The characteristics of household transmission of COVID-19

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Summary: The secondary attack rate of SARS-CoV-2 in household is 16.3%. Ages of contacts and spouse relationship with index case are risk factors for transmission of COVID-19. Quarantine of index patients since onset of symptom is helpful to prevent COVID-19 spread.

Abstract

Background

Since December 2019, SARS-CoV-2 virus has extended to most parts of China with more than 80 thousand cases and to at least 100 countries with more than 60 thousand international cases by March 15, 2020. Here we applied household cohort study to determine the features of household transmission of COVID-19.

Methods

Total 105 index patients and 392 household contacts were enrolled. Both index patients and household members were inspected by SARS-CoV-2 RT-PCR. The information of all recruited people was extracted from medical records and confirmed or supplemented by telephone interviews. The baseline characteristics of index cases and contact patients were described. Secondary attack rates of SARS-CoV-2 to the contact members were computed and the risk factors for transmission within household were estimated.

Results

Secondary transmission of SARS-CoV-2 developed in 64 of 392 household contacts (16.3%). The secondary attack rate to children was 4% comparing with 17.1% to adults. The secondary attack rate to the contacts within the households with index patients quarantined by themselves since onset of symptoms was 0% comparing with 16.9% to the contacts without index patients quarantined. The secondary attack rate to contacts who were spouses of index cases was 27.8% comparing with 17.3% to other adult members in the households.

Conclusion

The secondary attack rate of SARS-CoV-2 in household is 16.3%. Ages of household contacts and spouse relationship with index case are risk factors for transmission of SARS-CoV-2 within household. Quarantine of index patients at home since onset of symptom is useful to prevent the transmission of SARS-Co-2 within household.

Background

In December 2019, an increasing cases of patients with pneumonia of unknown etiology emerged in Wuhan, a large city of 11 million people in central China[1-3]. The pathogen was soon identified as a novel coronavirus which is similar to the coronavirus of severe acute respiratory syndrome (SARS-CoV) and shares more than 79% of its sequence[4]. Consequently, the novel virus was named as SARS-CoV-2 and its infection disease was announced as coronavirus disease 2019 (COVID-19) by World Health Organization (WHO)[5]. With its rapid spread, the virus has extended to most parts of China with more than 80 thousand cases and as well as to at least 100 countries with more than 60 thousand international cases by March 15, 2020[6]. Despite the increasing number of reports about COVID-19, the epidemic investigation of this disease is limited and little is known about the transmission probability and infectivity of SARS-CoV-2 in household. Here, the retrospective data on household transmission of COVID-19 were systemically analyzed and demonstrated certain epidemiological characteristics of COVID-19 between people.

Methods

Data sources

Data were collected from two local hospitals, Zaoyang First People's Hospital, 250 kilometers far away from Wuhan, and Chibi People's Hospital, 150 kilometers away, between January 1 and February 20, 2020. Eligible households were defined as the family only had one member, known as index patient, who had clear history of exposure to Wuhan (departed from or travelled to Wuhan) or people from Wuhan or high-risk sites such as hospitals, supermarkets or railway stations within 14 days before illness onset and other family members had clear non-history of exposure to these; all the family members resided in one house before the index cases were hospitalized. Index patients and infected contacts were confirmed by positive of their nasopharyngeal swab samples on SARS-CoV-2 RT-PCR[7] and uninfected household contacts were those who had no any symptom and at least twice negative on SARS-CoV-2 RT-PCR. All the family contacts were quarantined immediately after the index cases were confirmed for 14 days in special places designated by the local governments and monitored everyday by the health service personnels. The nasopharyngeal swab samples were collected at the beginning and the middle time of quarantine duration. The quarantined contacts who had symptoms were inspected at

least four times by SARS-CoV-2 RT-PCR until they were positive. The information of all recruited people was extracted from medical records and confirmed or supplemented by telephone interviews. The last enrolled index case in this study was hospitalized in February 13, 2020 and the final date of followed-up was at March 1, 2020. Household members were excluded if they lived less than 24 hours in the residence of the index cases. Total 105 households with 392 family contacts were enrolled.

Statistical analysis

Secondary attack rate is defined as the proportion of infected household contacts (or household members except index patient) in the total number of household contacts. For categorical variables, the percentages of patients in each category were calculated. Logistic generalized estimating equation model was applied to identify risk factors associated with the secondary attack rate while accounting for correlation of members within household[8].

Results

Baseline characteristics of index patients of COVID-19

The study included 105 index patients. The median age of the index patients was 51 years (25th to 75th percentile, 39 to 60 years) and 60 (57.1%) were male. Of the 105 patients, 65 (61.9%) patients had direct history of exposure to Wuhan, 13 (12.4%) patients had close contact with peoples from Wuhan and another 27 (25.7%) patients had visited to high-risk sites within 14 days before onset of illness. Of the 105 patients, 56 (53.3%) patients had fever at onset of illness, 31 (29.5%) cough, 20 (19%) fatigue, 12 (11.4%) chill, 6 (5.7%) dyspnea or anorexia, 5 (4.8%) dizziness or myalgia, 3 (2.9%) vomit or nausea, 2 (1.9%) diarrhea or rhinobyon and one patient had headache or palpitate. The period between onset of symptoms and hospitalization was 0 to 11 days. Of the 105 patients, 12 (11.4%) patients waited 0 to 1 day for hospitalization after onset of illness, 34 (32.4%) waited 2-5 days and 59 (56.2%) waited 7-11 days. There were 14 (13.3%) index patients quarantined by themselves at home that was with mask, dieting separately and residing alone immediately since onset of symptoms (Table 1).

Baseline characteristics of household contact patients of COVID-19

A total of 392 elegible household contacts from the 105 family clusters were enrolled in this investigation. The median of household size was 4 (25th to 75th percentile, 3 to 6). The median of adult age was 46 (25th to 75th percentile, 32 to 58) and that of child

was 6.5 (25th to 75th percentile, 4 to 11). There were 64 contacts infected with SARA-CoV-2. The median age of the secondary cases was 45 years (25th to 75th percentile, 30 to 57 years) and the median child age . Of the 64 contact patients, 33 (51.2%) were male; 36 (56.3%) contact cases had fever at onset of illness, 11 (17.1%) cough, 4 (6.3%) chill or fatigue, 3 (4.7%) diarrhea and one contact case had dizziness or myalgia or sneeze or anorexia. There were 9 (14.1%) asymptomatic patients in total SARS-CoV-2 positive contacts and 3 nucleic acid negative contacts with symptoms, 2 adult with cough, one adult fatigue and one child cough.

Of the 64 contact patients, 4 (6.3%) cases were aged below 18 years and all were male, 12 (18.8%) cases in 18 to 30 years, 14 (21.9%) cases in 31 to 40 years, 9 (14.1%) cases in 41 to 50 years, 18 (28.1%) cases in 51 to 60 years and 7 (10.9%) cases above 60 years (Table 2.). The median of interval time, from symptomatic onset of index cases to symptomatic onset of household contacts, was 6 days (25th to 75th percentile, 4 to 10).

The characteristics of secondary transmission of COVID-19 in households

The secondary attack rates to household contacts were evaluated in different conditions. The secondary attack to total 392 household contacts was 16.3%. When the data were stratified for analysis by the ages of contacts, the secondary attack rate to children (aged below 18 years) was 4% comparing with 17.1% to adult members (OR 0.18, 95% CI 0.06 to 0.54, p=0.002). The secondary attack rate to the contacts in the household with index patients quarantined at home immediately since onset of symptom was 0% compared to 16.9% to the contacts in the households without index patients quarantined during the period between initiation of symptom and hospitalization (OR 0, 95% CI 0.00 to 0.00, p=0.000). Spouse relationship was another risk factor for the infection of SARS-CoV-2 to household contacts and the secondary attack rate to individuals who were spouses of index cases was 27.8%, compared to 17.3% to other members in the households (OR 2.21, 95% CI 1.18 to 4.12, p=0.013). The gender, symptoms and the time between onset of illness of index patients and hospitalization were not related to the secondary attack rates of SARS-CoV-2 to household contacts (Table 3.).

Discussion

Household model has more clear and fixed exposure of infection sources which makes it feasible to estimate the transmissibility and infectivity of prevalent virus[7, 8]. Here, we found the general secondary attack rate of SARS-CoV-2 to contact members in households was 16.3%, which is the highest when comparing with those of two other coronaviruses related respiratory diseases, severe acute respiratory syndromes (SARS) and Middle East respiratory syndrome (MERS)[9, 10] and is also higher than that of pandemic influenza A in 2009 with 13%[8]. This might contribute to the dramatically higher number of infected cases than the two other coronaviruses related diseases. As the time and chance of infection exposure to susceptible people within household model were more than that in community and population-level, the transmission probability in household may be stronger than that in community and population-level in most case[8, 10, 11]. Although the household was different from community and large population, our results may exhibit a hint of transmission probability of SARS-CoV-2 in one aspect.

Although one center in China reported nine infants under 1 year infected with SARS-CoV-2[11] and the population distribution of COVID-19 in ages were described by several other groups[13, 12], there was no denominator number of peoples exposed to clear source of infection and the relative susceptibilities to SARS-CoV-2 for children and adults remain to be studied. In this report, the results showed secondary attack rate of SARS-CoV-2 to adults was dramatically higher than that to children which might reflect the different susceptibility to SARS-CoV-2 between children and adults and indicate adults were more susceptible to SARS-CoV-2 than children who aged below 18 years when they exposed themselves to the same sources of infection. This is similar with SARS virus that infected most peoples aged above 18 years. However, the real causes leading to the different secondary attack rates between adult and children needed to be more explored and many factors could influence the secondary transmission of epidemic diseases in household, such as behaviors of contacts and occupations of members[10].

Asymptomatic carriers exist in many infectious diseases[13]. In our data, we also found 9 cases in contact cases (14.1%). This is more than 10 times as that reported by other group in a large population-level[6]. In the household model, all the negative contacts were inspected by SARS-CoV-2 RT-PCR at least twice. However, in that retrospective study, the whole close contact population could not be scanned by the

laboratory test, which may lead to missing many symptom-free cases to be statistically counted and this may contribute to inconsistencies with ours. In this case, there might be more asymptomatic carriers than we expected based on previous report. We knew asymptomatic carrier of SARS-CoV-2 could transmit virus to other people[14], so more strategies may be needed to find out more asymptomatic cases in population.

The effect of self-quarantine at home was also assessed in household model. Of 105 index patients, 14 cases were quarantined by themselves at home immediately at onset of symptoms, that was with mask, repasting separately and residing alone. The results showed no infected contacts in the households with index cases who implemented quarantine immediately after appearance of symptoms, and so the secondary attack rate was zero. This indicated that home quarantine by themselves since onset of symptoms might make certain sense to prevent the transmission of SARS-CoV-2 in household. However, the power to make the conclusion for these was low since the number of cases was limited and large-scale investigation remained to be made.

Interestingly, the analysis of data stratified by spouses who were the husbands or wives of index cases, demonstrate that the secondary attack rate of SARS-CoV-2 to the spouses was significantly higher than that to other family members. This might be because the longer time of exposure to infection sources, the higher chance of illness for contacts and spouses might spend more time for each other to stay together than any other members they did with within household.

NOTES

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Table 1. Baseline characteristics of index patients of COVID-19

	Numbers (%)
Age, median (25th to 75th), y Genders	47 (40 to 56)
Male	
	60 (57.1)
Female	45 (43.9)
Exposure history within 14 days	
Physically in Wuhan before	65 (61.9)
Contacted with people from Wuhan	13 (12.4)
Physically in local high-risk sites before	27 (25.7)
Symptoms at onset of illness	
Fever	56 (53.3)
Cough	31 (29.5)
Fatigue	20 (19)
Chill	12 (11.4)
Dyspnea or anorexia	6 (5.7)
Dizziness or myalgia	5 (4.8)
Vomit or nausea	3 (2.9)
Diarrhea or rhinobyon	2 (1.9)
Headache or palpitate	1 (0.95)
Time from onset of illness to hospitalization	
0-1 days	12 (11.4)
2-5 days	34 (32.4)
> 5 days	59 (56.2)
Quarantine at home immediately after onset of symptoms	
Yes	14 (13.3)
No	91 (86.7)

Table 2. Baseline characteristics of household contact patients of COVID-19

	Numbers (%)
Household size, median (25th to 75th)	4 (3 to 6)
Age of total contacts	35(16 to 55)
Adult age, median (25th to 75th), y	46(32 to 58)
Child age, median (25th to 75th), y	6.5 (4 to 11)
Age of infected contacts, median (25th to 75th), y	45 (30 to 57)
Genders	
Male	33 (51.6)
Female	31 (48.4)
Ages of the contact patients	
< 18 years	4(6.3)
18-30 years	12 (18.8)
31-40 years	14 (21.9)
41-50 years	9 (14.1)
51-60 years	18 (28.1)
>60 years	7 (10.9)
Symptom of the contact patients	
Fever	36 (56.3)
Cough	11 (17.2)
Chill	4 (6.3)
Fatigue	4 (6.3)
Diarrhea	3 (4.7
Dizziness or anorexia	1 (1.6)
Headache or myalgia	1 (1.6)
Symptom-free	9 (14.1)
Interval time, Median (25th to 75th), days	6 (4 to 10)

Notes: Interval time, the time from symptomatic onset of index cases to symptomatic onset of household contacts

Table 3. The characteristics of secondary transmission of COVID-19 in households

	Infected cases	Total contacts	Secondary attack rates %	OR 95% CI	p Value
General attack rate	64	392	16.3		
Symptomatic attack rate	55	392	14		
Genders of contacts					
Female	31	181	17.1	0.92 (0.51 to 1.64)	0.78
Male	33	211	15.6		
Ages of contacts					
< 18 years	4	100	4	0.18 (0.06 to 0.54)*	0.002
0-5 years	1	44	2.3		
6-17 years	3	56	5.4		
≥ 18 years	60	292	20.5		
18-30 years	12	55	21.8		
31-40 years	14	76	18.4		
41-50 years	9	35	25.7		
51-60 years	18	71	25.3		
> 60 years	7	55	12.7		
Quarantine of index case at initiation of symptom					
Yes	0	43	0	0 (0.00 to 0.00)	0.00
No	64	349	18.3		
Relationships with index cases					
Spouse	25	90	27.8	2.27 (1.22 to 4.22)	0.010
No spouse (ex children)	35	202	17.3		
Genders of index cases					
Female	29	183	15.8	0.79 (0.42 to 1.47)	0.45
Male	35	209	16.7		
Symptoms of index cases					
No fever	26	194	13.4	0.61 (0.30 to 1.24)	0.169
Fever	38	198	19.2		
No cough	45	271	16.6	0.88 (0.47 to 1.64)	0.68
Cough	19	121	15.7		
Exposure-period categories					
0-1 day	10	46	21.7	0.90 (0.61 to 1.33)	0.58
2-5 days	14	91	15.4		
> 5 days	40	253	15.8		

Notes: OR, Odds Ratio; CI, confidence interval; Exposure-period, The time between onset of illness and hospitalization. p< 0.05 was considered statistically significant. *, comparing children with adults