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Major Article

Epidemic characteristics of the COVID-19 outbreak in Tianjin, a well-developed city in China

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Background: Coronavirus disease 2019 (COVID-19) is already a pandemic. Few studies investigated the epidemic characteristics of the COVID-19 outbreak in the well-developed cities.

Methods: Epidemiological data of 136 confirmed COVID-19 cases were collected from the dataset of COVID-19 in Tianjin. All confirmed cases were categorized according to their potential infection sources. Daily numbers of confirmed cases of each category were plotted by date of onset, and the epidemic form of each category was inferred.

Results: Among the 136 confirmed COVID-19 cases, 48 cases were categorized as imported cases and their close contacts, which were the majority of early cases. A total of 43 cases were found an epidemiological link to the Baodi department store, and they were inferred to be a common-source outbreak. Additionally, 35 cases were considered as familial clusters of COVID-19 cases, and 10 cases were sporadic. The 45 cases were inferred to be a propagated epidemic.

Conclusions: Local transmission of COVID-19 mainly occurred within families and a poorly ventilated public place in Tianjin. Besides the imported cases, the pattern of local transmission of COVID-19 was a mixture of the propagated epidemic and the common-source outbreak in Tianjin.

Coronavirus disease 2019 (COVID-19) is already a pandemic, and the ongoing COVID-19 outbreak has been also a big challenge for global health governance. Since the first discovery, the number of COVID-19 cases continues to rise worldwide, and almost seven million cases including 390,000 deaths have been reported globally as of June 8, 2020. Thus, the epidemic investigation on the COVID-19 outbreak in Tianjin. Besides, transmission from an asymptomatic case also happened among 4 families. For instance, human-to-human transmission had occurred largely.

In China, Wuhan was the epicenter where COVID-19 initially happened. All confirmed cases in other cities were geographically associated with Wuhan as a potential source before January 20, 2020. In our previous research, we found that the travelers departing from Wuhan before the Spring Festival were a main infection source of other cities in China. However, the disproportionately more cases were also observed in several well-developed regions of China, such as Zhejiang Province, Tianjin, Shenzhen, and Guangzhou. Moreover, over one-third of COVID-19 cases transmitted locally in Shanghai before February 19, 2020. These findings suggested that the imported cases from Wuhan might not be the majority of all confirmed cases in these well-developed regions any more, and local transmission had occurred largely.

To date, several patterns of local transmission have been noted in several published reports. For instance, human-to-human transmission had been reported in hospital and family settings. Besides, transmission from an asymptomatic case also happened among 4 staff working in the same workplace. However, so far, the exact pattern of local transmission of COVID-19 in the well-developed regions is still not clear, and few studies have investigated the epidemic characteristics of COVID-19 in these well-developed cities of China. It was encouraged to analyze the public dataset by independent teams and provide convincing evidences to guide interventions in the early stages.
stage of an outbreak of COVID-19. Fortunately, the availability of public datasets in China makes it possible to analyze the epidemic characteristics of COVID-19 in a selected city. Thus, the purpose of this study was to explore the epidemic characteristics of the COVID-19 outbreak in Tianjin, one of the well-developed cities in China.

METHODS

Data collection

The clinical and epidemiological data of all confirmed COVID-19 cases in Tianjin were collected from the official situation-reports published in the dataset of COVID-19 of the Tianjin Municipal Health Commission (http://wsjk.tj.gov.cn/). The deadline was at 11:59 p.m. March 13, 2020 (China standard time, CST). According to the official situation-reports, all cases were applied with the same diagnostic criteria based on the “diagnosis and treatment scheme for COVID-19 of China” issued by the National Health Commission of the People's Republic of China (http://www.nhc.gov.cn/). The confirmed cases conformed to the Case Definitions for Surveillance of COVID-19 as follows: (1) a suspect case was diagnosed clinically, (2) a suspect case of COVID-19 that is positive for SARS-Cov-2 by RT-PCR and sequencing at the Tianjin Centers for Disease Control and Prevention (CDC), and (3) asymptomatic cases with laboratory confirmation of COVID-19 infection were also included, irrespective of clinical signs and symptoms. No ethical approval was required for this study. Moreover, according to the “prevention and control scheme for COVID-19 of China” issued by the National Health Commission of the People's Republic of China (http://www.nhc.gov.cn/), investigators from the local CDC conducted a face-to-face epidemiological investigation for each case, and the contact tracking was also performed to identify the potential infection source of each case. According to this scheme, an active screening was performed to prompt testing. In addition to the suspect cases diagnosed clinically, the target population of SARS-Cov-2 testing also included close contacts who having been in contact with a confirmed or suspect COVID-19 case, individuals linked to a cluster of COVID-19 cases, and people facing high risk of infection found by a source tracking for SARS-Cov-2. Additionally, professionals in the front lines including health care workers were also included.

Classifications of confirmed cases according to the potential infection sources

Based on the rigorous epidemiological investigations, potential infection sources were identified successfully in most of confirmed cases. According to the potential infection sources, all confirmed cases were categorized as follows: (1) imported cases and their close contacts (collectively referred to as “imported cases”); A imported case was defined as a confirmed case who had an exposure history in Wuhan within 2 weeks or could provide the exact date of close contact with a confirmed or suspect COVID-19 case in other cities outside Tianjin. In addition, close contacts of these cases who confirmed SARS-Cov-2 infection finally were also included. (2) Confirmed cases originated from the same public place (collectively referred to as “cases linked to a certain public place”); The cases had no close contact with the above imported cases. But the initial infection source of these cases could be linked to the same public place. Moreover, close contacts of these cases who confirmed SARS-Cov-2 infection finally were also included. (3) Confirmed cases originated from family (collectively referred to as “familial cluster of COVID-19 cases”); The infection source of the index patient in a family was unknown (no association with 1 or 2). However, the potential infection source of other family members or relatives was able to be tracked back to the index patient. (4) Others (sporadic cases): A case belonged to none of the above categories. Daily numbers of confirmed cases of each category were plotted by date of symptoms onset or testing (for asymptomatic cases only). Epidemic curve of confirmed COVID-19 cases of each category was drawn. According to the epidemic curve, the epidemic form of confirmed COVID-19 cases of each category was inferred.

Comparisons of clinical and epidemiological characteristics among COVID-19 cases with different infection sources

The clinical characteristics including age, sex, symptoms onset, test times of PCR, and the disease severity when confirmed were also collected. All cases with a clear exposure history and an exact record of the medical visit were included to calculate the epidemiological indexes, like the incubation period, the period from illness onset to the first medical visit, and the period from illness onset to confirmation.

Statistical analysis

The data were analyzed by SPSS statistic 22.0 (SPSS Inc., Chicago, IL). Continuous variables were expressed as median (interquartile range), and the differences were analyzed using the Kruskal-Wallis test. Categorical values were expressed as frequencies, and the differences were analyzed using Fisher’s exact test. All statistical significance was defined as \( P < .05 \).

RESULTS

Clinical and epidemiological characteristics of 136 COVID-19 cases in Tianjin, China

As of March 13, 2020, clinical and epidemiological data were collected from 136 COVID-19 cases in Tianjin. The clinical and epidemiological characteristics of 136 COVID-19 cases in Tianjin, China were shown in Table 1. Of these, 83 cases (61.03%) were aged 30-60 years, 17 cases (12.50%) were aged <30 years, and 36 cases (26.47%) were aged >60 years. The median age was 49 years (interquartile range 36-46 years). More than half of the 136 cases (53.68%) were male. The most common symptom at the illness onset was fever (58.82%), while 36 cases were asymptomatic. Additionally, 16 cases were finally confirmed by at least 3 times nucleic acid detection. Among the 136 cases, 48 cases belonged to imported cases, 13 cases of which were imported from the regions outside of Wuhan. An epidemiological link to the Baodi department store between January 20, 2020 and January 24, 2020 was observed in 43 cases (31.62%), including 7 staff and 21 customers. A total of 35 cases (25.74%) were thought to be the familial clusters of COVID-19 cases. The number of each familial cluster of COVID-19 cases ranged from 2 to 10. In addition, a health care worker with COVID-19 infection was also reported.

Comparisons of clinical and epidemiological characteristics among COVID-19 cases with different infection sources

The comparisons of clinical characteristics among COVID-19 cases with different infection sources were shown in Table 2. The proportion of males and the proportion of severe cases initially confirmed in imported cases were higher than those in cases linked to the Baodi department store \( (P < .05) \). The proportion of cases with fever at symptom onset and the proportion of severe cases in imported cases were higher than those in the familial cluster of COVID-19 cases \( (P < .05) \). There were no differences in the above indicators between cases linked to the Baodi department store and the familial clusters of COVID-19 cases. The comparisons of epidemiological characteristics among COVID-19 cases with different infection sources were shown
Comparisons of epidemiological characteristics among COVID-19 cases with different infection sources in Tianjin, China

As shown in Figure 1, the epidemic curves of 136 COVID-19 cases with different infection sources in Tianjin presented that 136 confirmed cases with different infection sources distributed in three different stages. In the early stage (before January 27, 2020), most of confirmed cases were imported cases. Meanwhile, the peak of imported cases appeared on January 26, 2020, and then the number of imported cases decreased gradually. The number of cases linked to the Baodi department store increased gradually since January 21, 2020, and peaked on February 2, 2020. Thus, the second stage of the COVID-19 outbreak mainly included cases linked to the Baodi department store. According to this epidemic curve, it was considered as a large-scale common-source outbreak of COVID-19. Other cases of local transmission occurred at the same time as cases linked to the Baodi department store. With the decrease of the number of cases linked to the Baodi Department store, they gradually increased and peaked on February 10, representing the main transmission pattern in the late stage, which was considered as a propagated epidemic due to this epidemic curve.

Transmission chains of 43 COVID-19 cases linked to the Baodi department store in Tianjin

The transmission chains of 43 COVID-19 cases linked to the Baodi department store in Tianjin are shown in Figure 2. According to the official epidemiological investigation, a saleswoman in the Baodi department store might be the index patient, and other 6 saleswomen were suspected to be infected by this woman.8,9 On January 21, 2020, the index patient developed a symptom of fever. Meanwhile, 21 customers who had shopped in this Department store were suspected to be infected with SARS-Cov-2 finally. Most cases did not take any basic protective measures (eg, using masks) against the virus during that period. Moreover, all these cases were on the same floor, and then local transmission in this store might occur between customers and saleswomen. Therefore, it was considered as a large-scale common-source

Table 1
Clinical and epidemiological characteristics of 136 COVID-19 cases in Tianjin, China

| Characteristics                              | Cases (n = 136) |
|----------------------------------------------|----------------|
| Median (interquartile range) age (y)         | 49 (36-64)     |
| Age (y)                                       |                |
| <30                                          | 17 (12.50)     |
| 30-60                                        | 83 (61.03)     |
| >60                                          | 36 (26.47)     |
| Sex (n, %)                                    |                |
| Male                                         | 73 (53.68)     |
| Female                                       | 63 (46.32)     |
| Symptom of onset (n, %)                       |                |
| Fever                                        | 80 (58.82)     |
| Others                                       | 20 (14.71)     |
| Asymptomatic cases                           |                |
| Test times of PCR ≥ 3 (n, %)                 | 36 (26.47)     |
| Severe case initially confirmed (n, %)        | 21 (15.44)     |
| Potential infection source (n, %)             |                |
| Imported cases                               | 33/15 (35.29)  |
| From Wuhan                                   | 20/14 (25.00)  |
| From other areas except Wuhan                | 13/1 (10.29)   |
| Cases linked to the Baodi department store   | 43 (31.62)     |
| Staffs                                       | 7 (5.15)       |
| Customers                                    | 21 (15.44)     |
| Close contacts of the staffs or customers    | 15 (11.03)     |
| Familial cluster of COVID-19 cases           | 35 (25.74)     |
| Familial cluster 1                           | 10 (7.35)      |
| Familial cluster 2                           | 5 (3.68)       |
| Familial cluster 3                           | 5 (3.68)       |
| Familial cluster 4                           | 4 (2.94)       |
| Familial clusters (number 2-3)               | 11 (8.09)      |
| Sporadic cases                               | 10 (7.35)      |
| Health worker                                | 1 (0.74)       |

Table 2
Comparisons of clinical characteristics among COVID-19 cases with different infection sources

| Indexes                                      | Imported cases | Cases linked to the Baodi DS | Familial cluster of cases | Z/| P |
|----------------------------------------------|----------------|-------------------------------|----------------------------|-----|----|
| No. (n)                                      | 48             | 43                            | 35                         |     |    |
| Age (median, y)                              | 46             | 52                            | 49                         | 0.679 | .712 |
| Sex (n, %)                                   |                |                               |                            |     |    |
| Male                                         | 33 (68.75)*    | 15 (34.88)                    | 20 (57.14)                 | 10.668 | .005 |
| Female                                       | 15 (31.25)     | 28 (65.12)                    | 15 (42.86)                 |     |    |
| Case with fever at symptom onset (n, %)       | 37 (70.08)†    | 24 (55.81)                    | 12 (37.14)†                | 13.551 | .001 |
| Test times of PCR ≥ 3 (n, %)                 | 5 (10.41)      | 6 (13.95)                     | 3 (8.57)                   | 0.604 | .739 |
| Severe case initially confirmed (n, %)        | 16 (33.33)†‡   | 3 (6.98)†                     | 2 (5.71)†                  | 15.255 | .000 |

DS, department store.

*P < .05 between imported cases and cases linked to the Baodi DS.
†P < .05 between imported cases and familial cluster of COVID-19 cases.

Table 3
Comparisons of epidemiological characteristics among COVID-19 cases with different infection sources

| Infection sources | No. | Incubation periods (d) | Illness onset to the first medical visit (d) | Illness onset to confirmation (d) |
|-------------------|-----|------------------------|---------------------------------------------|----------------------------------|
|                   |     | Median | IQR | Median | IQR | Median | IQR |
| Imported cases    | 24  | 7      | 5-11| 0      | 0-1 | 2      | 1-4 |
| Cases linked to the Baodi DS | 21  | 7      | 6-11| 4      | 2-6 | 7      | 4-10 |
| Z                 | -0.136 | 0.000 | 3-6.27 | 2-6 | 3-2.48 | 0.001 |

DS, department store; IQR, interquartile range.
Fig 1. Epidemic curves of 136 COVID-19 cases with different infection sources in Tianjin, China. Daily total (A) and new (B) numbers of confirmed cases for each classification were plotted by date of symptoms onset.

Fig 2. Transmission chains of 43 COVID-19 cases linked to the Baodi department store in Tianjin. A saleswoman was suspected to be the index patient, and other 6 saleswomen were suspected to be infected by this woman. Local transmission might occur between customers and saleswomen. Additionally, these customers and saleswomen were also able to transmit the virus to their families. DS, department store; R, relative; H, husband; S, son; N, neighbor; D, daughter; ML, mother-in-law; DL, daughter-in-law; F, friend; B, brother; SI, sister-in-low.
outbreak of COVID-19. Additionally, these customers and saleswomen were also able to transmit the virus to their families.

DISCUSSION

The prevention and control of emerging infection diseases bring great pressure on a well-developed city due to its huge population and high population density. Tianjin, one of the largest cities in China and a northern economic center, owns a population of over 15 million and a population density of almost 1,000 people per square kilometer. As of March 13, 2020, 136 COVID-19 cases including three deaths were reported in Tianjin. Among them, there were 36 asymptomatic cases (26.47%). Most of these asymptomatic cases were identified from screening close contacts of COVID-19 patients. Of note, the asymptomatic cases reported in this study were found on the date of testing, but some cases may develop symptoms during the disease course and should be reclassified as the presymptomatic or symptomatic cases.10,11 Thus, the proportion of the asymptomatic cases in our study might be overestimated. To date, the exact proportion of the asymptomatic cases is not fully explored. An estimated asymptomatic proportion at 17.9% (95% confidence interval 15.5-20.2%) was reported in the Diamond Princess Cruise ship.12 What is surprising is that 16 cases were finally confirmed based on at least three times nucleic acid detection. In line with our result, a previous study reported that 9 COVID-19 cases were unconfirmed until a third-time nucleic acid detection.13 This result may be partly explained by the fact of false-negative happened in virus nucleic acid detection. For instance, recent evidence demonstrated that the positive ratio of nucleic acid detection for COVID-19 was only 47.4% in suspect patients.14 Hence, the problem of false-negative of RT-PCR for COVID-19 is a challenge to control the spread of the disease. Fortunately, some advancement had been achieved in this field, such as rapid IgM-IgG combined antibody test and a combination of nucleic acid detection and chest CT examination.15,16

To date, the transmission pattern of the COVID-19 outbreak in the well-developed cities is still not clear. In the early stages of an outbreak in Tianjin, the most of confirmed cases were imported cases and their close contacts. Our results suggested that Wuhan was not the only source of the imported cases in Tianjin, and about one-third of the total imported cases were from areas outside of Wuhan, especially like other cities in Hubei Province. This finding indicated that the local transmission in other cities of Hubei Province might be far earlier than that in cities outside of Hubei. In the late stage, the local transmission largely occurred within Tianjin, and the poorly ventilated public place had become an important transfer station for virus transmission. The Poorly ventilated public place including large supermarkets, major department stores, places of worship, and nightclubs, is usually crowded and suffering a weak circulation of fresh air. All these characteristics determine it as a high-risk place for SARS-Cov-2 transmission. In this study, a total of 43 cases were found, an epidemiological link to the Baodi department store, indicating that a large-scale common-source outbreak of COVID-19 occurred in a typical poorly ventilated public place. It is easy to be infected with the virus if people have unprotected contact with the COVID-19 case in such a place. To our knowledge, droplets and fomites during close unprotected contact are the main transmission routes of COVID-19. However, the exact transmission routes in this department store were not very clear. Whether COVID-19 can also be transmitted by the airborne route is unconfirmed. Importantly, recent evidences had shown that both SARS-Cov-2 and SARS-Cov-1 exhibited a similar half-live in aerosols with median estimates around 2.7 hours.17 Moreover, a positive result of SARS-Cov-2 in samples from air outlet fans was also observed, suggesting that small virus-laden droplets might be displaced by airflows and deposited on some equipment such as vents.18 Given this, airborne transmission of SARS-Cov-2 is possible when virus-laden droplets might not be displaced by airflows quickly in a poorly ventilated place.19 Furthermore, human coronaviruses such as SARS-Cov-1, MERS-Cov could persist on inanimate surfaces for up to 9 days.20 Meanwhile, SARS-Cov-2 was also found on inanimate surfaces like a door handle, cell phone, and window bench when environmental surveillance performed in confirmed COVID-19 cases, indicating that the indirect contact was another route of transmission for COVID-19.21,22 Therefore, the indirect contact transmission and potential airborne transmission could be possible contributors to the large-scale common-source outbreak of COVID-19 in this department store. Recently, a similar large-scale common-source outbreak of COVID-19 that happened in the poorly ventilated public place such as a shopping mall and a church was also reported.23,24 This meaningful case series is of great warning significance for other cities where large-scale local transmission has not yet happened in a poorly ventilated public place. In addition, the finding also further emphasizes the significance of taking basic protective measures (eg, hand hygiene and maintaining social distance or using masks) when visiting a public place. A similar pattern did not emerge again as a strict isolation policy had been implemented since January 24, 2020 in Tianjin. Given this result, accurate and rapid blocking and control measures had successfully prevented the large-scale spread of COVID-19 in public places of Tianjin.

Notably, our results also indicated that local transmission of COVID-19 was largely occurring within families, and led to a propagated epidemic of COVID-19 in Tianjin. Familiar clusters of COVID-19 cases had been reported by previous studies.25-27 According to the Report of the WHO-China Joint Mission on COVID-19, among 344 clusters including 1,308 cases in Guangdong and Sichuan Province, about 78%-85% of clusters occurred in families.26 In our study, the household transmission was the main pattern of local transmission in the late stage of an outbreak in Tianjin. In agreement with our results, a prior study exhibited that two-thirds of confirmed cases in Hong Kong came from eight familiar clusters.22 Similarly, a family cluster of COVID-19 cases involving 11 patients in Nanjing was also observed.23 In our study, a case in point is a familial cluster involving 10 COVID-19 cases. This phenomenon presented a serious threat to public health because of the difficulty to process a strict isolation among family members. Importantly, to interrupt household transmission as early as possible, individuals living with family members suffering COVID-19 infection should be closely monitored and examined to rule out infection, even if they did not have any symptoms.25

It was interesting to note that the disease severity in imported cases was more serious than that in other cases. In line with our finding, it had been reported that the symptoms of COVID-19 cases in Zhejiang Province were relatively mild compared with cases initially infected with SARS-Cov-2 in Wuhan.29 Moreover, as of March 13, 2020, the mortality of COVID-19 in the other part of China outside of Wuhan (2.04%) was far lower than that in Wuhan (4.89%), and especially lower in areas outside of Hubei Province (0.90%).30 Furthermore, it was reported that the viral load of SARS-Cov-2 gradually decreased in tertiary patients.31 Accordingly, we inferred that the pathogenicity of SARS-Cov-2 might decrease when transmitted to the next generation in China. In spite of that, there was no direct evidence to support this inference so far. Thus, future studies on the current topic are still required.

Despite the intriguing findings of our study, several important limitations should be taken into account. First, our study was based on the data from the official situation-reports in a public dataset. There may be some reporting bias existed in the information of COVID-19 cases, especially for the epidemiological information. Particularly, the details of the test method used in Tianjin including sensitivity and specificity were not disclosed in the dataset of COVID-19. Second, the sample size in this research was not large enough. Last but not least, several key epidemiological indexes such as the basic
reproductive number could not be estimated owing to the imperfect data at present. This will be an important issue to be explored in our future research.

CONCLUSIONS

In conclusion, besides the imported cases, the pattern of local transmission of COVID-19 was a mixture of the propagated epidemic and the common-source outbreak in Tianjin. Local transmission of COVID-19 mainly occurred within families and a poorly ventilated public place in Tianjin. To interrupt household transmission as early as possible, an active screening to prompt SARS-CoV-2 testing in individuals with family members suffering SARS-CoV-2 infection should be considered seriously. Besides, it was necessary to implement effective measures to prevent the large-scale spread of COVID-19 in poorly ventilated public places at the early stage of an outbreak. In view of local transmissions observed in a growing number of countries, our findings might offer several valuable information to support other countries to control a potential future spread of nationwide epidemics.

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