The characteristics of household transmission during COVID-19 outbreak in Okinawa, Japan from February to May 2020

Yumani Kuba[1*], Ayako Shingaki[1], Minoru Nidaira[1], Tetsuya Kakita[1], Noriyuki Maeshiro[1], Minori Oyama[1], Tsuyoshi Kudeken[1], Ayano Miyagi[1], Miyuki Yamauchi[1] and Hisako Kyan[1].

[1]Okinawa Prefectural Institute of Health and Environment, Okinawa, Japan.

***Corresponding author:** Yumani Kuba

Okinawa Prefectural Institute of Health and Environment,

17-1 Kanekadan, Uruma, Okinawa 904-2241, Japan

E-mail: kubayuma@pref.okinawa.lg.jp

Phone: +81-98-987-8222, Fax: +81-98-987-8210

Keywords: COVID-19, household, close contact, secondary attack rate

Running head: Household transmission of COVID-19 in Okinawa

沖縄県における新型コロナウイルス感染症（COVID-19）の家庭内感染

久場　由真仁[1*]、新垣　あや子[1]、仁平　稔[1]、柿田　徹也[1]、眞榮城　徳之[1]、大山　み乃り[1]、久手堅　剛[1]、宮城　綾乃[1]、山内　美幸[1]、喜屋武　向子[1]

1 沖縄県衛生環境研究所

＊責任著者：久場　由真仁

沖縄県衛生環境研究所

郵便番号 904-2241

沖縄県うるま市字兼箇段 17 番地 1

TEL: 098-987-8222

FAX: 098-987-8210

Email: kubayuma@pref.okinawa.lg.jp

SUMMARY

From February 14 to May 31, 2020, the Okinawa prefecture confirmed 142 cases of coronavirus disease (COVID-19). Among them, 78 were the first cases of a household, with 174 household contacts. Of the 174 contacts, 21 contracted infection, indicating a secondary attack rate of 12.1% (95% confidence interval (CI) 7.6–17.9%). No significant differences were observed in the demographics and quantitative reverse transcription polymerase chain reaction (qRT-PCR) test results between first cases who became the source of infection to the household members or not. The secondary attack rates per various characteristics of the household members were significantly different: aged > 69 years (40.9% [95% CI 20.7–63.6%]) and those with underlying diseases (36.0% [95% CI 18.0–57.5%]). When the period from the onset to the isolation of the first household case was within 3 days, the secondary attack rate was low (4.5% [95% CI 0.1–22.8%]). Among the 21 secondary cases, 11 (52.4%) developed within 5 days from symptom onset in the first case within the same household. This indicates that secondary infection within the household occurred immediately after symptom onset in the first case. Thus, isolation of a suspected patient is a solution to reduce secondary household infections.

In late 2019, severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), which causes the coronavirus disease (COVID-19), was identified in patients with pneumonia in Wuhan, China (1). In Japan, the first COVID-19 case was reported on January 14, 2020 (2), and the virus quickly spread nationwide (3). In response, the Japanese government declared a state of emergency and implemented

strong countermeasures, including mobility limitations, school closures, and discontinuation of social events and activities, from April 7 to May 25, 2020 (4). In the Okinawa prefecture, Japan, the first COVID-19 case was confirmed on February 14, 2020; subsequently, 142 patients were confirmed by May 31, 2020.

Closed environment contributes to the secondary transmission of SARS-CoV-2 (5); the transmission of SARS-CoV-2 has largely occurred in families (6). However, few studies have characterized the epidemiological features and risk factors of household transmission in Japan. To understand the characteristics of secondary household transmission of SARS-CoV-2, we conducted a cohort study of household transmission in Okinawa, Japan, from February 14 to May 31, 2020.

A COVID-19 patient is defined as an individual tested positive by quantitative reverse transcription polymerase chain reaction (qRT-PCR) using N2 primers, following the national PCR testing guideline (7). All six public health centers (PHCs) in Okinawa prefecture performed an epidemiological investigation and collected the demographic, clinical, and behavioral information of patients. The first case within a household was defined as the individual who developed relevant symptoms (fever, cough, or other respiratory symptoms) first in the household. Household contact was defined as an individual who resided in the same house as the first case from 2 days before symptom onset to isolation. The health conditions of the close contacts were followed up for 14 days by PHC staff, and if symptoms of COVID-19 were noted, clinical specimens (throat swab, nasopharyngeal swab, and/or sputum) were collected and tested using qRT-PCR. To compare the characteristics and qRT-PCR results between demographic groups, we performed Fisher's exact test or Mann-Whitney U test. The

secondary attack rate was defined as the proportion of infected household contacts among all household contacts. The risk ratio compared the secondary attack rate with the reference category and the corresponding 95% confidence intervals (CI) were calculated for different attributes. All statistical analyses were performed using EZR (8), which is a graphical user interface for R.

A flow diagram of household transmission of SARS-CoV-2 is shown in Figure 1. Of the 142 COVID-19 cases, 78 were first cases. Among 174 household contacts of the first cases, 41 developed symptoms and underwent qRT-PCR, and 21 showed positive results. These 21 secondary cases contracted SARS-CoV-2 from 18 of the 78 first cases.

The demographic characteristics and qRT-PCR results of the first cases are compared in Table 1. There were no significant differences in sex and age distribution between the first cases who did and did not become the source of infection in households (infectious and non-infectious first cases). No significant differences were observed in the clinical symptoms and proportion of underlying diseases between the two groups. The most common underlying diseases were hypertension, cardiovascular disease, respiratory disease, and diabetes. Families with two members were the most common household composition (approximately 40%). The median period from symptom onset to specimen collection and qRT-PCR test results (positivity rate and Ct value) showed no significant difference between the two groups.

The overall secondary attack rate among household contacts was 12.1% (95% CI 7.6–17.9%). The secondary attack rates according to household contact characteristics are shown in Table 2. The attack rates were the highest among those aged > 69 years (40.9% [95%CI 20.7–63.6%]) and significantly

higher than the reference group, i.e, aged 10–19 years (risk ratio, 7.98 [95% CI 1.89–33.68]). The attack rate among the first case's children was the lowest 4.2% (95% CI 0.9–11.7%) among other family members. The higher attack rate was observed among household members with underlying diseases compared to those without underlying diseases (risk ratio, 3.03 [95%CI 1.44–6.38]). The most common underlying diseases in household members were similar to those in the first cases among households (data not shown). The secondary attack rate was 4.5% (95% CI 0.1–22.8%) in households with the first cases isolated within 3 days of symptom onset.

There were no significant differences in the demographics and qRT-PCR results between the infectious and non-infectious first cases (Table 1). However, comparing the secondary attack rates among households with different characteristics indicated that elderly individuals aged >69 years and those with underlying diseases had a high risk of developing COVID-19 (Table 2). A systematic review showed that the household secondary attack rate was 16.6% (95% CI, 14.0–19.3%), and was increased in adult contacts compared that in child contacts (9). Our results indicated that a large proportion of the SARS-CoV-2 transmission among households occurred between spouses, which is similar outcome with previous report (10), or from the first adult cases to their parents. There were no first cases aged <20 years, the age group with lower secondary attack rate as well in this study. School closures during the study period may have contributed to this result. A previous contact survey in China showed that school closure and social distancing significantly reduced the rate of COVID-19 among school-aged children (11). In addition, as previous report suggested, children index cases may have limited roles in household transmission (12).

As 52.4% (11 of 21 cases) of household secondary cases developed within 5 days after symptom onset in the first case, secondary infections were likely to occur in the early stage of symptom onset in the first cases. In a previous report, the secondary attack rate among household contacts exposed within 5 days of symptom onset in the first case was higher than that after 6 days (13). Prompt isolation of household first cases is necessary to prevent transmission among family members.

Our study had several limitations. First, we did not conduct qRT-PCR tests for asymptomatic close contacts; therefore, we might have underestimated the number of asymptomatic cases. Although the proportion of asymptomatic secondary cases were less than that of symptomatic secondary cases (14), further study is required to elucidate the role of asymptomatic cases during SARS-CoV-2 transmission in household setting. Second, even with thorough investigation at local PHCs, there is a chance that patients with detected secondary infections may have been infected by external exposure.

In conclusions, in addition to how rapidly the first case is isolated from household members, the risk of the first case infecting their household depends on the characteristics of the contacts. Age, underlying diseases, and the relationship with the first case could be the risk factors for household transmission of SARS-CoV-2. In households having members with risk factors, the first cases should be immediately isolated to prevent the transmission of SARS-CoV-2 in household settings.

ACKNOWLEDGEMENTS

The authors thank the staff at PHCs, hospitals, and Okinawa prefectural government office who vigorously worked to control the COVID-19 outbreak and contributed to data collection. We also

thank Drs. Hajime Kamiya and Tomimasa Sunagawa of National Institute of Infectious Diseases for their technical support.

Conflict of interest

None to declare.

REFERENCES

1. Zhu N, Zhang D, Wang W, et al. A Novel Coronavirus from Patients with Pneumonia in China, 2019. N Engl J Med. 2020;382(8):727-33.
2. Ministry of Health, Labour and Welfare. The first case of novel coronavirus infection in Japan. Tokyo. Abailable at <https://www.mhlw.go.jp/stf/newpage_08906.html> Accessed October 28, 2020. In Japanese.
3. National Institute of Infectious Disease. Descriptive epidemiology of 516 confirmed cases of novel coronavirus infection reported by the national epidemiological surveillance of infectious diseases (NESID) system and active epidemiological surveillance (as of March 23, 2020). Available at <https://www.niid.go.jp/niid/en/2019-ncov-e/2484-idsc/9555-covid19-14-200323-e.html> Accessed October 28, 2020.
4. Cabinet Secretariat, Government of Japan. Japan's Response to the Novel Coronavirus Disease: Declaration of a State of Emergency. Available at <https://corona.go.jp/en/> Accessed October 28, 2020.

5. Nishiura H, Oshitani H, Kobayashi T, et al. Closed environments facilitate secondary transmission of coronavirus disease 2019 (COVID-19). medRxiv. Preprint published online April 16, 2020.

6. World Health Organization. Report of the WHO-China Join Mission on Coronavirus Disease 2019 (COVID-19). February 16-24, 2020. Available at < https://www.who.int/publications/i/item/report-of-the-who-china-joint-mission-on-coronavirus-disease-2019-(covid-19)> Accessed February 17, 2021.

7. Shirato K, Nao N, Katano H, et al. Development of Genetic Diagnostic Methods for Detection for Novel Coronavirus 2019 (nCoV-2019) in Japan. Jpn J Infect Dis. 2020;73(4):304-7.

8. Kanda Y. Investigation of the freely available easy-to-use software 'EZR' for medical statistics. Bone Marrow Transplant. 2013;48(3):452-8.

9. Madewell ZJ, Yang Y, Longini IM Jr, et al. Household transmission of SARS-CoV-2: A systematic review and meta-analysis. JAMA Netw Open. 2020;3(12):e 2031756.

10. Li W, Zhang B, Lu J, et al. The characteristics of household transmission of COVID-19. Clin Infect Dis. 2020; ciaa450.

11. Zhang J, Litvinova M, Liang Y, et al. Changes in contact patterns shape the dynamics of the COVID-19 outbreak in China. Science. 2020;368:1481-6.

12. Kim J, Choe YJ, Lee J, et al. Role of children in household transmission of COVID-19. Arch Dis Child. 2020: archdischild-2020-319910.

13. Cheng HY, Jian SW, Liu DP, et al. Contact tracing assessment of COVID-19 transmission dynamics in Taiwan and risk at different exposure periods before and after symptom onset. JAMA

Intern Med. 2020;180(9):1156-63.

14. Carroll C, Conway R, O'Donnell D, et al. Routine testing of close contacts of confirmed COVID-19 cases – national COVID-19 contact management programme, Ireland, May to August 2020. Public Health. 2021;190;147-51.

Figure legends

Fig.1. Flow diagram of COVID-19 first cases and close contacts in the household setting in Okinawa prefecture, Japan, from February to May 2020.

Table 1. The characteristics of 78 COVID-19 first cases among household.

Characteristics, n. (%)	Total number n=78	Source of infection to household contact n=18	Not source of infection to household contact n=60	p value
Sex (male)	53 (67.9)	15 (83.3)	38 (63.3)	0.15
Age, median (range)	51.5 (20-83)	54 (21-82)	49.5 (20-83)	0.54
<10	0 (0)	0 (0)	0 (0)	
10-19	0 (0)	0 (0)	0 (0)	
20-29	10 (12.8)	1 (5.6)	9 (15.0)	
30-39	6 (7.7)	3 (16.7)	3 (5.0)	
40-49	20 (25.6)	2 (11.1)	18 (30.0)	
50-59	11 (14.1)	5 (27.8)	6 (10.0)	
60-69	15 (19.2)	2 (11.1)	13 (21.7)	
>69	16 (20.5)	5 (27.8)	11 (18.3)	
Symptom				
fever (≧37.5℃)	69 (88.5)	17 (94.4)	52 (86.7)	0.68
upper respiratory tract symptom	28 (35.9)	6 (33.3)	22 (36.7)	1
cough	48 (61.5)	13 (72.2)	35 (58.3)	0.41
Underlying disease				
with	36 (46.2)	9 (50.0)	27 (45.0)	0.79
hypertension	16 (20.5)	4 (22.2)	12 (20.0)	
cardiovascular disease	8 (10.3)	3 (16.7)	5 (8.3)	
respiratory diseases	7 (9.0)	3 (16.7)	4 (6.7)	
diabetes	7 (9.0)	2 (11.1)	5 (8.3)	
dyslipidemia	3 (3.8)	1 (5.6)	2 (3.3)	
hyperuricemia	2 (2.6)	1 (5.6)	1 (1.7)	
kidney disease	4 (5.1)	0 (0)	4 (6.7)	
malignant tumor	3 (3.8)	0 (0)	3 (5.0)	
other	2 (2.6)	1 (5.6)	1 (1.7)	
without	41 (52.6)	9 (50.0)	32 (53.3)	1
unknown	1 (1.3)	0 (0)	1 (1.7)	1
Household size				
2	31 (39.7)	8 (44.4)	23 (38.3)	0.79
3	17 (21.8)	6 (33.3)	11 (18.3)	0.20
4	18 (23.1)	1 (5.6)	17 (28.3)	0.06
>4	12 (15.4)	3 (16.7)	9 (15.0)	1

The period from onset to isolation, median (range)	7 (0-18)	6.5 (3-12)	7 (0-18)	0.74
0-3	8 (10.3)	1 (5.6)	7 (11.7)	
4-5	18 (23.1)	6 (33.3)	12 (20.0)	
6-7	21 (26.9)	4 (22.2)	17 (28.3)	
8-9	14 (17.9)	3 (16.7)	11 (18.3)	
>9	17 (21.8)	4 (22.2)	13 (21.7)	
The period from onset to specimen collection, median (range)	5 (0-16)	4 (1-10)	5 (0-16)	0.39
0-3	20 (25.6)	4 (22.2)	16 (26.7)	
4-5	26 (33.3)	8 (44.4)	18 (30.0)	
6-7	13 (16.7)	2 (11.1)	11 (18.3)	
8-9	11 (14.1)	3 (16.7)	8 (13.3)	
>9	8 (10.3)	1 (5.6)	7 (11.7)	
Positivity rate (%) *				
throat swab	27/31 (87.1)	9/9 (100)	18/22 (81.8)	0.30
nasopharyngeal swab	37/42 (88.1)	10/10 (88.9)	27/32 (84.4)	0.31
sputum	39/41 (95.1)	8/9 (88.9)	31/32 (96.9)	0.40
Ct value in qRT-PCR, median (Interquartile range) *				
throat swab	25.3 (20.6-31.9)	23.7 (19.8-30.8)	26.7 (21.9-35.8)	0.30
nasopharyngeal swab	24.4 (20.0-28.2)	25.6 (21.0-29.1)	22.8 (19.9-28.0)	0.78
sputum	24.6 (20.0-32.9)	22.6 (19.7-26.1)	24.6 (20.3-35.3)	0.24

*Because 6 of 60 non-infectious source cases were genetically tested outside our laboratory, 6 cases were excluded from the qRT-PCR results.

Table 2. Secondary attack rate for COVID-19 among the 174 household contacts by different characteristics.

	Number of secondary cases n=21	Total number of household contacts n=174	Secondary attack rate, % (95% CI)	Risk ratio (95% CI)	P value
Sex					0.16
male	5	70	7.1 (2.4-15.9)	1 [ref.]	
female	16	104	15.4 (9.1-23.8)	2.15 (0.83-5.61)	
Age, median (range)	62 (14-83)	31 (1-97)			< 0.01
<10	0	17	0	0	
10-19	2	39	5.1 (0.6-17.3)	1 [ref.]	
20-29	0	16	0	0	
30-39	3	9	33.3 (7.5-70.1)	6.50 (1.27-33.37)	
40-49	3	15	20.0 (4.3-48.1)	3.90 (0.72-21.08)	
50-59	2	16	12.5 (1.6-38.3)	2.44 (0.38-15.84)	
60-69	2	12	16.7 (2.1-48.4)	3.25 (0.51-20.67)	
>69	9	22	40.9 (20.7-63.6)	7.98 (1.89-33.68)	
unknown	0	28	0	0	
Relationship with first case					0.02
parent	5	24	20.8 (7.1-42.2)	1 [ref.]	
spouse	12	53	22.6 (12.3-36.2)	1.09 (0.43-2.74)	
child	3	72	4.2 (0.9-11.7)	0.20 (0.05-0.78)	
sibling	1	10	10.0 (0.3-44.5)	0.48 (0.06-3.61)	
other	0	15	0	0	
Household size					0.03
2	8	31	25.8 (11.9-44.6)	1 [ref.]	
3	7	34	20.6 (8.7-37.9)	0.79 (0.33-1.94)	
4	1	54	1.9 (0.05-9.9)	0.07 (0.009-0.55)	
>4	5	55	9.1 (3.0-20.0)	0.35 (0.13-0.98)	
Underlying disease					<0.01
without	12	101	11.9 (6.3-19.8)	1 [ref.]	
with	9	25	36.0 (18.0-57.5)	3.03 (1.44-6.38)	
unknown	0	48	0	0	
The period from symptom onset to isolation of first case, median (range)	7 (3-12)	7 (0-18)			0.95

0-3	1	22	4.5 (0.1-22.8)	1 [ref.]
4-5	7	36	19.4 (8.2-36.0)	4.28 (0.56-32.48)
6-7	4	44	9.1 (2.5-21.7)	2.02 (0.24-16.84)
8-9	5	37	13.5 (4.5-28.8)	2.97 (0.37-23.83)
>9	4	35	11.4 (3.2-26.7)	2.51 (0.30-21.06)

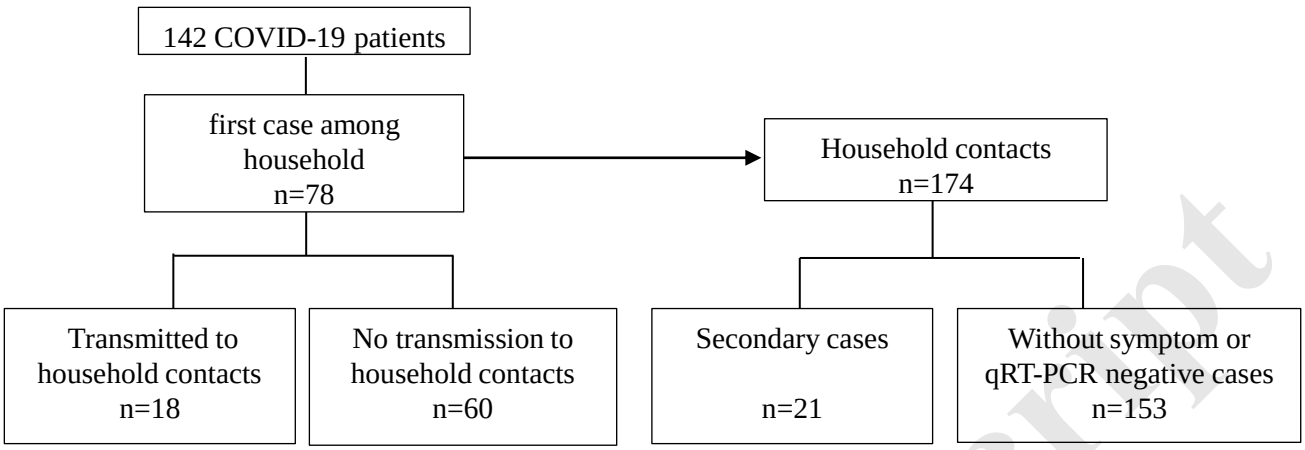

Fig. 1.