



Review Article

# Secondary Attack Rate of COVID-19 in Non-Household Contacts - A Systematic Review of Global Studies

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## A B S T R A C T

**Objective:** Secondary Attack Rate (SAR) of COVID-19 varies across various populations. We aim to assess global articles reporting SAR in non-household contacts of COVID-19 patients through systematic review approach.

**Methods:** Four databases - MEDLINE, SCOPUS, Google Scholar and EMBASE were systematically searched for retrieval of articles reporting SAR of COVID-19 in various contacts. Initial search provided 436 articles, which through series of evaluation finally yielded 14 articles.

**Result:** Findings suggested that SAR in various contacts varies widely. Substantial number of studies (50%) were from China; however, the two largest studies were from India. Irrespective of type of contacts, overall SAR ranged from 0.55-6%. Highest risk was found from non-household close (family, friends) contacts (2.2-22.31%) followed by casual contact (travel, meal and health-care contacts). In spite of prolonged contact with the patients, SAR was lowest in health-care workers (0-7.3%). Review highlighted that the included studies were suffering from limitations of missing data and continuously evolving operational guidelines.

**Conclusion:** The review showed that studies furnishing SAR data in non-household contacts are limited in number and exact mode of transmission is yet not clear. Six-percent of overall SAR indicates that though the disease is infectious in nature and proper precautions must be taken, not everybody that comes in contact with the index case is infected. However, with greater risk in non-household close contacts, it is important to identify vulnerable population and implement effective preventive strategies in them. Review also indicated serious data gaps in the published literature and stipulated need of more global studies.

**Keywords:** Covid-19, Non-Household Contact, Secondary Attack Rate



## Introduction

In continuation to our previous review that studied Secondary Attack Rate (SAR) in household contacts,<sup>1</sup> current systematic review was planned to understand secondary transmission in non-household contacts of COVID-19 patients. The transmission trends of COVID-19 are still dynamic with multiple factors contributing to the SAR in different types of contacts. As stated by WHO understanding how, when and in what types of settings SARS-CoV-2 spreads between people is critical to develop effective public health and infection prevention measures to break chains of transmission.<sup>2</sup> And unlike household contacts where few systematic reviews are already published, epidemiological features of SAR in non-household contacts are sporadically reported. With global lifting of lockdowns and gradual start of economic activities, it is important to study disease transmission in non-household contacts, identify its determinants and categorize population at risk. This will have direct implication on infection control and preventive strategy that needs to be opted during this new normal time.

Primarily COVID-19 transmission occurs through contact with respiratory droplets of infected symptomatic cases.<sup>3</sup> Some of the early reports stated that close contact with a positive case within one meter and for prolonged period of time increases risk of secondary transmission in gym, travel, workplace and meal contacts.<sup>4,5</sup> In medical settings airborne transmission is suspected due to variety of aerosol generating procedures. With this review, we aimed to extract information from globally published peer-reviewed studies regarding secondary transmission in non-household contacts of COVID-19 such as health care workers, travel contacts, family members and other close relatives (not sharing the same household), and meal contacts.

## Methods

### Search Strategy

The systematic review was conducted using the recommended method for systematic reviews and reporting based on Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA). The “Cochrane Handbook for Systematic Reviews of Interventions” was followed for planning and conducting the review.<sup>6,7</sup> Though studies reporting non-household SAR were selected for review, if mentioned, details of household SAR were also extracted from the studies.

### Search Strategies and Selection Criteria

For identifying eligible articles, MEDLINE (through PubMed and CENTRAL) database was used. Search strategy was designed using keywords related to COVID-19 and secondary transmission. The key terms used were (“SARS-CoV-2” OR

“COVID- 19” OR “Coronavirus”) AND (“secondary attack rate” OR “close contacts” OR “contact transmission”). After initial search in MEDLINE, Google scholar, EMBASE and SCOPUS was also explored to identify relevant articles along with the reference list of all the included articles. Articles published between December 2019 to 2<sup>nd</sup> August 2020 were screened by two reviewers using title and abstracts evaluation. After that, screened articles were assessed using full text evaluation by four independent reviewers. Any discordance between the authors were settled by discussion and any difference of opinion arose was resolved through mutual consensus. Articles published in English language were included in the study. Other language articles were also included if summary in English was available.

Screening for duplicates removal and eligibility were conducted after initial search. Studies with missing data regarding SAR, population profile, number of included participants were excluded from the analysis. The articles meeting inclusion and exclusion criteria were finally selected for the systematic review and data regarding individual studies were extracted in excel. Thirty percent of the extracted data was validated by one of the reviewers before evidence synthesis. The flow chart of the screening and study selection is provided as PRISMA Figure 1.

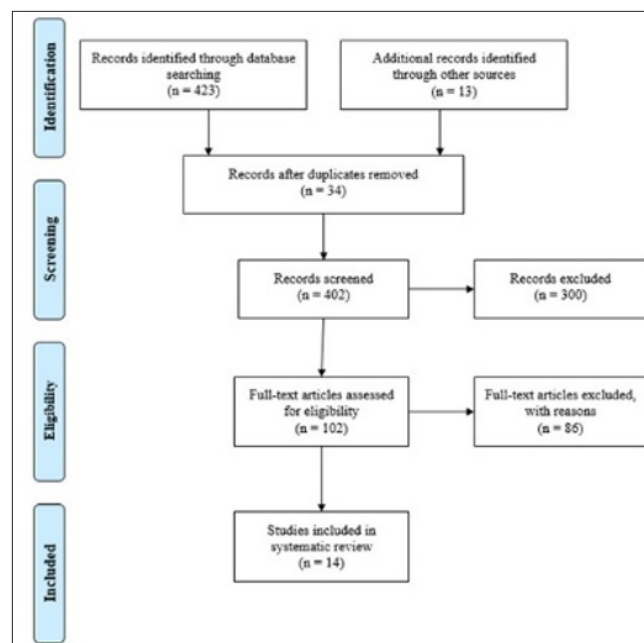


Figure 1. PRISMA diagram of included studies

### Data Extraction and Data Synthesis

Data extraction was completed using a predefined tool and an excel matrix. The matrix was filled by six reviewers where same excel was used to avoid error. All six reviewers extracted the data and two of them verified it. Information regarding authors, country, study duration, time of patient enrolment, type of primary contact, number of primary and

secondary cases, type of secondary cases, SAR in various types of contacts, key features and limitations of study were extracted from each article.

## Result

After initial screening of 436 articles through series of evaluation between December 2019 and August 2020, 14 articles<sup>5,8-20</sup> reporting SAR in all contacts of COVID-19 cases

were included in the review. We did not include articles assessing SAR exclusively in household contacts as it was already reported by the authors during previous work and by others as well. The scope of the review was restricted to the contacts other than household that included casual contacts, workplace and healthcare workers contacts. The systematic review included 14 articles reporting SAR in various countries and population.<sup>8-23</sup>

**Table I. Characteristics of the studies included in the systematic review**

S. No.	Author	Title	Country	Number of contacts	Number of Primary case	Type of contacts	Study duration
1.	Abraham et al., 20208	Laboratory surveillance for SARS COVID-2 in India: Performance of testing and descriptive epidemiology of detected COVID 19	India	1021518	40184	All contact	22 <sup>nd</sup> January-30 <sup>th</sup> April 2020
2.	Bi et al., 20209	Epidemiology and transmission of COVID-19 in 391 cases and 1286 of their close contacts in Shenzhen, China: a retrospective cohort study	China	1286	391	Close contacts	Jan 14 to Feb 12, 2020
3.	Chen et al., 202010	Epidemiological analysis of infection among close contacts of novel coronavirus pneumonia in Ningbo	China	2147	157	Family members, friends and medical staff	January 21 to March 6, 2020
4.	Cheng et al., (a) 202011	Contact Tracing Assessment of COVID-19 Transmission Dynamics in Taiwan and Risk at Different Exposure Periods Before and After Symptom Onset	Taiwan, China	2761	100	Contact with household, family, and health care	January 15 to March 18
5.	COVID-19 National Emergency Response Center <sup>3</sup>	Coronavirus Disease-19: Summary of 2,370 Contact Investigations of the First 30 Cases in the Republic of Korea	Republic of Korea	2370	30	All contacts	24 <sup>th</sup> January - 10 <sup>th</sup> March
6.	Draper et al., 202012	The first 2 months of COVID-19 contact tracing in the Northern Territory of Australia, March April 2020	Australia	445	28	Cruise ship passengers, household contacts, aircraft passengers, healthcare workers	1 <sup>st</sup> March and 30 <sup>st</sup> April 2020

7.	Haung et al. <sup>13</sup>	Estimation of the secondary attack rate of COVID-19 using proportional meta-analysis of nationwide contact tracing data in Taiwan	Taiwan, China	3795	32	Close-contact during meal, household or travel environments	April 8 <sup>th</sup> , 2020
8.	Kwok et al., 202014	Epidemiological characteristics of the first 53 laboratory-confirmed cases of COVID-19 epidemic in Hong Kong, 13 February 2020	Hong Kong	206	24	Close contacts	13-Feb-20
9.	Laxminarayan et al., 202015	Epidemiology and transmission dynamics of COVID-19 in two Indian states	India	64031	33584	All contacts	April 1 <sup>st</sup> to 4 <sup>th</sup> June
10.	Luo et al.,202016	Contact Settings and Risk for Transmission in 3410 Close Contacts of Patients With COVID-19 in Guangzhou, China	Guanghou, China	3410	391	Close contacts	13 January and 6 March 2020
11.	Macartney et al., 202017	Transmission of SARS-CoV-2 in Australian educational settings: a prospective cohort study	Australia	1448	27	All contacts	Jan 13 to May 1, 2020
12.	Shen et al., <sup>18</sup>	A Cluster of Novel Coronavirus Disease 2019 Infections Indicating Person-to-Person Transmission Among Casual Contacts from Social Gatherings: An Outbreak Case Contact Investigation	USA	539	7	Close and casual contacts	Mid-January to early February 2020
13.	Wang et al., 202019	Basic epidemiological parameter values from data of real world in mega-cities: the characteristics of COVID-19 in Beijing, China	China	2902	602	Close contacts	Jan 1 <sup>st</sup> to Apr 3 <sup>rd</sup> 2020
14.	Wee et al., 202020	Containing COVID-19 outside the isolation ward: The impact of an infection control bundle on environmental contamination and transmission in a cohorted general ward	Singapore	45	28	Staff and patient close contacts	February 7 to May 7, 2020

Table 2. Secondary attack rate in different contacts of COVID-19 primary case

All contact		Non-household close contacts		Casual contacts		Health care workers	
Author	SAR (%)	Author	SAR (%)	Author	SAR (%)	Author	SAR (%)
Abraham et al., 2020	Unadjusted SAR -6%; Adjusted -3.9%	Bi et al., 2020	Meal contact - 8.6% (6.8-10.9)	Bi et al., 2020	Travel contact - 5.7% (3.6-8.8)	Chen et al., 2020	0%
Chen et al., 2020	6.15%	Chen et al., 2020	Friends/pilgrims (22.31%); Non-household family members (18.01%); Relatives (4.73%)	Draper et al., 2020	Travel contact - 4.3% (95% CI 0.5-14.8%)	Chen et al., 2020	0.9% (95 CI, 0.4%-1.9%)
Chen et al., 2020	0.7% (95% CI, 0.4%-1.0%)	Chen et al., 2020	Non-household family contact - 5.3% (95% CI, 2.1%-12.8%)	Chen et al., 2020	Multiple setting: 0.1% (95% CI - 0%-0.3%)	Draper et al., 2020	0%
COVID-19 National Emergency Response Center	0.55% (95% CI 0.31-0.96)	Kwok et al., 2020	Close contact - 11.7% (95% CI:7.61 to 16.8)	Laxminarayan et al., 2020	Community - 2.6% (1.6-3.9%); Travel contact - 80.8% (48.6-98.5%); Other multiple settings - 2.1% (0.4-4.4%)	Laxshminarayan et al., 2020	1.0% (0.0-5.4%)
Haung et al	0.88% (95% CI: 0.42% - 1.69%)	Shen et al., 2020	0.29%	Luo et al., 2020	Travel contact - 0.1 (0.0-0.4); Multiple setting - 13.0 (0.0-26.8)	Luo et al., 2020	1.0 (0.3-1.8)
Laxminarayan et al., 2020	6.0% (95% CI: 5.0-7.3%)	Wee et al., 2020	Close contact - 2.2%	Shen et al., 2020	0.60%	Wang et al., 2020	7.30%
Luo et al., 2020	3.72% (95% CI, 3.1% - 4.4%)			Wang et al., 2020	Other social contacts - 4.6%; Non-health care workers - 4.2%	Wee et al., 2020	0%
Macartney et al., 2020	0.012%	-	-	-	-	-	-
Wang et al., 2020	4.6% (95% CI: 4.0-5.3)	-	-	-	-	-	-

### Characteristic details of the Included Studies

As presented in Table 1, substantial number of studies have reported SAR from China (n=7, 50%) - the country from where the disease was originated. Two large studies assessing transmission trends in 10,21,518 and 64,031 contacts were published from India. Abraham et al<sup>8</sup> represented National statistics of SAR across all States of India whereas Laxshinarayan et al.,<sup>15</sup> studied disease transmission dynamics from two south Indian States. Studies were completed between the months of January to early June 2020, with varied sample size of the primary cases

(28 - 40184 laboratory confirmed cases). The studies have documented SAR in non-household family contacts, relatives, health care workers and close travel contacts.

### Secondary Attack Rate in Contacts of COVID-19

SAR in different types of contacts are presented in Table 2. It was observed that irrespective of type of contacts, overall SAR ranged from 0.55% to 6%. Highest risk was found non-household close contacts (2.2%-22.31%) followed by casual contact (travel, meal and health care contacts). In spite of prolonged contact with the patients, SAR was lowest in health care workers (0 - 7.3%). This could be

due to preventive measures implemented at healthcare settings. Travelling, meal and other casual contacts have showed varied degree of SAR (0.1%-22.31%). Only one study published by Laxshinarayan et al.,<sup>15</sup> showed very high SAR - 80.8% in travel contact. The authors used the data generated through public health surveillance activities undertaken by the Health and Family Welfare Department

of the Government of Tamil Nadu and the Department of Health, Medical and Family Welfare Department of the Government of Andhra Pradesh. However, detailed methodology regarding contact tracing and testing for calculating SAR in travel contacts could not be retrieved from the article. Hence, we excluded these findings from overall synthesis.

**Table 3. Key findings and limitations of the included studies**

S. No.	Author	Key findings	Limitations
1.	Abraham et al., 2020	<ol style="list-style-type: none"> <li>1) The secondary attack data was corrected for missing data using sensitivity analysis and it reduced from 6% to 3.9%. The corrected SAR was highest in Chandigarh (11.5%) and Maharashtra (10.6%).</li> <li>2) SAR in different state ranged from 0-11.5%.</li> <li>3) SAR analysis was different between groups with known versus unknown contacts. This might have contributed in variation in SAR.</li> </ol>	<ol style="list-style-type: none"> <li>1) For some variables such as patient category or date of symptom onset, the proportion of entries with missing data was high.</li> <li>2) Overall individual and system level variations need to be considered during analysis</li> </ol>
2.	Bi et al., 2020	<ol style="list-style-type: none"> <li>1) Household contacts and those travelling with a case were at higher risk of infection (odds ratio 6.27 [95% CI 1.49-26.33] for household contacts and 7.06 [1.43-34.91] for those travelling with a case) than other close contacts.</li> <li>2) Children were as likely to be infected as adults (infection rate 7.4% in children &lt;10 years vs population average of 6.6%).</li> <li>3) Reproductive number (R) was 0.4 (95% CI 0.3-0.5), with a mean serial interval of 6.3 days (95% CI 5.2-7.6).</li> </ol>	<ol style="list-style-type: none"> <li>1) Variation due to continuously evolving protocols and multiple level data collection.</li> <li>2) Implementation of contact tracing guideline hugely depended on local testing capacity and surveillance resources.</li> </ol>
3.	Chen et al., 2020	<ol style="list-style-type: none"> <li>1) Difference between infection rates in close contacts of confirmed cases and asymptomatic infections was not statistically significant.</li> <li>2) Among close contacts of different relationships, friends/pilgrims, family members, and relatives have higher infection rates.</li> <li>3) No infection occurred in close contacts of medical staff.</li> <li>4) Living with the case (13.26%), taking the same means of transportation (11.91%), and having dinner and entertainment (7.18%) were all-high-risk factors for infection. Cross-infection in the hospital diagnosis and treatment environment was 1.94%.</li> </ol>	
4.	Cheng et al., (a), 2020	<ol style="list-style-type: none"> <li>1) The attack rate was higher among the contacts whose exposure to index cases started within 5 days of symptom onset (1.0% [95% CI, 0.6%-1.6%]) compared with those who were exposed later (95% CI, 0%-0.4%).</li> <li>2) The contacts with exclusive pre-symptomatic exposures were also at risk (attack rate, 0.7% [95% CI, 0.2%-2.4%]).</li> <li>3) The attack rate was higher among household (4.6% [95% CI, 2.3%-9.3%]) and non-household (5.3% [95% CI, 2.1%-12.8%]) family contacts than that in health care or other settings.</li> <li>4) The attack rates were higher among those aged 40 to 59 years (1.1% [95% CI, 0.6%-2.1%]) and those aged 60 years and older (0.9% [95% CI, 0.3%-2.6%]).</li> </ol>	<ol style="list-style-type: none"> <li>1) No complete examination of contacts before the symptom onset of the index cases.</li> <li>2) Effect of household and non-household contact in early phases could not be separated out.</li> </ol>

5.	COVID-19 National Emergency Response Center, Epidemiology and Case Management Team, Korea Centers for Disease Control and Prevention	<p>1) Risk of symptomatic cases from transmission to contacts was low.</p> <p>2) The transmission of COVID-19 was significant among household contacts.</p> <p>3) Contact tracing relies on other concurrent aspects of the COVID-19 containment strategies such as investigating, classifying, tracking, and managing contacts by identifying the patient's route.</p>	<p>1) With increase in number of cases the control strategy has changed. Its impact has not been evaluated.</p> <p>2) Secondly, potential risk factors such as the characteristics of a household and other transmission routes were not assessed.</p>
6.	Draper et al., 2020	Transmission of COVID-19 to household contacts and close contacts from a cruise ship with known on-board transmission is detected.	In flight transmission was not evaluated
7.	Haung et al., 2020	<p>1) Low SAR in close contact environment.</p> <p>2) The low SAR of COVID-19 in Taiwan may result from the effective strategic approaches, including inspecting imported passengers with symptoms, monitoring quarantined individuals by government-issued cell phones, the efficient distribution of facial masks to people in need, and discouraging mass gathering.</p>	
8.	Kwok et al., 2020	<p>1) Pre-symptomatic transmission and containment delay, which in turn fosters symptomatic transmission, occurred during the early phase of the COVID-19 epidemic in Hong Kong.</p> <p>2) With a considerable containment delay and short serial interval, contact-tracing effectiveness may not be optimised to halt the transmission with rapid generations replacement.</p> <p>3) Transmission risk of social interaction and pivotal role of physical distancing in suppressing the epidemic was highlighted by the study.</p>	<p>1) Recall bias might have affected data accuracy.</p> <p>2) Unclear data reporting.</p> <p>3) Availability of insufficient information.</p> <p>4) Limited understanding on clinical characteristics of COVID-19.</p>
9.	Laxmi-narayan et al., 2020	<p>1) Reproduction numbers ranged from ~2-3 during in March. Reduction was observed after lockdown and social distancing.</p> <p>2) Substantial variation in individuals' likelihood of transmitting: no secondary infections were linked to 83% of cases whose contacts were traced.</p> <p>3) No difference in infection risk among contacts of infected children and adults.</p> <p>4) Equivalent transmission risk across ages.</p> <p>5) 50% of fatalities occurring within the first 5 days of testing - substantially shorter time to mortality.</p>	<p>1) Gaps in availability of contact tracing data.</p> <p>2) Lack of data on timing of exposure and symptoms onset in relation to testing dates.</p> <p>3) Varied sensitivity of RT-PCR might have misclassified some cases.</p>
10.	Luo et al., 2020	<p>1) Compared with the household setting, the secondary attack rate was lower for exposures in healthcare settings (1.0%; odds ratio [OR], 0.09 [CI, 0.04 to 0.20]) and on public transportation (0.1%; OR, 0.01 [CI, 0.00 to 0.08]).</p> <p>2) The secondary attack rate increased with the severity of index cases.</p> <p>3) Index cases with expectoration were associated with higher risk for secondary infection (13.6% vs. 3.0% for index cases without expectoration; OR, 4.81 [CI, 3.35 to 6.93]).</p>	<p>1) Potential recall bias regarding symptom onset among patients with COVID-19.</p> <p>2) Severity of index cases were not assessed at the time of exposure to contact.</p>

11.	Macartney et al., 2020	<p>1) Low incidence of attendance of children and staff members with COVID-19 at educational facilities.</p> <p>2) The use of enhanced surveillance and serological testing of close contacts within the educational setting contributed in preventive strategies.</p>	<p>1) Changing operational definitions might have contributed in the under/over interpretation.</p> <p>2) Inability to assess adherence to or the effect on transmission of recommendations regarding hygiene or physical distancing in educational settings, and these progressively increased in magnitude over the study period.</p>
12.	Shen et al.	<p>1) There was strong evidence of COVID-19 transmission to contacts outside of the immediate family members.</p> <p>2) COVID-19 is possibly transmitted more via a droplet mechanism rather than airborne as indicated by large difference between the SAR in casual and close contacts.</p> <p>3) COVID-19 prevalence continues to increase, the attack rate from casual contact between individuals with COVID-19 and susceptible individuals is critical to understanding further spread of the epidemic.</p> <p>4) COVID-19 can be transmitted through casual contact with a source patient at social events even in areas of fewer cases.</p>	<p>Compromised sensitivity of the diagnostic tests might have contributed in misinterpretation of some cases</p>
13.	Wang et al., 2020	<p>1) The household secondary attack rate of COVID-19 was slightly higher than SARS.</p> <p>2) Due to the atypical or unspecific presence of mild infection or asymptomatic infection, the family members had been fully exposed to cases before they were confirmed, and this increased the risk of infection among household close contacts.</p> <p>3) SAR of HCWs was relative higher than that of non-HCWs'.</p>	<p>1) Lost to follow up of some close contacts.</p> <p>2) Detailed information on exposure history as frequency, intensity, and duration for all cases was not available.</p> <p>3) The relationship between index cases and their quarantined close contact was not well recorded.</p>
14.	Wee et al., 2020	<p>An infection control bundle comprising infrastructural enhancements, improved PPE and social-distancing mitigated the risk of environmental contamination and transmission in a cohorted general ward setting.</p>	<p>1) Only symptomatic cases were included. As the diagnostic yield of PCR testing for SARS-CoV-2 is likely dependent on the quality of sampling.</p> <p>2) The viability of the virus found from environmental samples could not be ascertained.</p> <p>3) Inability to perform air sampling for index cases, as upon confirmation of COVID-19.</p>



## Key Features and Limitations of the Included Studies

Detailed information regarding trends and characteristics of transmission in various types of contacts were extracted from each study and is presented in Table 3. The summary of the findings can be listed as follows:

- SAR varies widely among various studies and various settings
- Friends, family, and relatives of index cases were having highest risk for SAR
- Travel contacts and other casual contacts such as community contacts were at relatively low risk with reported range of 0.1%-4.6%. Only one study showed very high (80.8%)<sup>15</sup> secondary transmission rate from travel contact
- All seven studies have clearly indicated very low SAR in health care workers
- SAR of health care workers (HCWs) was relative higher than that of non-HCWs'
- Contacts aged 40-59 and more than 60 years are more susceptible to secondary infection
- Containment policies, quarantining of positive and susceptible cases, wearing masks and contact tracing have significant impact on reduction in secondary infection.
- Frequency and duration of contact with primary case has close association with SAR. Exposure to primary case within 5 days of symptom onset has resulted in higher SAR as compared to exposure after 5 days
- Symptomatic or primary case with symptoms infected more contacts than cases without symptoms
- Mass gatherings and social events triggered more secondary infections even in case of fewer primary patients
- Attack rate from casual contact between individuals with COVID-19 and susceptible individuals is still unclear and needs to be explored further

Majority of the authors identified limitation in the study and have explicitly listed them down while interpreting the findings (Table 3). The commonly presented limitations were as follows:

- Almost all the studies have accepted the issue of data gaps and few of the investigators undertook sensitivity analysis to adjust the missing data bias
- With continuously evolving guidelines of testing, isolation and quarantining, there were several operational changes in studies that might have influenced analysis and actual statistics of SAR
- Testing of all the contacts was a main challenge faced by majority of the countries as contact tracing and surveillance hugely depend on countries, provinces and cities preparedness in terms of testing capacity

and surveillance capacity

- A significant proportion of contacts might be missed during pre-symptomatic phases and hence identification of source of infection (e.g. household, non-household) was also a challenge in them
- Recall bias was also an important possible confounder of SAR assessment as cases may have missed/forgotten to list all contacts
- Varied sensitivity of the diagnostic tools (70% sensitivity of RTPCR) might have underestimated secondary cases

## Discussion

The global review summarises findings from 14 different studies and reports that overall SAR of COVID-19 varies widely with multifactorial transmission trend. To the best of our knowledge, this is the first review reporting SAR in non-household contacts that included findings from close contacts such as family, friends and relatives as well as casual contacts such as travel, community and health care contacts.

Review yielded three important pieces of information regarding secondary transmission of COVID-19 in various contacts: 1) Overall SAR is relatively low, with some selected contacts being more vulnerable to secondary infection due to variety of reasons. Various studies when assessed SAR irrespective of contact type found that overall SAR ranges from 0.55-6.15%. This indicates that though the disease seems to be highly infectious in nature, majority of the secondary cases are contributed by particular type of contacts only. This also emphasises the need to relook at overall containment and quarantining strategies. 2) Non-household family members, relatives and friends of index cases are at highest risk of secondary infection due to similar reasons what we have observed in household contacts during our previous review. This might be due to lack of protective gears such as mask and greater contact time with the index cases.<sup>9</sup> These contacts did not share same household with the patients but due to their relation with the case it is expected that they might have frequent interactions with patients. This could be during both symptomatic and asymptomatic state of the index case. It reinforces the need to introduce specific contact tracing, screening and testing strategies for these contacts. Though this group had lower risk of secondary infection as compared to household contacts (reported SAR range: 5-50%), the review indicates that it contributes to the significant number of secondary cases. Hence after household contacts, these contacts are at higher risk of SAR. 3) Casual contacts are at lowest risk of SAR. Three studies reported transmission risk while travelling with a positive contact and it was found be ranging from 0.1%-5.7%. Firstly, due to global lockdowns very limited number of studies have reported this. However, the lower rate

could be explained by adequate protective and preventive measures implemented by various Governments. Wide use of mask, personal protective equipment, strict restriction on unnecessary travel and screening for any symptoms might have contributed for this lower secondary transmission in the travel contacts. Only one study identified transportation as high-risk exposure settings. Authors found that individuals who travelled in close (<1m) proximity to an index case in a shared conveyance were at the greatest risk of infection: this exposure was associated with 30.61 (23.03-40.75) fold higher risk than community exposure.

One of the important finding of the review is the low SAR in health care contacts in spite of multiple contacts with the patients. Several explanations can be proposed for this: 1) It is known that a positive case is most infectious 2 days prior to and 3 days after the symptom onset and during this phase the viral shedding is highest. As per operational guidelines of various countries mild and moderate cases during this phase are generally advised home quarantine. Hence, healthcare workers do not have much exposure to patients at this time. It is the severe cases at much later stage of infection are being treated at hospital set ups. 2) It might be also due to appropriate infection control measures, usage of personal protective equipment and following of disease prevention guidelines. 3) Due to familiarity with the treatment strategies and better awareness regarding signs and symptoms there might be some early intervention in this groups of contacts and hence lower reporting as well. However, these results should be evaluated with cautions as there are emerging grey literature reporting increased infection in health care workers and even documenting fatal outcomes in many.

Apart from these key observations, the included studies have mentioned some of the important limitations. The disease is continuously evolving and so is the scientific fraternity's knowledge regarding the disease. This has affected operational guidelines of respective country for contact tracing and testing on which SAR data was hugely dependant. Similarly, enormous amount of resources are needed to track and test all the contacts. Hence there was substantial gap in terms of contacts that has been tested. Majority of the studies have accepted the assumption that "not tested is not positive". Only few studies have conducted sensitivity analysis for adjustment of this assumption. In conclusion, the current report is one of the first systematic review providing important clue in understanding the secondary transmission trends in various contacts, although it might be just a tip of an iceberg with lot of information still needing to be explored.

## Conclusion

The review suggests that studies reporting SAR in non-household contacts are limited in number and exact mode

of transmission is yet not clear. It showed that the disease is infectious in nature and hence adequate precautions must be taken to prevent secondary transmission. However, it is important to note that not everybody that comes in contact with the index case is infected. It is recommended to identify vulnerable population and implement effective preventive strategies in them. However, SAR studies have some inherent bias that may have led to underestimation of the transmission in contacts.

**Conflict of Interest:** None

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