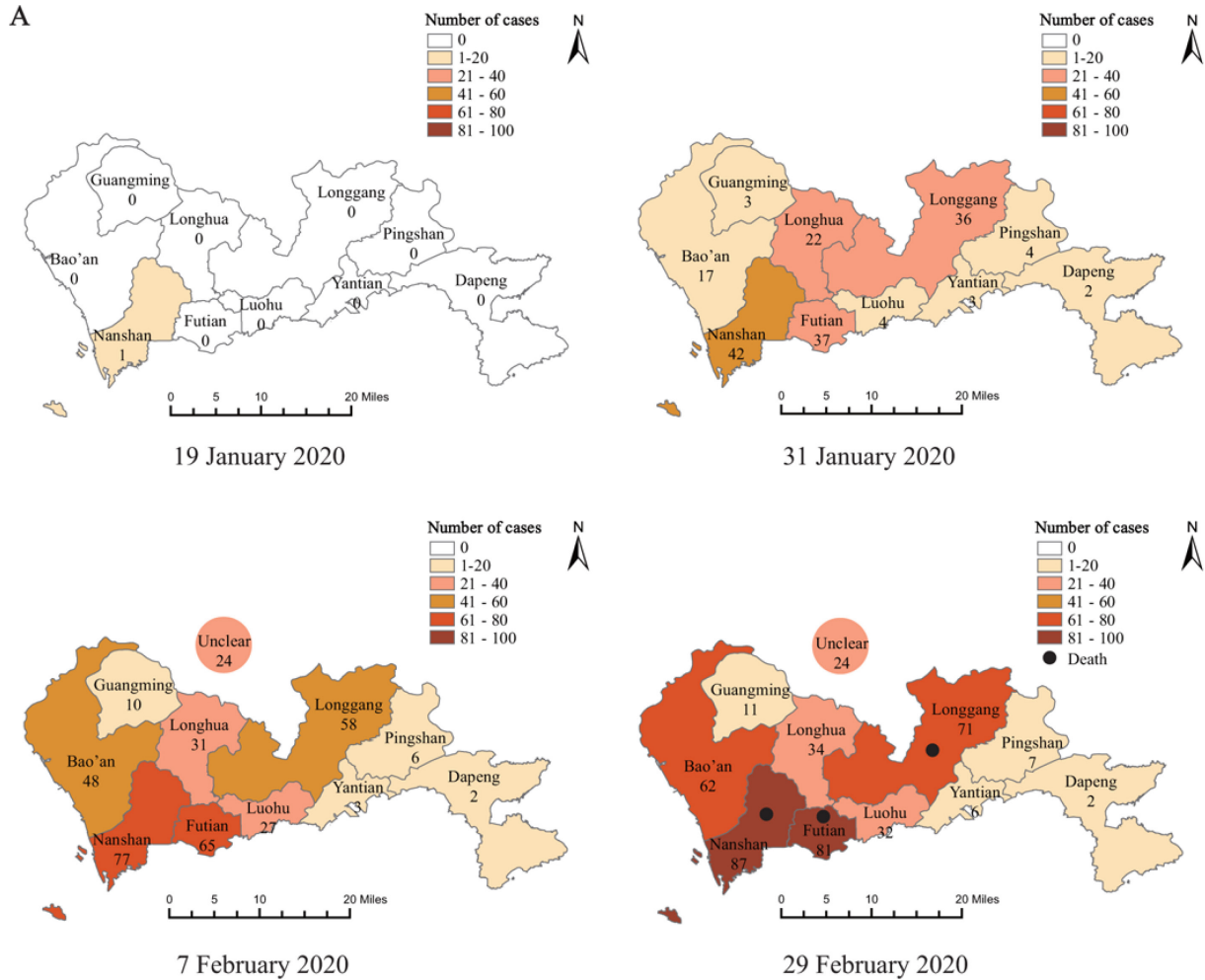
A: Daily number of new infections in each district on map by the end of 19 January, 31 January, 7 February and 29 February 2020. **B:** The Pearson linear correlation model showed that the number of confirmed cases ($r = 0.990$, $p < 0.001$) as well as incidence of COVID-19 ($r = 0.766$, $p = 0.010$) was positively correlated with the gross domestic product (GDP) of district.

Ethical Statement

The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Ethics Committee of the School of Public health, Sun Yat-sen University [No. 2020 (003)]. Informed consent was obtained from all subjects in this study.

Results

A total of 417 COVID-19 cases, including 331 (79.4%) imported and 86 (20.6%) local patients, were diagnosed in Shenzhen before 29 February 2020. The first confirmed patient, an imported case from Wuhan, was diagnosed in Nanshan district on 19 January. The number of confirmed cases increased rapidly thereafter. Geographically, all ten districts reported COVID-19 cases by 29 February with Nanshan (n = 87), Futian (n = 81) and Longgang (n = 71) districts reporting the most confirmed cases (Figure 1A). The Pearson linear correlation model showed that the number of confirmed cases (r = 0.990, p < 0.001) as well as incidence of COVID-19 (r = 0.766, p = 0.010) was positively correlated with GDP of district (Figure 1B).

Epidemic curves of daily new confirmed cases were drawn based on the date of onset, the date of diagnosis and the date of discharge, which were stratified by imported and local origin (Figure 2A). There was a time delay regarding the median date of onset (5 days) and diagnosis (5 days) between imported and local cases (median date of onset: 25 January and 30 January; median date of diagnosis: 1 February and 6 February, respectively). The interval from symptom onset to admission before 21 January was 5 (3 - 7) days (n = 62) among imported cases, and shortened to 1 (0.25 - 4) days after 31 January (n = 52). For local cases, the interval from symptom onset to admission [11 (4.5 - 16)] days (n = 5) was longer than that of imported cases before 21 January, but shortened to 1 (0 - 2) days after 31 January (n = 37). Similar trends were observed in the interval from symptom onset to diagnosis and the interval from symptom onset to discharge (Figure 2B).

The characteristics of imported and local cases with COVID-19 are showed in Table 1. There were no significant differences in age and gender between imported and local cases. The overall proportion of severe infection was 2.9% (n = 12), and no significant difference was observed between the two groups (p = 0.458). Family clusters were more commonly found in local cases. Compared with local patients, imported patients had earlier symptom onset (p < 0.001) and diagnosis (p < 0.001), but longer interval from symptom onset to admission (p = 0.030), diagnosis (p = 0.003) as well as discharge (p = 0.016). Also, imported and local

cases had different geographical distributions (p < 0.001).

We analysed the characteristics of confirmed cases discharged before 25 February 2020 (n = 262). Older and severe cases had lower discharge density (0.024 and 0.018, respectively); On the contrary, cases with subclinical symptoms exhibited higher discharge density (0.052) (Table 2).

Discussion

This study found that COVID-19 cases were predominantly imported infections (79.4%) in Shenzhen, and the incidence was positively correlated with district GDP. There was a 5-day delay between imported cases and local cases, in terms of the date of onset as well as the date of diagnosis. Family clusters were more commonly observed in local cases. Both imported cases and especially local cases exhibited shortened intervals from onset to admission, diagnosis and discharge as the epidemic evolved over time. This study provides detailed data of the spreading trend and characteristics of COVID-19 epidemic in Shenzhen.

As an international metropolis, Shenzhen is a large city located in southern China, close to Hong Kong. The city has a large proportion of domestic migrants, temporary residents and travellers. Our results showed that imported COVID-19 cases accounted for nearly 80% of the total, among which 63.1% (n = 209) were from Wuhan city. The population that emigrated from Wuhan was the main infection source in other cities and provinces. A previous study of ours showed that the correlation coefficient between the provincial number of cases and emigration from Wuhan was up to 0.943 [12]. These data indicated the importance of screening the individuals with exposure to the epidemic source [13]. We also found a positive correlation between the number of cases and GDP of district. As a number of studies reported, some socio-economic factors, such as domestic transportation, may affect the spread of the epidemic and the pattern of the transmission [14-16]. It is possible that economic level may be one of the factors affecting the transmission of COVID-19, which needs further exploration.

As previous reported, the epidemic of COVID-19 doubled in size every 6.4 – 7.4 days at its early stage and lagged in imported cities of 1–2 weeks, with the basic reproductive number (R0) estimated to be 2.20 - 2.68 [4,14,17]. Consistently, our findings showed that the number of cases increased from 170 on 31 January to 351 on 7 February. The onset of local cases was 5-days lagging behind imported cases, which was in line with the median incubation period of COVID-19 of 5.0

days [18]. In addition, compared with the local cases, the imported cases had an overall earlier onset but longer intervals form onset to diagnosis, admission and discharge. On the whole, the intervals form onset to diagnosis, admission and discharge were shortened at the later stage of the epidemic, no matter in imported or local cases, indicating the improvement in diagnostic and therapeutic services as well as enhanced awareness towards COVID-19 infection as the epidemic evolved over time.

In this study, there were no significant differences in age and gender, disease severity between imported and local cases. Cases in familial clusters of COVID-19 accounted for 56.6%, and the proportion of local cases was higher than that of imported cases (70.9% vs. 52.9%), suggesting that indoor isolation might prevent

the widespread spread of infections, but vigilance should be taken to be aware of the transmission within the family, especially in the local cases. In addition, there were 10 patients with subclinical symptoms of infection, who were positive for viral nucleic acid tests during screening of high-risk populations. Subclinical or asymptomatic infections were also reported in previous studies [5,19,20]. There is likelihood that some mild or asymptomatic patients do not seek health care but as a source transmitting the virus to other humans, which may complicate or delay the effectiveness of infection-control measures [21]. Thus, laboratory screening of individuals with high-risk exposures is necessary.

Figure 2. Temporal distribution of confirmed COVID-19 cases in Shenzhen.
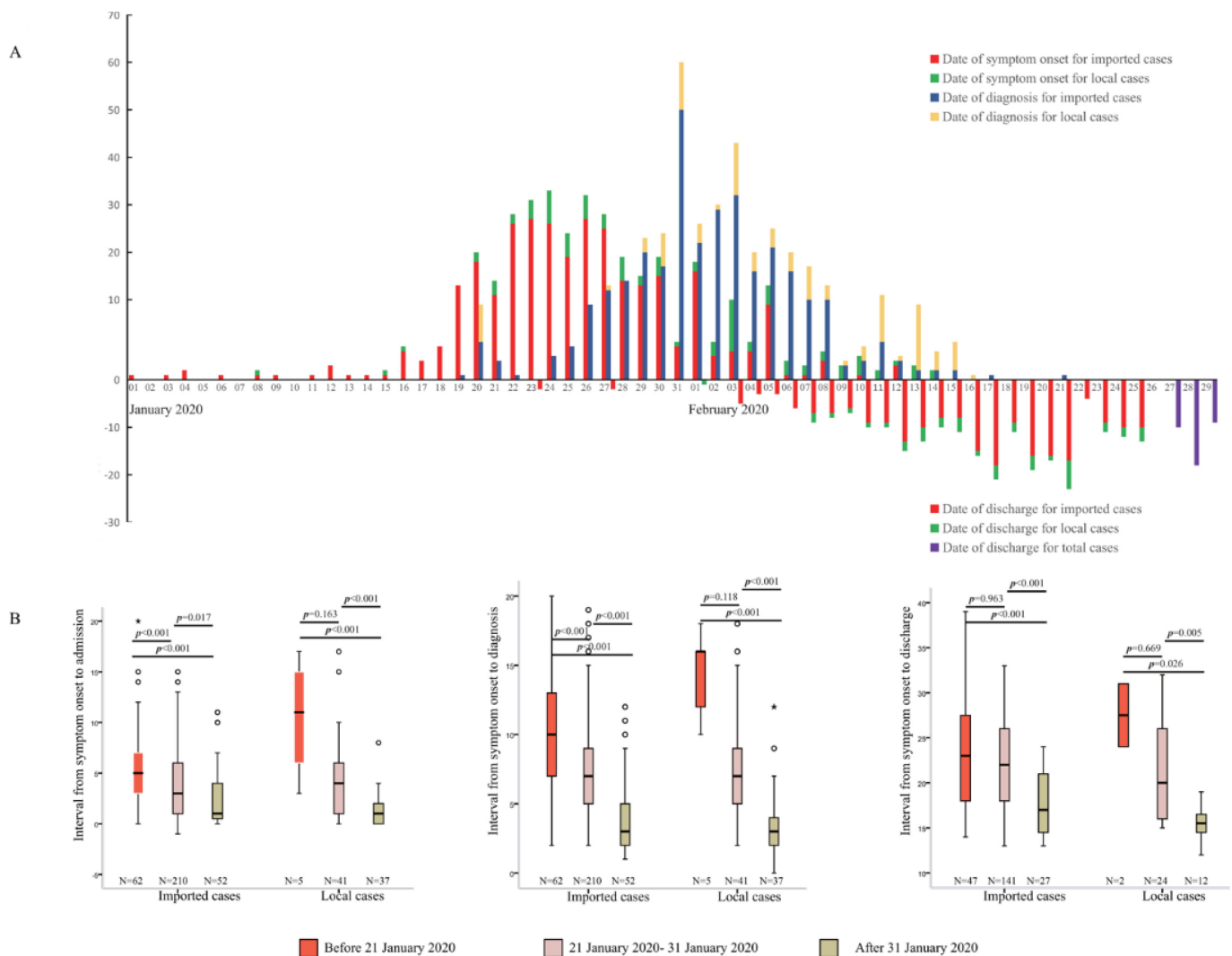
A: Epidemic curves of daily new confirmed cases were drawn based on the date of onset, the date of diagnosis and the date of discharge, stratified by imported and local origin. **B:** The interval from symptom onset to admission (left), diagnosis (middle) and discharge (right).

Table 1. Characteristics of imported and local cases with COVID-19.

Characteristics	Total (n = 417)	Local cases (n = 86)	Imported cases (n = 331)	P
Age, years, Mean ± SD	45 ± 18	45 ± 17	45 ± 18	0.790
Age, n (%)				0.978
0-	11 (2.6)	2 (2.3)	9 (2.7)	
6-	20 (4.8)	3 (3.5)	17 (5.1)	
18-	285 (68.3)	60 (69.8)	225 (68.0)	
61-	101 (24.2)	21 (24.4)	80 (24.2)	
Gender, n (%)				0.397
Male	198 (47.5)	37 (43.0)	161 (48.6)	
Female	219 (52.5)	49 (57.0)	170 (51.4)	
Wuhan-related exposure, n (%)				**< 0.001**
No	169 (40.5)	55 (64.0)	114 (34.4)	
Yes	248 (59.5)	31 (36.0)	217 (65.6)	
Family cluster, n (%)				**0.003**
No	181 (43.4)	25 (29.1)	156 (47.1)	
Yes	236 (56.6)	61 (70.9)	175 (52.9)	
Severe cases, n (%)				0.458
No	405 (97.1)	82 (95.3)	323 (97.6)	
Yes	12 (2.9)	4 (4.7)	8 (2.4)	
Date of symptom onset, n (%)				**< 0.001**
Before 21 January 2020	67 (16.1)	5 (5.8)	62 (18.7)	
21 January – 31January	251 (60.2)	41 (47.7)	210 (63.4)	
After 31January 2020	89 (21.3)	37 (43.0)	52 (15.7)	
Unclear[1]	10 (2.4)	3 (3.5)	7 (2.1)	
Date of diagnosis, n (%)				**< 0.001**
Before 1 February 2020	170 (40.8)	22 (25.6)	148 (44.7)	
1 February – 7 February	181 (43.4)	35 (40.7)	146 (44.1)	
After 7 February 2020	66 (15.8)	29 (33.7)	37 (11.2)	
Interval from symptom onset to admission, days, median (IQR)	3 (1-6)	2 (1-4)	3 (1-6)	**0.030**
Interval from symptom onset to admission, n (%)				0.299
0-	191 (45.8)	47 (54.7)	144 (43.5)	
3-	103 (24.7)	19 (22.1)	84 (25.4)	
6-	67 (16.1)	9 (10.5)	58 (17.5)	
9-	45 (10.8)	8 (9.3)	37 (11.2)	
Admission before symptom onset [2]	11 (2.6)	3 (3.5)	8 (2.4)	
Interval from symptom onset to diagnosis, days, median (IQR)	6 (4–9)	5 (3–8)	7 (4–9)	**0.003**
Interval from symptom onset to diagnosis, n (%)				**0.030**
0-	75 (18.0)	25 (29.1)	50 (15.1)	
4-	135 (32.4)	27 (31.4)	108 (32.6)	
7-	103 (24.7)	16 (18.6)	87 (26.3)	
10-	94 (22.5)	15 (17.4)	79 (23.9)	
Unclear[1]	10 (2.4)	3 (3.5)	7 (2.1)	
Interval from symptom onset to discharge, days, median (IQR)	21 (17–25)	18 (15.25–23.5)	22 (17.5–25.5)	**0.016**
Interval from symptom onset to discharge, n (%)				**0.001**
12-	36 (8.6)	10 (11.6)	26 (7.9)	
16-	59 (14.1)	12 (14.0)	47 (14.2)	
20-	70 (16.8)	6 (7.0)	64 (19.3)	
24-	88 (21.1)	10 (11.6)	78 (23.6)	
Unclear[3]	164 (39.3)	48 (55.8)	116 (35.0)	
District, n (%)				**< 0.001**
Nanshan	67 (16.1)	28 (32.6)	39 (11.8)	
Futian	60 (14.4)	18 (20.9)	42 (12.7)	
Longgang	57 (13.7)	16 (18.6)	41 (12.4)	
Bao'an	50 (12)	11 (12.8)	39 (11.8)	
Longhua	29 (7)	2 (2.3)	27 (8.2)	
Luohu	23 (5.5)	6 (7.0)	17 (5.1)	
Guangming	7 (1.7)	2 (2.3)	5 (1.5)	
Pingshan	2 (0.5)	1 (1.2)	1 (0.3)	
Yantian	2 (0.5)	0 (0)	2 (0.6)	
Unclear[4]	120 (28.8)	2 (2.3)	118 (35.6)	

[1]miss data (n = 10); [2]Positive viral nucleic acid tests before symptom onset; [3]miss data of onset (n = 9) and discharge (n = 155); [4]miss data (n = 120).

Discharge density was used to evaluate the resilience to COVID-19 in different groups, as a larger value represented a higher probability of discharge when observing the same person days. The results showed that older and severe cases had lower discharge density. Based on a previous study, patients treated in the intensive care unit (ICU) (n = 36), compared with patients not treated in the ICU (n = 102), were older (median age, 66 years vs. 51 years) [22]. Also, other studies showed that older age was associated with severe infection even deaths from COVID-19 [23-26]. The data suggested the necessity of paying more attention to patients with older age or severe infection.

This study provided detailed data regarding the COVID-19 epidemic of Shenzhen. However, this study has some limitations. All cases in this study were clinically diagnosed, and a fairly high percentage of cases were investigated by professional epidemiologists. However, some data were not be collected or missed in the system. On the other hand, memory bias might exist in the epidemiological investigation, for instance, date of symptom onset, which could lead to inaccurate estimates of some variables.

In conclusion, this study provides evidence on the epidemic of COVID-19 by analysing the epidemiological characteristics of imported and local cases in Shenzhen city. COVID-19 patients were predominantly imported cases in Shenzhen and the spatial distribution was closely related to district GDP. Imported and local cases differed in the intervals from onset to admission, diagnosis and discharge. Moreover, family-based transmission should not be ignored, especially in local cases.

Acknowledgements

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Table 2. Characteristics of discharged cases.

Characteristics	Discharged cases	Total observation time (person day)	Discharge density (person day)
Total	262	8292	0.032
Age group, n (%)			
0-	8 (3.1)	188	0.043
6-	14 (5.3)	346	0.040
18-	183 (69.8)	5419	0.034
61-	57 (21.8)	2339	0.024
Gender, n (%)			
Male	128 (48.9)	4020	0.032
Female	134 (51.1)	4272	0.031
Source of exposure, n (%)			
Imported	222 (84.7)	6715	0.033
Local	40 (15.3)	1577	0.025
Wuhan-related exposure, n (%)			
No	95 (36.3)	3172	0.030
Yes	167 (63.7)	5120	0.033
Severe cases, n (%)			
No	256 (97.7)	7962	0.032
Yes	6 (2.3)	330	0.018
Date of symptom onset, n (%)			
Before 21 January 2020	49 (18.7)	1457	0.034
21 January – 31 January	165 (63.0)	5247	0.031
After 31 January 2020	39 (14.9)	1414	0.028
Unclear*	9 (3.4)	174	0.052
Date of diagnosis, n (%)			
Before 1 February 2020	126 (48.1)	3730	0.034
1 February– 7 February	111 (42.4)	3559	0.031
After 7 February 2020	25 (9.5)	1003	0.025

A total of 262 cases were discharged by 25 February 2020. *n = 9 positive for viral nucleic acid tests during screening of high-risk populations who had close contact with confirmed cases. These patients had subclinical symptoms.

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Corresponding author

Jiahai Lu, Ph. D., Professor
Department of Epidemiology, School of Public Health, Sun Yat-sen University
No.74, 2nd Road, Yuexiu District, 510080 Guangzhou City, Guangdong Province, P.R. of China
Tel: 86-020-87332438
Fax: 86-020-87332438
Email: lujiahai@mail.sysu.edu.cn

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