Original Article

Transmission Dynamics of COVID-19 and Utility of Contact Tracing in Risk Assessment of Health-Care Worker Exposure during COVID-19 Pandemic

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Abstract

Background: In the COVID-19 pandemic, the frontline health-care workers (HCWs) are at increased risk of acquiring infection either through household or workplace exposure. **Objectives:** To assess the risk of acquiring infection after COVID-19 exposure, we evaluated the effectiveness of a contact tracing assessment to identify the high-risk contacts. **Materials and Methods:** All HCW who tested COVID-19 positive in July 2020 were interviewed to do risk assessment based on their exposure, advised quarantine, and then followed up on day 14 for development of symptoms of COVID-19. **Results:** Contact tracing identified 2569 HCW contacts for 422 index positive cases, among which 1642 (63.9%) were contactable for follow-up. Among 1642 contacts, 12.97% developed COVID-19 symptoms within 14 days of the exposure. Household contacts comprising (142 out of 956, 14.9%) had a higher risk of becoming symptomatic than workplace contacts (71 out of 686, 10.3%) ([odds ratio 0.66 (confidence interval 0.49–0.89)]. Of these, 76.6% of the household exposure and 55.4% of significant workplace exposure were tested positive for COVID-19. **Conclusions:** Based on the risk assessment, we found that a HCW is likely to acquire infection at home rather than at the workplace, and hence, an appropriate quarantine policy can help decrease the transmission and mitigate staff shortage.

Keywords: Contact tracing, COVID-19, health-care workers, quarantine policy, risk assessment

Introduction

The World Health Organization declared that there was ongoing community transmission of COVID-19 in most of the countries during July and August 2020.[1] During a pandemic, there is an immediate threat to the safety of frontline health-care workers (HCWs) as there is an increased risk of exposure to COVID-19 cases in the hospital environment. Although protecting HCWs by providing appropriate personal protective equipment is a priority, sometimes exposure occurs during emergency clinical care or in the community where there is ongoing community transmission.[2]

While most of the studies published in the context of COVID-19 transmission dynamics are community-based transmission rates,[3,4] it is presumed that the risk to a HCW getting infected from a health-care setting is higher than from the community.[2] When there is significant exposure to a HCW at the workplace to a COVID-19 confirmed case, it would be ideal to quarantine the HCW to prevent further transmission to other HCWs and patients. However, quarantine of frontline HCWs leads to the shortage of skilled staff at a time when there is an increased need for HCWs, especially in an overburdened situation. Case investigation, contact tracing, and risk stratification are important to prevent cross-transmission of infections in health-care settings. In addition, contact tracing also helps in the passive assessment of PPE usage and infection control practices among HCWs. Even though routine testing of HCWs at frequent intervals is followed at certain hospitals,[5] we instead followed strict

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standard precautions and risk stratification of exposed HCWs and implemented quarantine measures from the beginning of pandemic due to nonavailability of diagnostic kits, lack of regulatory permissions to screen asymptomatic high-risk contacts, and cost associated with the routine screening of HCWs. In this study, we aimed to assess the risk of developing COVID-19 infection after exposure to a positive individual and to estimate the differences in the risk between a household contact and a workplace contact.

Materials and Methods

The study was approved by the institutional review board and ethics committee. The study was conducted in a 2600 bedded tertiary care hospital which included 892 demarcated COVID-19 beds with 10,600 HCWs. The HCWs who were tested positive for COVID-19 during July 2020 were included as participants. A dedicated contact tracing team obtained telephonic consent and collected information over the phone from COVID-19-positive HCWs and also from electronic medical records. A questionnaire with both open and closed-ended questions was used to determine the possible mode of acquisition of infection and exposure details in the 48 h preceding the onset of symptoms with household members and other HCWs. Then, the exposed HCW was contacted over the phone, assessed, and advised quarantine and/or COVID-19 testing.

Risk assessment criteria

Based on the World Health Organization (WHO) guidelines,[6] a significant contact was defined as anyone with the following exposures to the index HCW from 48 h before the onset of symptoms or 48 h before a positive result in case of asymptomatic individuals.

- Distance of <1 m with a COVID-19 confirmed patient
- Prolonged contact of >15 min with a confirmed COVID patient. An inadequate respiratory protection is defined by the absence of a surgical or N95 respirator during interaction with a COVID confirmed patient
- HCW who is a household contact of a COVID confirmed case.

Based on this risk assessment, all household HCW contacts were quarantined for 14 days. All workplace high-risk exposures were quarantined for 14 days, and low/no risk exposure was followed up on day 14 but not quarantined. If anyone was found to be symptomatic at the time of risk assessment, they were advised immediate COVID-19 testing.

Definitions of COVID-19

Confirmed COVID-19 infection: A person with RT-PCR confirmed COVID-19 infection.

Probable COVID-19 infection: A person with clinical signs and symptoms consistent with COVID-19 infection after workplace or household exposure.

In the initial phase of the pandemic, we were unable to perform COVID-19 testing for research purposes due to testing restrictions placed by national guidelines. Hence, the development of symptoms consistent with COVID-19 within 14 days from the last contact with the index HCW was used for analysis rather than actual results of COVID-19 test.

Statistical analysis

Fisher's exact test was done to measure the significance of association between variables in the contingency tables. Relative risk and odds ratio (OR) were calculated with a confidence interval to measure the strength of association between variables in contingency tables wherever appropriate. A $P < 0.05$ was considered statistically significant. All statistical analyses were done in R programming language.

Results

Figure 1 shows the exposure and test results of health-care workers contacts. The odds of becoming symptomatic were lower among workplace contacts [Table 1].

The odds of developing symptoms among workplace contacts with different types of exposures is given in Table 2. Overall, workplace contacts wearing a surgical mask with prolonged physical proximity, categorized as High risk exposure, had an increased odds of developing probable COVID-19 infection (OR: 1.83 (CI: 1.03–3.3).

We also assessed overall HCW test positivity during the study period and we found that 422 HCWs tested positive out of 2386 total positives for COVID-19. There were 228 females (54%) and 194 males (46%). The median age of the positive HCW was 33 years (interquartile range 27–42 years). The perceptions of a COVID-positive HCW regarding exposure details were questioned. Three hundred (75.4%) of them were found to work in non-COVID areas such as offices, non-COVID wards, and outpatient areas. Among the 422 HCWs, 43.36% (183/422) had a known history of exposure with a laboratory-confirmed positive person. 384 (97.2%) HCWs were symptomatic at the time of testing. The average time taken by the HCWs to undergo testing after becoming symptomatic was 2.3 days [Table 3].

Discussion

In this study, we noted that 12.97% of 1642 contacts had probable COVID-19 infection and 12.48% had confirmed COVID-19 infection within 2 weeks of their exposure. Of the 553 contacts tested voluntarily irrespective of their exposure, it was found that 25.49% (141/553) were symptomatic, 11.57% (64/553) were asymptomatic and confirmed to have COVID-19 infection. The proportion of contacts who developed symptoms was similar among households (142 out of 950, 14.9%) and those deemed to have high-risk exposures at the workplace (18 out of 122, 14.8%). Contacts who developed symptoms after a low-risk exposure at the workplace were significantly lower (48 out of 566, 8.5%, $P < 0.001$). A quarantine policy based on risk assessment minimizes the risk of workplace transmission of COVID-19 and avoids unnecessary quarantine of HCWs, thus ensuring

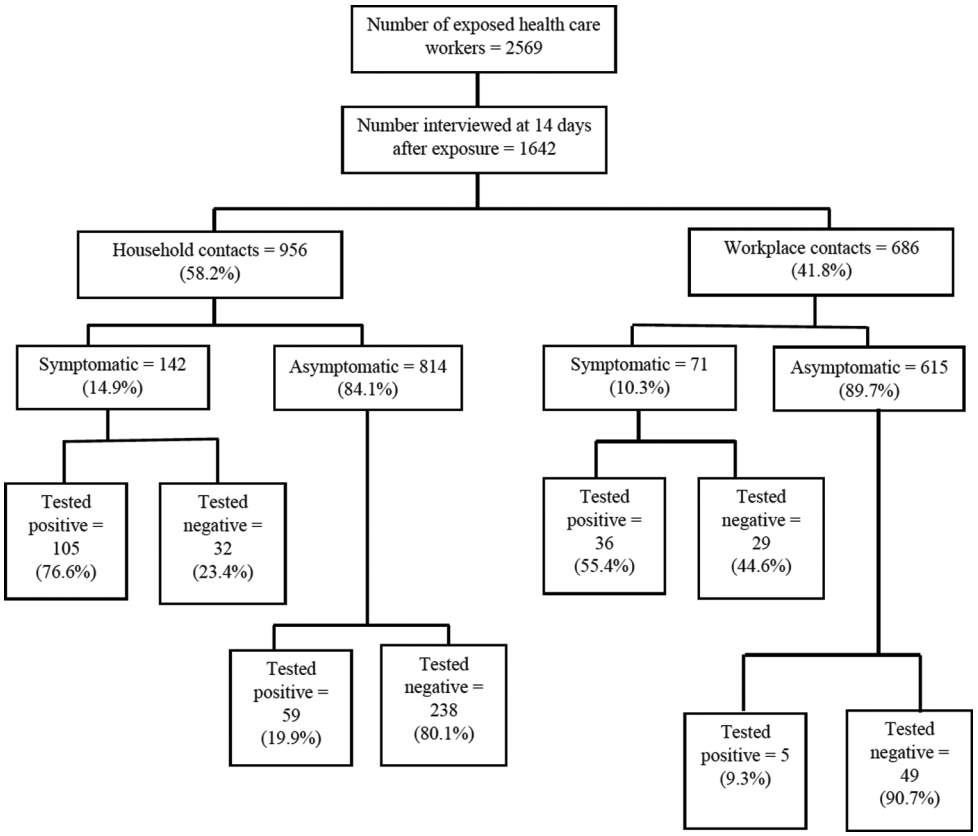

Figure 1: Flow diagram showing the exposure and test results of health-care workers contacts

Table 1: Relation of becoming symptomatic within 14 days of exposure by type of contact

Type of Contact	Symptomatic *n* (%)	Asymptomatic *n* (%)	OR
Household[#]	142 (14.9)	814 (84.1)	0.66 (0.49-0.89)
Workplace	71 (10.3)	615 (89.7)	

[#]Reference category, $P<0.05$

Table 2: Relation of Workplace Contacts becoming symptomatic within 14 days of exposure with various factors

Factors	Symptomatic *n* (%)	Asymptomatic *n* (%)	OR
Duration of Contact (*n*=449)			
<15 min[#]	29 (10)	262 (90)	0.88 (0.45-1.72)
>15 min	14 (8.9)	144 (91.1)	
Distance of Contact (*n*=509)			
>1m[#]	24 (7.6)	285 (92.4)	1.62 (0.89-2.94)
<1m	24 (12)	176 (88)	
Use of PPE			
N95 mask[#]	20 (9.85)	183 (90.15)	
Surgical mask with shield (*n*=584)	1 (5)	19 (95)	0.005 (0.001-0.041)
Surgical mask	12 (7.1)	157 (92.9)	0.52 (0.24-1.09)
No mask	21 (10.9)	171 (89.1)	0.98 (0.52-1.88)
Exposure risk* (*n*=680)			
Low[#]	48 (8.5)	510 (91.4)	1.83 (1.03-3.3)
High	18 (14.8)	104 (85.2)	

[#]Reference category, * $P<0.05$

an adequate number of HCWs to manage patients during the COVID-19 pandemic. A similar study conducted by Kaur *et al.,* 2020 was conducted among HCWs in India which showed that risk stratification avoids unnecessary quarantine.[7] However, the present study included only the HCWs who were the index cases and evaluated their household and workplace contacts at the risk of developing probable COVID-19 infection, based on the type of PPE used, distancing, and duration of exposure with the index case.

We found that the household contacts are at an increased risk of getting the COVID-19 infection. This could be due to various reasons such as prolonged exposure in closed spaces, with no use of masks at home, and sharing of objects and toilets. This finding is supported by Lei *et al.,* 2020 who found that the secondary attack rates (SAR) among household contacts were 10 times higher than other contacts (OR = 10.72, 95% CI: 5.70–20.17; $P < 0.001$).[8] The risk of developing an infection after a high-risk exposure at the workplace (10.3% CI: 8%–12.6%) was similar to a household exposure (14.9% CI: 12.6%–17.2%). Similarly, Laxminarayan

Table 3: Variables associated with coronavirus disease-2019-positive health-care workers index cases

Variables	*n* (%)
Mode of transport used by the index HCW to the workplace (*n*=422)	
Motorbike (personal)	131 (31.04)
Bus (public)	44 (10.45)
Walk	23 (5.45)
Car (personal)	17 (4.03)
Auto rickshaw (public)	9 (2.12)
Multiple modes	198 (46.91)
Known history of contact with a laboratory-confirmed positive case before infection (*n*=422)	
Yes	183 (43.36)
No	125 (29.62)
Not sure	114 (27.02)
History of possible source of infection (index HCW perception) (*n*=422)	
Coworker	77 (18.25)
Household member	51 (12.08)
Patient	49 (11.61)
Not sure	245 (58.06)

HCW: Health-care workers

et al. 2020[9] analyzed the contact tracing and testing data from two Indian states (Tamil Nadu and Andhra Pradesh) during the peak of the first wave and found that the SAR in health-care settings was lowest at 1.2% (0.0%–5.1%) followed by 2.6% (1.6%–3.9%) in the community and highest among household contacts at 9.0% (7.5%–10.5%). We know from published literature[8-10] that household contacts are at increased risk of getting infected due to prolonged exposure in closed spaces with no use of masks at home and sharing of objects and toilets.

In our study, 97.2% of the symptomatic contacts and 24.7% of asymptomatic contacts were tested. Of these, 69.2% and 18.2% tested positive for SARS-CoV2, respectively. However, the latter is likely a gross underestimate as only a quarter of asymptomatic contacts could be tested. Our results for the asymptomatic contacts, i.e., 8.23% (64/553) was similar to the study by Grijalva *et al*., 2020[11] who reported an 18% (95% CI: 13%–24%) infection rate among asymptomatic household contacts in Tennessee and Wisconsin during April to September 2020. Their infection rates among symptomatic contacts were 36% (95% CI: 29%–43%) which was much lower than the 69.2% in our study. This lower rate of positivity in the study done by Grijalva *et al*. 2020 could be due to self-collection of respiratory samples by the patients.[11] A meta-analysis by Madewell *et al*., 2020 on household transmission has shown that symptomatic cases (19.9%; 95% CI: 14%–25.7%) lead to a significantly higher SAR than asymptomatic cases (0.7%; 95% CI: 0%–3.8%) ($P < 0.001$).[12] Hence, it is imperative to detect and quarantine contacts of symptomatic patients as their transmission potential is higher.

A subgroup analysis of the mode of exposure among HCW at the workplace, i.e., having lunch/coffee together, sharing the same office space, or speaking with a coworker in close range, led to only 10%–20% of the contacts developing symptoms during the 14-day follow-up period. This has been corroborated by Kaur *et al*. in their study as well where informal interactions while having snacks/meals together seemed to be one of the highest risk factors for nosocomial acquisition of COVID-19 infection.[7] As per the WHO[6] recommendations, our study confirmed that workplace exposure occurring at a distance of <1 m seemed to have a similar risk as a household contact. On the contrary, the duration of exposure whether it was less than or more than 15 min did not make a major difference in the risk of developing symptoms.

In the initial phase of the pandemic, there were no clear-cut contact tracing and quarantine protocols. Hence, these quarantine protocols were periodically assessed, and we found that wearing a surgical mask alone was found protective in non aerosol generating exposures. This study revealed that even with a prolonged duration of exposure or close contact with a positive individual, appropriate PPE in a workplace will prevent nosocomial transmission of infection. The stringent infection control practices and constant updates in the protocols based on an in-house evidence synthesis approach helped prevent HCW exposures in the workplace without compromising staff numbers.

Our study had few limitations. First, we were able to contact only around 64% of the contacts for a 2-week follow-up. However, we did have a reasonable denominator of household and workplace exposed employees to perform statistical analysis. Second, not all contacts had testing for SARS CoV-2 during the quarantine period or at the end of quarantine due to government testing restrictions in force at that time. Hence, we used the development of symptoms consistent with COVID-19 as the surrogate for COVID-19 infection in our analysis. Third, recall bias could have confounded some of the observations as our study relied on telephonic interviews.

Conclusions

Our study highlights the importance of contact tracing, especially in the health-care setting during COVID-19 pandemic. The transmission dynamics in our study showed that the household contacts are at an increased risk of getting the COVID-19 infection. Acquisition of infection at the workplace had very specific modifiable risk factors, and hence, nosocomial transmission can easily be controlled with educational interventions. A risk-based assessment and appropriate quarantine policy for HCWs is beneficial in decreasing transmission in the health-care setting and prevents unnecessary quarantine of staff, thereby preventing HCW shortage during the pandemic.

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Conflicts of interest

There are no conflicts of interest.

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