EPIDEMIOLOGY OF COVID-19 IN NON-CORE INFECTED REGIONS BASED ON PATIENT MOVEMENT TRAJECTORIES – A REPORT FROM CHONGQING, CHINA (11 JANUARY – 21 FEBRUARY 2020)

Jun Qiu[1*], Ao Yang[2*], Lu-Man Ye[1], Ya Guo[1], Ding-Yuan Du[1] and Liu Yang[1]

[1]Chongqing University Central Hospital, Chongqing Emergency Medical Center, Chongqing, PR China; [2]Daping Hospital, Army Medical Center of the PLA, Chongqing, PR China

Abstract. Epidemiological characteristics of COVID-19 in non-core infected regions were identified to provide evidences for prevention and management of COVID-19 epidemic in China. Data collected through an online reporting system were age, gender, source of infection, date of disease occurrence, date and type of primary medical examination and treatment, and classification of COVID-19, mode of infection and clinical symptoms. Confirmed COVID-19 patients (n = 518) constituted male:female ratio of 1.19:1, 30-75 years of age (82.74%), and with clustered cases significantly higher than sporadic cases, percent close contact transmission during dining being highest (39.30%), 88.89% of the patients having a latent period of 2-14 days, duration from primary medical examination to diagnosis ranging from 1 to 16 days, and 43.83% of the patients having fever or cough. In order to prevent further spread of COVID-19 epidemic, measures should be taken to increase detection and isolation of infection sources, reduce unsafe contact behavior, and impose 14-day quarantine of suspected contact individuals together with periodic tests of SARS-Cov-2 infection.

Keywords: SARS-CoV-2, China, COVID-19, epidemiology, non-core infected region

INTRODUCTION

COVID-19 is an infectious disease caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). To date, SARS-CoV-2 has spread to 219 countries and territories, infecting more than 31.44 million people and causing 970,307 deaths (Ifeng News, 2020). Although mortality attributed to COVID-19 in China has decreased, cautionary measures need to be applied to prevent further transmission of SARS-CoV-2 to the world.

Chongqing is a sprawling municipality located in Southwest China, comprising an area of 82,400 km^2, with a population of 34,036,400, among whom 31,017,900 (91.13%) are permanent residents, and a mean density of 413/km^2 (Chongqing Municipal Bureau of Statistics, 2020). Chongqing was one of the first regions in the country with reports of COVID-19

Correspondences: Ding-Yuan Du and Liu Yang, Chongqing University Central Hospital, Chongqing Emergency Medical Center, Chongqing 400014, PR China
Tel: +86 02363692037
E-mail: 1022447341@qq.com
* Jun Qiu and Ao Yang co-wrote the first draft of the manuscript, and contributed equally to the study.

infection and as of 21 February 2020, there were 572 confirmed COVID-19 cases, a prevalence of 1.68/100,000 population, accounting for 4.5% of all confirmed COVID-19 patients in mainland China except for Hubei Province.

In order to prevent further spread of COVID-19, we investigated epidemiological characteristics of the infection in the Chongqing Municipality, including comparison of latent periods of infection between imported and local COVID-19 patients to explore properties of second-generation SARS-CoV-2 transmission and infection. Findings should provide scientific evidence to assist in development of prevention and management strategies of COVID-19 pandemic in China and promotion of appropriate interventional measures for each region of the country.

MATERIALS AND METHODS

Data source, collection and processing

Data of confirmed COVID-19 patients between 11 January and 21 February 2020 reported online by the Leading Group for the Prevention and Management of COVID-19 of Chongqing Municipality and districts and counties under its administration were collected. The data included were: patient's age, gender, movement trajectory, transport mode, type of human contact, date of first medical examination and treatment, and date of diagnosis. Individual identity and other personal information were removed prior to receipt. Patients with only identification numbers and transportation routes and no other data were excluded, the others were enrolled in the study.

The relative risks (RR) of infecting COVID-19 by patients of different age groups were calculated according to the equation:

$$RR = \frac{\left(\frac{Ci}{\sum Ci}\right)}{\left(\frac{Yi}{\sum Yi}\right)}$$

where Ci = number of patients in the corresponding age group and Yi = number of subjects in the corresponding age group retrieved from the 2018 National Population Sample Survey (National Bureau of Statistics of China, 2020) (Lemaitre and Carrat, 2010; Li, 2010). In addition, standardization of constituent ratio of the ages (SRa) of COVID-19 patients was performed according to the following equation:

$$SRa = \left(\frac{Ci}{\sum Ci}\right) \times \left(\frac{Yi}{\sum Yi}\right)$$

where Ci = number of patients in the corresponding age group and Yi = number of subjects in the corresponding age group retrieved from the 2018 National Population Sample Survey (National Bureau of Statistics of China, 2020). Standardization of constituent ratio of gender of COVID-19 patients (SRg) was performed according to the following formula:

$$SRg = \left(\frac{C_1 i}{\sum C_1 i}\right) \times \left(\frac{Gi}{\sum Gi}\right)$$

where $C_1 i$ = number of patients of corresponding gender and Gi = number of subjects of the corresponding gender retrieved from the 2018 National Population Sample Survey (National Bureau of Statistics of China, 2020).

Since the information of the COVID-19 cases in this study was collected through an online reporting system (http://cq.bendibao.com/news/202024/81459.shtm), ethical clearance was not required.

Definitions

Core regions: Hubei province (including Wuhan) is classified as core

infected region, while other provinces (excluding Hubei) are classified as non-core infected regions.

Latent period: this is defined as date from first contact with source of infection to date of symptoms occurrence (disease onset) (Li, 2010).

Classification of COVID-19: this follows guidelines issued by the National Health Commission of the People's Republic China (National Health Commission of the People's Republic China, 2016) and Guideline for the Outbreak of Infectious Diseases issued by the hospital concerned, with two or more patients from the same family or living in the same building considered a "clustered case" and otherwise defined a "sporadic case".

Types of confirmed cases: patients with a history of living or traveling in other provinces (municipalities) within 14 days prior COVID-19 diagnosis are termed "first-generation cases", local cases with confirmed COVID-19 subsequent to contact with first generation cases considered "second-generation cases", local cases with confirmed COVID-19 after contact with second-generation cases considered "third-generation cases", and "fourth- and fifth-generation cases" are similarly defined (National Health Commission of the People's Republic China, 2016).

Mode of infection: first-generation case is defined as "living (traveling) in an infected area infection", through social contact with direct relatives as "family-living contact infection", through social contacts with indirect relatives in family was as "other-living contact infection", through possible body contact during regular communication with other persons or during social activity and/or work as "regular contact infection", through other activities or communal dining as "close (dietary) contact infection", and through transmission from other persons within a distance of one m or in the same closed room/carriage but without body contact as "close non-contact infection" (Li, 2010; National Health Commission of the People's Republic China, 2016).

Statistical analysis

IBM Statistical Package for the Social Sciences (SPSS) version 23.0 (SPSS Inc, Chicago, IL) was used for statistical analysis. Quantitative data are presented as mean ± SD if they have normal distribution, otherwise, presented as median [interquartile range (IQR)], and qualitative data are presented as number (%) or percentage. A Chi-square test was used for comparison between two or more independent samples and Mann-Whitney U test for comparison of unidirectional variables. A p-value <0.05 is considered statistically significant.

RESULTS

A total of 572 COVID-19 confirmed patients were reported by the Municipal Health Commission of Chongqing up to 21 February 2020 (Municipal Health Commission of Chongqing, 2020), among whom movement trajectories of 522 patients were obtained from the online website and 50 patients without data and 4 with incomplete data (only patients' identification numbers and transportation routes available) were excluded, resulting in a total of 518 patients enrolled in the study. This cohort consisted of 261 males, 230 females and 27–whose gender was not indicated, had a mean (range) age of 45 years (7 months to 87 years) (n = 446), 37.89% in the 45-60 years old age group (Table 1).

Of 385 confirmed patients, majority

Table 1
Demographic profile of COVID-19 patients in Chongqing Municipality and districts and counties under its administration, PR China (11 January - 21 February 2020).

Characteristic	Number	Percent	Standardized ratio	RR	95% CI
Gender (n = 491)					
Male	261	53.16	27.18	1.04	0.87-1.24
Female	230	46.84	22.89	0.96	0.80-1.15
Age group, years (n = 446)					
0-15	12	2.69	0.45	0.16	0.09-0.28
15-30	43	9.64	1.85	0.50	0.38-0.67
30-45	131	29.37	6.64	1.30	1.13-1.50
45-60	169	37.89	8.91	1.61	1.43-1.82
60-75	69	15.47	2.13	1.12	0.90-1.40
≥75	22	4.93	0.20	1.20	0.80-1.80

CI: confidence interval; RR: relative risk.

were first-generation patients, followed by second-generation patients, and local patients accounted for 47.54% (Table 2). Among 337 patients, 67.96% were infected through contact with patients from Hubei Province (including Wuhan) and 27.00% through contact with local patients. Regarding case types, 296/518 (57.14%) were considered clustered cases (234 family-clustered) and 104 (20.08%) sporadic cases, with no information for the remaining patients. For 201 confirmed COVID-19 local (non-imported) patients, close (dietary) contact infection accounted for 79 out of 201 (39.30%), followed by other life contact infection 62 out of 201 (30.85%).

Information on symptoms of COVID-19 was available for 292 patients: 113 (38.69%) presenting no subjective symptoms but positive after screening during isolation, followed by 82 (28.07%) with fever, 75 (25.69%) with cough (Table 3). Although the period when imported (first-generation) patients were unknown, for local (second, third, fourth, and fifth-generation) patients (n = 81), median latent period of COVID-19 was 11 days (range = 2-21 days), with 89% having a latent period of 2-14 days (Table 4). Mean duration from first medical examination to diagnosis was 2 days (ranging from day of examination to 16 days); however, mean duration for local patients is significantly shorter than for imported patients (p-value <0.05, Mann-Whitney U test). Overall, COVID-19 diagnosis was obtained within 3 days following first medical examination (Fig 1).

DISCUSSION

The retrospective survey of epidemiological characteristics of COVID-19 in Chongqing reveals standardized male-to-female ratio of the confirmed COVID-19 patients was similar to those reports of patients infected with SARS-CoV (excluding medical personnel, *ie* male:female ratio of 56:44) and MERS-CoV (male:female ratio of 67:33) (Peak *et al*, 2017; Benvenuto *et al*, 2020; Zhu *et al*, 2020). Risk of COVID-19 infection

Table 2
Epidemiological characteristics of COVID-19 patients in Chongqing Municipality and districts and counties under its administration, China (11 January - 21 February 2020).

Characteristic	Number	Percent
Case type (n = 385)		
First-generation	202	52.47
Second-generation	132	34.29
Third-generation	45	11.69
Fourth-generation	4	1.04
Fifth-generation	2	0.52
Infection source (n = 337)		
Patients from Wuhan, Hubei	188	55.79
Patients from Hubei (excluding Wuhan)	41	12.17
Patients from other provinces (excluding Hubei)	17	5.04
Local patients	91	27.00
Mode of infection (local patients, n = 201)		
Family living contact	31	15.42
Other life contact	62	30.85
Regular contact	23	11.44
Close (dietary) contact	79	39.30
Close non-contact	6	2.99

First-generation: patients with a history of living or traveling in other provinces (municipalities) within 14 days prior COVID-19 diagnosis; Second-generation: local cases with confirmed COVID-19 subsequent to contact with first generation cases; Third-generation: local cases with confirmed COVID-19 after contact with second-generation cases; Fourth-generation: local cases with confirmed COVID-19 after contact with third-generation cases; Fifth-generation: local cases with confirmed COVID-19 after contact with fourth-generation cases.

Table 3
Symptoms prior to diagnosis of COVID-19 patients (n = 292) in Chongqing Municipality and districts and counties under its administration, China (11 January - 21 February 2020).

Symptom	Number	Percent
Fever	26	8.90
Fever and cough	29	9.93
Fever and other cold symptoms	25	8.56
Fever and digestive tract symptoms	2	0.68
Cough	31	10.62
Cough and other cold symptoms	15	5.14
Other cold symptoms	48	16.44
Digestive tract symptoms	1	0.34
Digestive tract symptoms and other cold symptoms	2	0.68
Asymptomatic	113	38.69

Table 4
Duration from first medical examination until COVID-19 diagnosis of patients in Chongqing Municipality and districts and counties under its administration, China (11 January - 21 February 2020).

Day(s)	Number of cases	Percent
Local cases (n = 227)		
1	65	28.63
2	98	43.17
3	28	12.33
4	13	5.73
5	8	3.52
6	4	1.76
7	5	2.20
8	3	1.32
9	0	0.00
10	2	0.88
15	0	0.00
16	1	0.44
Imported cases (n = 182)		
1	42	23.08
2	85	46.70
3	34	18.68
4	4	2.20
5	2	1.10
6	7	3.85
7	3	1.65
8	2	1.10
9	1	0.55
10	0	0.00
15	1	0.55
16	1	0.55

was relatively higher in subjects greater than 30 years of age compared to those less than 30 years of age, consistent with the knowledge SARS-CoV-2 is mainly transmitted through exposure to droplets and close contacts (Chen, 2020; Lee and Hsueh, 2020; Ong *et al*, 2020) and thus risk of COVID-19 infection among relatively young subjects would be lower due to their limited social activities, thereby more limited viral exposure.

The study reveals a higher number of confirmed COVID-19 first-generation than local patients, with patients from Wuhan predominant. Thus, an important measure in management of COVID-19 epidemic is to prevent import of cases and optimize identification of second-generation contact cases. The number of local cases decreased among further generations of COVID-19 patients, *ie* with widening of circles of possible contacts, attributable to timely isolation upon detection of early cases patients together

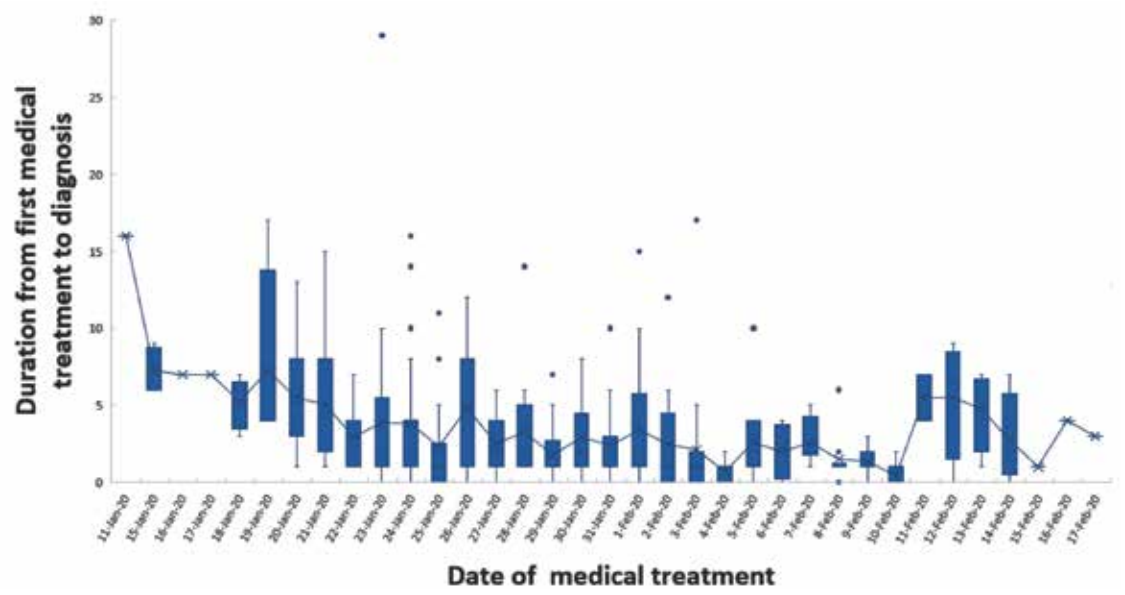

Fig 1-Duration (days) from date of first medical treatment to COVID-19 diagnosis of patients in Chongqing Municipality and districts and counties under its administration, PR China [11 January (Jan) -17 February (Feb) 2020 (20)].

Data were obtained from the Leading Group for the Prevention and Management of COVID-19 of Chongqing Municipality and districts and counties under its administration.

× represents date of medical treatment; Vertical line represents duration from first medical treatment to diagnosis; Box shows a spread of data in the date of medical treatment.

with a 14-day quarantine of close contacts (National Health Commission and State Administration of Traditional Chinese Medicine, 2020).

As expected percent clustered was higher than sporadic cases, family-clustered patients was the majority. Movement trajectories reveal highest rate of local infection occurred during the Spring Festival holidays (24 January – 2 February 2020). Although clustering from close contacts favored viral transmission, social contacts also played an important role, in agreement with the findings of Ong *et al* (2020).

Latent period of SARS-CoV-2 infection among first-generation patients was not known, but latent period of local COVID-19 patients ranged from 2 to 21 days, majority of patients presenting latent period lasting 2-14 days, similar to findings of Sun *et al* (2020). However, as there were patients with longer latent periods, it would be prudent to conduct follow-up of close contacts subsequent to the mandatory 14-day quarantine to ensure these carriers do not become potential sources of further infection.

The duration from the first medical treatment to diagnosis was shorter for local than first-generation patients, suggesting more attention being paid to patients with possible COVID-19 symptoms once the outbreak was realized, as well increase in ability to diagnose and treat such patients. Nevertheless, the lag

period between identification of a possible COVID-19 patient and confirmation should be shortened, preferably at on-site, and this issue needs to be brought to the attention of the relevant Health Departments.

Symptoms of confirmed COVID-19 patients are in general similar to SARS and MERS (Lee and Hsueh, 2020), typically respiratory distress, with cough and fever commonly observed in the early period (Lee and Hsueh, 2020), which have led to misdiagnosis (common flu) and is a key factor for large-area spread of COVID-19 in the early phase of the epidemic in the country. Recently, Zhang (2020) isolated SARS-CoV-2 from fecal samples of COVID-19 patients, and thus, gastrointestinal samples should also be collected and processed for COVID-19 diagnosis. Thorough disinfection of sanitary sewer discharge and floor drains should not be neglected.

In conclusion, it is important to enhance the isolation of susceptible subjects and infection sources, and reduce the unsafe living contacts in order to rapidly prevent the widening of the COVID-19 epidemic. The potentially infected subjects are routinely isolated for 14 days, while further re-examinations after the 14-day isolation are necessary. In addition, improving the diagnosis and screening methods, and shortening the diagnosis time are important for the prevention and management of the epidemic.

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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