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Dynamics of transmission of COVID−19 cases and household contacts: A prospective cohort study

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ABSTRACT

Objective: To study the transmission dynamics of coronavirus disease 2019 (COVID-19) among 101 confirmed cases and their 387 household contacts and to determine risk factors associated with secondary attack among the household contacts.

Methods: A prospective cohort study was conducted from January 1st 2021 to February 28th 2021, among 101 SARS-CoV-2 cases and 387 household contacts who were followed up for 14 days from the last day of contact with the index case of COVID-19. The dynamics of disease transmission was estimated, and factors affecting transmission risk were analyzed. Besides, the association between various factors and household secondary attack rate was determined.

Results: The median incubation period was found to be 5 days, and the observed reproductive number (R) was found to be 1.63 (95% *CI*: 1.28-1.98). The mean household secondary attack rate was 40.7%. Contacts with comorbidities like diabetes mellitus, hypertension, dyslipidemia, and hypothyroidism had significantly higher attack rates ($P<0.05$).

Conclusions: As new variants of SARS-CoV-2 emerges, it is crucial to know the trasmission dynamics. This study shows a high secondary attack rate of COVID-19 among household contacts that must be closely monitored.

KEYWORDS: Dynamics; Transmission; COVID-19; Kerala; Prospective cohort

1. Introduction

The coronavirus disease (COVID-19) pandemic continues to spread globally[1]. It has been reported in more than two hundred countries and territories, causing millions of deaths. Given the overwhelming influence of the disease, COVID-19 was declared a pandemic on March 11st, 2020, by the World Health Organization[2]. On 30th January 2020, the first case of COVID-19 was reported in our city, Thrissur, India from a student who returned from abroad[3]. Since then, the disease has spread to over 93 611 176 people and caused 2 004 431 deaths across the globe[4]. The symptoms of COVID-19 are fever, tiredness, cough, sore throat, breathing difficulty, loss of smell, runny nose, or diarrhea[5]. Since the emergence of the disease, there was a swift response from the scientific community

Significance

As new variants of SARS-CoV-2 with varied transmission dynamics emerges, it is vital to identify the COVID-19 cases early and trace their primary contacts meticulously. This study would help not only to curb the spread of disease, but also to provide estimates of the median incubation period, serial interval, observed reproductive number and secondary attack rate.

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worldwide, attempting to fathom out its major epidemiological and clinical characteristics. A variant of SARS-CoV-2 with a D614G substitution in the gene encoding the spike protein lineage known as B.1.1.7 emerged in late October 2020 in U.K. Studies in human respiratory cells and animal models demonstrated that compared to the initial virus strain, the strain with the D614G substitution has increased infectivity and transmission[6].

It may be remembered that the Spanish flu, yellow fever, *etc.* could be controlled with public health approaches, though not eradicated. Understanding the epidemiology of communicable diseases could help develop appropriate public health strategies in a way that facilitates control measures more rapidly and effectively. Thus, studying the pattern and magnitude of the spread of communicable diseases contributes to strategy development.

The natural history and dynamics of transmission of this new wave of COVID-19 can be studied if the cases are identified early and the primary contacts are meticulously traced. Although studies have been done in this domain of COVID-19, emerging variations in the genetic characteristics of the virus and subsequent variations in the transmission dynamics as evidenced by high transmission rates of the second wave of the pandemic in India demand ongoing region-specific research. A carefully designed follow-up study of COVID-19 cases and their high-risk primary contacts would help provide estimates of the median incubation period, serial interval, observed reproductive number, and secondary attack rate specific to our region. Here, we traced 101 COVID-19 cases and their 387 high-risk household contacts, from January 2021 and followed them up to March 2021 to determine the dynamics of transmission of the second wave of COVID-19 and to describe its clinical-epidemiological characteristics.

2. Patients and methods

2.1. Study design and patients

A prospective cohort study was conducted from January 1st 2021 to March 31st 2021 among confirmed cases of COVID-19 and their household contacts.

All patients who attended our hospital with symptoms suggestive of COVID-19 or having a history of contact with confirmed SARS-CoV-2 cases from January 1st, 2021 to February 28th, 2021 were tested for SARS-CoV-2 either by real-time RT PCR (TeqPath COVID-19 CE-IVD RT-PCR kit, Thermo fisher scientific, USA) or Rapid Antigen Test (Meriscreen COVID-19 antigen detection test kit, Meril Diagnostics, India). A confirmed case is defined as a clinical suspect with positive detection of SARS-CoV-2 nucleic acid by real-time RT-PCR or qualitative detection of SARS-CoV-2 antigen using rapid immunochromatographic assay test (COVID-19 antigen detection test). Confirmed cases were categorized as category A, B, or C according to the clinical categorization guidelines by the directorate of health services, the government of Kerala[7], and were isolated and treated in hospital or advised home isolation as per the clinical category.

2.2. Ethical approval

The study is approved by the Institutional Ethics Committee of Jubilee Mission Medical College and Research Institute, Thrissur, Kerala, India (39/21/IEC/JMMC&RI).

2.3. Contact tracing and epidemiological investigation

The household primary contacts of the index case were identified through contact tracing. Household contacts were defined as family members who live in the same house and had interacted with the index case from 48 h before symptom onset to the day the index case is isolated. The contacts were followed up for a period of 14 d from the last day of contact with the index case for any symptoms suggestive of COVID-19. Those contacts that developed symptoms and found to be COVID-19 positive were further followed up for two more weeks.

2.4. Study tools and data collection

Data was collected using a structured interview schedule consisting of questions on demographic and clinical details of index cases and their household contacts. The dynamics of COVID-19 transmission among the contacts was studied by closely monitoring the confirmed cases and their close household contacts for the development of symptoms.

Based on the close follow-up of all the household contacts of each index case, the incubation period was calculated as the time interval between the last day of contact with the index case and the appearance of the first symptom of COVID-19. Serial interval is calculated as the time interval between symptom onset in the index cases and their infected contacts. The household secondary attack rate was calculated as the percentage of household contacts that were later confirmed to have SARS-CoV-2 infection. The observed reproductive number (R) of COVID-19 was calculated as the mean number of secondary cases caused by each index case.

2.5. End points

Primary end points: To estimate the median incubation period, serial interval, observed reproductive number, and secondary attack

rate of COVID-19.

Secondary end point: To determine risk factors associated with secondary attack among the household contacts.

2.6. Statistical analysis

Data were coded and entered into Microsoft Excel and analyzed using IBM SPSS version 25. Qualitative data are expressed as frequency and proportion and quantitative data as the median and interquartile range (IQR). The association between various factors and household secondary attack rate was analyzed using *Chi*-square tests and binary logistic regression method.

3. Results

From January 1st, 2021, to February 28th, 2021, we identified 101 index cases and their 387 household contacts. The majority of the index cases were females (77.23%), but there were a higher proportion of males (52.97%) among household contacts. For the median age (interquartile range) of the study population, index cases, and household contacts were 32 (19-52), 33 (27-41), and 32 (15-55) years respectively. Adults (18-65 years) comprised the maximum proportion of the index cases (97%) and household contacts (60.7%). Among the index cases, 89% were employed, and among the contacts, 72.9% were unemployed (Table 1).

Among the 387 household contacts of the index cases, 165 (42.6%) tested positive for SARS-CoV-2; Among them, 77 (46.6%) were females, and 88 (53.3%) were males. Only 4.95% of index cases were asymptomatic, whereas, 23.64% were asymptomatic among household contacts. The early symptoms among index cases were fever (41.7%), myalgia (13.5%), headache (12.5%), rhinitis (10.4%), sore throat (5.2%), fatigue (4.2%) and loss of smell and taste (4.2%). The early symptoms in household contacts were fever (56.3%), cough (9.5%), headache (9.5%), sore throat (8.7%), myalgia (5.6%), fatigue (1.6%), rhinitis (63%) and loose stools (1.6%) (Figure 1).

The median incubation period (time taken for 50% of the household contacts to develop symptoms following exposure to the index case) was found to be 5 d (95% *CI*: 4.45-5.55). Serial interval (time interval between symptom onset in the index cases and their infected contacts) was found to be 3 d (95% *CI*: 2.45-3.55). The proportion of cases who developed symptoms of SARS-CoV-2 by days after infection is depicted in Figure 2.

The observed reproductive number (R) was calculated using individual level contact tracing of the 101 index cases, and it was found to be 1.63 (95% *CI*: 1.28-1.98). The mean household secondary attack rate was 40.7%. In 40 households none of the close contacts were tested positive for COVID-19, whereas in 27 households, all the close contacts were tested positive (Figure 3).

Children below the age of 5 years and individuals in the age group of 18-65 showed similar attack rates (44.9% and 45.1%, respectively) (Figure 4).

Contacts with comorbidities like diabetes mellitus, hypertension, dyslipidemia and hypothyroidism had significantly higher attack rates (Table 2). There were 37 households with household secondary attack rate more than 50%. Households which consisted of two or more members in the vulnerable age group (<10 years and above 60 years) were categorized as high risk households. It was observed that the attack rate was similar in both groups (Table 3).

The COVID-19 positive cases and contacts were followed up for a period of 14 d after their Rapid Antigen test turned negative for the presence of any persisting symptoms. Among them, 24 (14.5%) complained about persistence of symptoms. The most common persisting symptom was anosmia [5 (20.8%)] and [myalgia 5 (20.8%)], followed by fatigue, headache and cough.

Table 1. Socio-demographic characteristics and clinical profile of the index cases and primary contacts.

Variables	Index cases (*n*=101)	Primary contacts (*n*=387)
Age, *n* (%)		
≤5	1 (0.99)	49 (12.66)
5-18	1 (0.99)	62 (16.02)
18-65	98 (97.03)	235 (60.72)
>65	1 (0.99)	41 (10.59)
Gender, *n* (%)		
Male	23 (22.77)	205 (52.97)
Female	78 (77.23)	182 (47.03)
Occupation, *n* (%)		
Employed	90 (89.11)	105 (27.13)
Unemployed	11 (10.89)	282 (72.87)
COVID−19 positive, *n* (%)		
Symptomatic	96 (95.05)	126 (76.36)
Asymptomatic	5 (4.95)	39 (23.64)
Comorbidities, *n* (%)		
DM	7 (6.93)	42 (10.85)
HTN	3 (2.97)	38 (9.82)
Hypothyroid	9 (8.91)	10 (2.58)
CHD	1 (0.99)	6 (1.55)
Asthma	0 (0.00)	7 (1.81)
Dyslipidemia	3 (2.97)	6 (1.55)
Chronic kidney disease	1 (0.99)	3 (0.78)
Pregnant	4 (3.96)	1 (0.26)
Others	0 (0.00)	8 (2.07)

DM: Diabetes mellitus; HTN: Hypertension; CHD: Coronary heart disease.

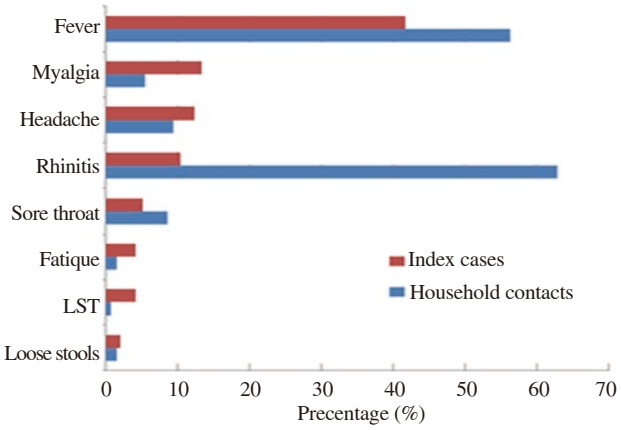

Figure 1. Early symptoms of index cases and primary contacts. LST: Lost of smell and taste.

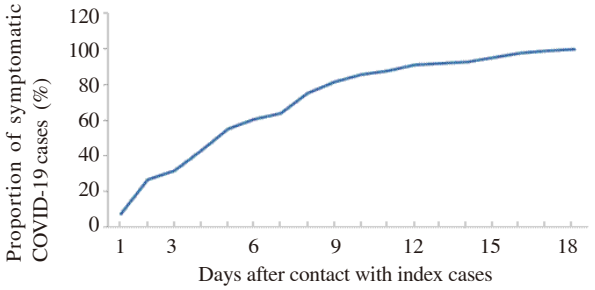

Figure 2. The proportion of cases who developed symptoms of SARS-CoV-2 by days after infection.

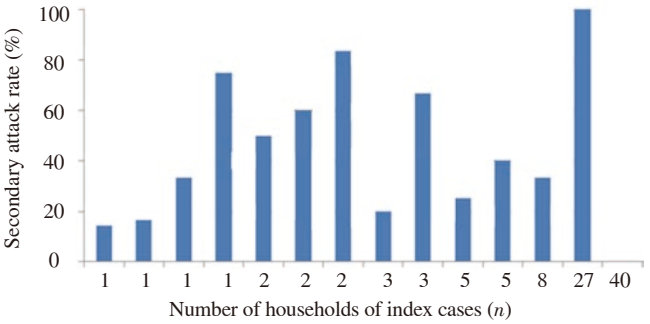

Figure 3. Secondary attack rate among the household contacts.

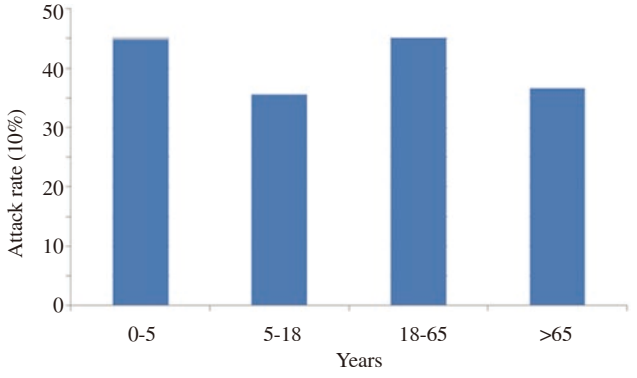

Figure 4. Attack rate among household contacts by age group.

Table 2. Secondary attack rate and its risk factors among primary contacts.

Variables	Total	Attack rate, *n* (%)	*OR*	95% *CI*	*P*
Gender					
Female	182	77 (42.31)	Reference		0.902
Male	205	88 (42.93)	1.026	0.685-1.536	
Age					
⩽5	49	22 (44.90)	Reference		0.458
5-18	62	22 (35.48)	0.708	0.303-1.655	
18-65	235	106 (45.11)	1.049	0.461-2.385	
⩾65	41	15 (36.59)	0.702	0.354-1.393	
Diabetes mellitus					
No	345	141 (40.87)	Reference		0.044
Yes	42	24 (57.14)	1.929	1.009-3.687	
Hypertension					
No	349	143 (40.97)	Reference		0.045
Yes	38	22 (57.89)	1.981	1.005-3.904	
Hypothyroidism					
No	377	156 (41.38)	Reference		0.002
Yes	10	9 (90.00)	12.75	1.599-101.662	
Coronary artery disease					
No	381	164 (43.04)	Reference		0.195
Yes	6	1 (16.67)	0.265	0.031-2.287	
Bronchial asthma					
No	380	164 (43.16)	Reference		0.126
Yes	7	1 (14.29)	0.220	0.026-1.841	
Dyslipidemia					
No	381	159 (41.73)	Reference		0.004
Yes	6	6 (100.00)	2.396	2.128-2.698	
Chronic kidney disease					
No	384	163 (42.45)	Reference		0.398
Yes	3	2 (66.66)	2.712	0.244-30.160	

Table 3. Household characteristics and secondary attack rate.

Variables	Secondary attack rate		χ^2	*P*
	≥50, *n* (%)	<50, *n* (%)		
Over crowding				
Yes	12 (35.29)	22 (64.70)	0.040	1.000
No	25 (37.31)	42 (62.68)		
Toilet				
Common	16 (40.00)	24 (60.00)	0.323	0.674
Separate	21 (34.42)	40 (65.53)		
Household risk				
High risk	15 (30.61)	34 (69.38)	1.487	0.223
Low risk	22 (42.30)	30 (57.69)		
Type of isolation of index case				
Home	19 (28.78)	47 (71.21)	5.050	0.025
Hospital	18 (51.42)	17 (48.57)		

4. Discussion

We did a prospective study to find out the transmission dynamics and epidemiological characteristics of COVID-19 among the cases and their household contacts from January to March 2021. In our study we traced 387 high risk contacts of the 101 index cases. As fever was the most common symptom, 41.7% of index cases and 56.3% of the primary contacts had history of fever. Other symptoms like Myalgia, headache, rhinitis, sore throat, loose stools were also reported. In a study by Bhandari *et al.*[8] cough was the most common symptom followed by fever, myalgia, headache and dyspnea. According to studies by Wang *et al.*, and Guan *et al.*[9,10], it was found that fever was the most common symptom which is consistent with our findings. In our study the median incubation period was found to be 5 d (95% *CI*: 4.45-5.55). In a meta-analysis study done by Quesada *et al*. they found the mean incubation period was 5.6 d, where the lowest value reported was 5.0 d which is consistent with our finding[11-13].

R0 represents the average number of people infected by one infectious individual. If R0 is greater than 1, it denotes the number of infected people is likely to increase and is an early warning signal for an epidemic or pandemic[14]. The observed reproductive number (R) in our study was calculated using individual level contact tracing of the 101 index cases and it was found to be 1.63 (95% *CI*: 1.28-1.98). According to recent reports, India's effective reproductive number, which is a measure of how fast an infection spreads, has dropped to 0.92, but shows a rise in the second wave of the pandemic due to the mutant strain. In studies done earlier, Zhao *et al.* estimated the mean basic reproduction number (R0) of SARS-CoV-2 to range between 2.24 and 3.58 and Imai *et al*. reported it is 2.6, in the early phase of the outbreak[15,16]. In a study done by Shah *et al.* they found out that secondary attack rate varies widely across countries with lowest reported rate as 4.6% and highest as 49.56% in India, consistent with our finding of the household secondary attack rate of 40.7%[17]. Thus, the rates may be immune from confounders such as population of the country, lockdown status and geographic location. The review also suggests greater vulnerability in spouse and elderly population for secondary transmission than other household members, and they also observed that quarantining and isolation are most effective strategies for prevention of the secondary transmission of the disease, and the symptomatic status of the index case is an important factor in determining the transmission probability[17]. A study by Jing *et al*. found out that SARS-CoV-2 was more transmissible in households than SARS-CoV and MERS-CoV, and elderly were most vulnerable for household transmission. It is not possible to contain the pandemic by case finding and isolation alone, but need to integrate with strict restriction of human movement[18]. In our study those households where index cases were isolated at home showed a significantly higher household secondary attack rate as compared to those who were isolated and treated in hospitals. This result implies that the patinets who were isolated at home need practice adequate social distancing and other preventive measures strictly at home and monitored periodically by government authorities.

We found out that those who have comorbidities like diabetes mellitus, hypertension, dyslipidemia and hypothyroidism had significantly higher attack rates than those who didn't have any comorbidity. According to the Health Ministry data, Government of India, while 53% deaths were reported among 60-year-old and above, 35% deaths were recorded in the age group of 45-60 years, 10% aged 26-44 years and 1% in the age group of 18-25 years and below 17 years. In the age group of 45-60 years, 13.9% had comorbidities and 1.5% had no comorbidity. Among the patients below 45 years of age, those with comorbidities accounted for 8.8% of the fatalities while 0.2% did not have any comorbidity.

The overall case fatality rate is 15 times higher in those with comorbidities. Several meta-analyses studies have reported the prevalence of comorbidities in patients with COVID-19[19-21]. In a study done by Singh *et al.*, recent meta-analysis that included 18 studies (n=14 558) from China, USA and Italy after carefully excluding the overlapped studies, have reported a prevalence of hypertension in 22.9%, diabetes in 11.5%, CVD in 9.7%, cancer in 3.9%, COPD in 3.1% in patients with COVID-19[22].

Being a single center study, the index cases included only those reported to our center with symptoms suggestive of COVID-19. In addition, only those contacts who undergone testing and provided information about their symptoms and other personal information to the contact tracing team were followed up. These factors could be considered as limitations against generalizations. Our hospital caters to low and middle socio-economic categories of patients, which could affect their household characteristics. This factor coupled with the closed study setting, might have resulted in an overestimation of secondary attack rate compared to population level estimates.

SARS-CoV-2 is continuing to spread across the globe in an alarming state. Thus, it is crucial to expand our knowledge about the transmission dynamics of this disease. Prospective studies with data on meticulous contact tracing and identification of source of infection are useful for estimating critical values such as incubation period and observed reproductive number. These estimates are expected to provide inputs for setting up public health policies and interventions to curb further spread of the disease.

Conflict of interest statement

The authors report no conflict of interest.

Authors' contributions

The project was conceptualized by P.R.; The literature searches and data collection were performed by P.R. and P.J.; The manuscript was written by P.R., P.J. and J.A.T.; Data management and analysis was done by J.T. and U.U.G.; The manuscript was critically reviewed and edited by L.R., S.K. and P.K.

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