Original Research Article

A cross-sectional study of SARS-CoV-2 seroprevalence among asymptomatic healthcare workers in a tertiary healthcare centre: Assessing the impact of PPE guidelines

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ABSTRACT

Purpose: The present study estimates the seroprevalence of SARS-COV-2 among asymptomatic HCWs and assess the impact of various categories of PPE.

Methods: A cross-sectional study of asymptomatic HCW using different levels of PPE as per their risk profile was undertaken between 18th and 24th September 2020. Participant demographics and other relevant details including the levels of PPE used were recorded using a customized questionnaire. IgG antibodies against SARS-COV-2 were detected by chemiluminescence method & used as a surrogate marker for incomplete protection.

Results: Out of 1033 HCWs tested, overall SARS-COV-2 sero-prevalence was 25.8%. Univariate and multivariate analysis both demonstrated that ancillary workers including security staff (OR 5.589, P < 0.001) and sanitary workers (OR 3.946, P < 0.001) were at significantly higher risk of seropositivity irrespective of the PPE used as per guidelines, whereas doctors were at significantly lower risk of seropositivity (OR 0.307, P = 0.005). Staff working in office areas was associated with reduced risk of seropositivity (OR 0.21, P = 0.045).

Conclusions: We document high seroprevalence of SARS-COV-2 antibodies in asymptomatic HCWs. Doctors who are at the highest risk had the lowest seropositivity and seroprevalence among office staff having a risk level comparable to the general community was lower than that reported in general population, supporting the efficacy of PPE practices as per guidelines in these groups. In contrast, much higher rates of seropositivity were seen among ancillary workers despite the availability of adequate PPE. Active screening, proper PPE use as per guidelines, and regular infection control trainings including Covid appropriate behaviour are therefore essential to contain COVID-19 spread among HCW & preventing them to transfer infection to the patients.

1. Introduction

Personal protective equipment (PPE) is one of the main strategies to prevent SARS-CoV-2 transmission in HCWs. In spite of the use of PPE as per their risk profile as per International, National [1–3] and institution specific guidelines, HCW across the world have been disproportionately infected by SARS-COV-2. Improper or inconsistent use of PPE has been reported to be one of the factors associated with increased risk of COVID-19 infection among HCW [4].

A recent study from Italy has reported SARS-COV-2 PCR positivity ranging from 1.6% to 24.2% in asymptomatic & symptomatic HCW [5]. Asymptomatic or pre-symptomatic transmission is a reality in SARS-COV-2 infection and is estimated to account for around half of the cases of COVID-19 [6,7]. Antibodies to SARS COV-2 generally start appearing after two weeks of infection, and may last for several months. Though antibody based sero-assays may not be useful for detecting acute infection, they are important tool for assessing the level of exposure among hospital staff and identifying high-risk areas. Understanding the factors associated with SARS-COV-2 infection is important for protection of both the HCW and the patients. Depending upon the level of

seroprevalence of infection in HCW at different levels of risk of exposure, appropriate interventions can be planned and implemented for prevention and control of the disease among HCW.

The present study was performed to estimate the seroprevalence of SARS-COV-2 among asymptomatic HCWs using various categories of PPE as per the guidelines. Various risk factors that could result in their seroconversion in spite of using different varieties of PPE were also evaluated.

2. Methods

2.1. Design and setting

A cross-sectional seroprevalence study for SARS-COV-2 antibodies among asymptomatic HCW at a 675 bedded tertiary care hospital in New Delhi India that got converted into a hybrid hospital with predominately (80%) being Covid and rest as non-Covid. The study was undertaken between 18th - 24th September 2020 during the peak period of the first year of the pandemic which was approved by the institutional review board of the hospital.

2.2. Population

Asymptomatic HCW were divided into 3 categories: high risk, intermediate and low risk, depending upon their levels of exposure to SARS-COV-2 infected patients. The characteristics and the PPE worn by each category (as per the institution guidelines) are summarized in Table 1. The institutional guidelines were essentially based on the international and national guidelines [1–3] with few fortifications. The ancillary staff like sanitary workers posted in Covid areas were perceived to be at a high risk as per international guidelines therefore were provided with Type 3 PPE but they were perceived as at moderate risk as per national guidelines. Further the staff in administrative section in non-Covid areas were provided with surgical triple layer mask instead of a simple face cover. The latter was recommended as per national guidelines whereas no PPE was recommended as per the international guidelines.

At the time of enrollment, the sero-prevalence of COVID-19 infections in community in Delhi was reported to be around 23% [8]. Taking the community surveillance data, the required minimum sample size for estimating the said prevalence (0.23) was 254, with a precision (margin of error) of 5% and a confidence level of 95% for the finite population (number of HCW in the hospital: n = 3711). However no sero-prevalence data was available among HCW at the time when study was planned; hence, a targeted sample size of 400 per category of HCW was planned to be included in the study.

Exclusion Criteria: Symptomatic HCW and previously Covid RTPCR positive HCW were excluded from the study.

Randomised Selection of HCWs at all levels: Selection of eligible participants, meeting the inclusion criterion, was done through computerized random selection from each category of HCW to remove the bias in selection of population. Participants were informed about their enrollment in the study through staff e-mails.

2.3. Data collection

Temporary research stations were set up to collect data and blood samples in the Sample collection centres of the hospital. Data was collected via an in-house electronic data sheet created by the hospital computer data centre supported by the Hospital Information System (HIS). HCW were asked to present at the research stations, where after taking informed consent, they were asked to complete a brief questionnaire and then blood samples were drawn. Survey data included demographics; place of posting within 2 weeks of enrollment, levels of PPE used; medical history (including co-morbidities); any history of symptoms consistent with SARS-COV-2 infection like fever, cough, sore throat, myalgia since March 2020 or any history of exposure to SARS-COV-2 infected individuals and dates and results of any prior nucleic acid testing for SARS-COV-2.

Serology for SARS COV-2: Blood was collected by trained personnel at the hospital sample collection centres in plain vacutainers vials and was transported to the microbiology laboratory which is National Accreditation Board for Testing and Calibration Laboratories (NABL) accredited and Indian Council of Medical Research (ICMR) authorised Covid testing centre vide their number SGRH001. Samples were preserved at 2–8 °C for a maximum period of 7 days till testing was done.

IgG antibodies against SARS-COV-2 were detected using the VITROS Immunodiagnostic Products Anti-SARS-CoV-2 IgG test kit (Food and Drug Administration's Emergency Use Authorization) on chemiluminescent automated (CLIA) system (VITROS ECi/ECiQ/3600 Immunodiagnostic Systems and VITROS 5600/XT 7600 Integrated Systems, Ortho Clinical Diagnostics, USA). Results were calculated by the VITROS Systems, by using a ratio of signal of test sample over the signal at the cut-off value. Samples with a ratio of ≥ 1 were reported as Reactive and those with a ratio of < 1 were reported as Non-reactive.

2.4. Data analysis

Seroprevalence data was expressed as percentage positive. Characteristics of the seropositive and seronegative were compared using Student's t-test or Mann-Whitney U-tests for continuous variables and chi-squared tests for categorical variables. Statistical analyses were conducted using SPSS version 17. To identify potential factors associated with Covid 19 seropositivity univariate analyses were performed. Multivariate logistic regression model was used to identify independent risk factors for Covid 19 seropositivity. An enter approach was used to enter new terms into the model, with a limit of $p < 0.05$ to enter the terms. Statistical significance is considered to be at a p–value of <0.05.

Table 1
PPE protocol as per the Risk category in HCWs.

Risk Category of HCW	High Risk	Moderate Risk	Low Risk
	Staff working in designated COVID-19 areas, handling linen	Chambers of Dental/otolaryngology/Ophthalmology doctors	Staff working in non- COVID areas
	Involved in procedures that generate aerosols	Pre- anesthetic check-up clinic	Routine Sample collection and processing of routine (non-respiratory) samples
	Working in high risk areas (ICU, HDU, CCU, PICU, NICU, Cardiac Catheterization lab, Dialysis, BMT unit, stem cell wards, Delivery room)	Ward/ICU/Critical care (Non-COVID)	Imaging services, blood bank services etc. CSSD
	Involved in sample collection & processing from suspected COVID-19 patients.	Intra-partum care Labor ward: Doctors, nurses Surgeons & Anesthesiologists	Administrative, Financial, Engineering and dietary services,
	Handling & transport of SARI patients/COVID-19 bodies	Security staff in (ICU, HDU, CCU, PICU, NICU, Cardiac Catheterization lab, entrance gate of hospital)	
PPE Description	**Type 3**	**Type 2**	**Type 1**
	Shower cap, N-95 mask, Disposable overall/disposable gown with pyjama, gloves, 3 M goggles, face-shield, impervious shoe covers	Shower cap, N-95 mask, reusable cloth gown, gloves, face-shield, impervious shoe covers	Shower cap, surgical mask, reusable cloth gown, gloves, impervious shoe covers

ICU: Intensive Care Unit, HDU: High Dependency Unit, CCU: Coronary Care Unit, PICU: Pediatrics Intensive Care Unit, NICU: Neonatology Intensive Care Unit, BMT: Bone Marrow Transplant, SARI: Severe Acute Respiratory Infection, CSSD: Central Sterile Services Department.

3. Results

Between 18th – September 24, 2020, 1200 HCW workers were invited to take part in the study. 1054 (87%) gave consent, of which 21 were excluded as they were previously SARS-COV-2 PCR positive. Finally, a total of 1033 HCW were included in the study. The median age of the participants was 39 years, 545 (52.8%) participants were female and 488 (47.2%) were male and most (83.5%) reported no underlying co-morbidities (Table 2). Among 1033 enrolled HCW, 297 (28.8%) were nurses, 240 (23.2%) were doctors, 203 (19.7%) were sanitary workers, 89 (8.6%) were technical staff, 83 (8%) were administrative staff, 68 (6.6%) were ward boys and 53 (5.1%) were Security staff. As per their location of work, 129 (12.6%) reportedly worked primarily in Covid designated areas (45, 77 and 7 in Covid ICU, Covid ward and Fever clinic, respectively), 131 (12.7%) primarily in ICU, 426 (41.2%) in wards, 172 (16.6%) in OPD, 63 (6.1%) in Laboratories, 29 (2.8%) in Emergency Department, 23 (2.2%) in OTs 39 (3.8%) in Office areas and 21 (2%) in other miscellaneous areas. Percentage of participants using Type 1, 2 and 3 PPE were 32.7%, 32.6% and 34.7%, respectively (Table 2).

Among the 1033 participants, 267 (25.8%) had detectable SARS-COV-2 antibodies. Seropositivity was significantly lower among females (20.9%) than among males (31.4%), ($p < 0.001$) and among doctors (6.7%, p p < 0.001), technical staff (13.4%, p < 0.001) and nurses (17.8%, p < 0.001). Seropositivity was significantly higher among security staff (60.4%, p < 0.001), sanitary workers (55.42%, p < 0.001) and ward boys (41.2% p < 0.001). As per primary location of work,

seroprevalence was highest (though not statistically significant) among those working in Covid ICU (37.8%). On the other hand seroprevalence was significantly lower in Office areas (5.1%, p < 0.001) and laboratories (6.3%, p < 0.001) Table 2. Seropositivity rates were similar in participants with presence of any chronic medical condition to those without any chronic medical condition, i.e. 20.6% v/s 26.9% (p =0.087). Only 9 (0.9%) of the HCW gave a history of residing in the containment zones and there was no significant difference between seropositivity among HCWs residing in containment zones v/s those not residing in containment zones (p = 1.000). Table 2.

Seropositivity was higher in participants using Type 1 PPE than those using Type 2 or Type 3, but was not statistically significant (Table 2). As per their risk profile, doctors (37.5%) and nurses (54.9%) maximally used Type 3 PPE whereas most among the administrative staff (61.5%), ward boys (54.5%) and sanitary workers (57.2%) used Type 1 PPE (Table 3). Among each professional category of the participants, there was no effect of use of different levels of PPE on the seropositivity (Table 3).

Notably, out of the 267 participants with detectable antibodies, 228 (85.4%) did not give any history of previous exposure to COVID-19 and none of them reported any symptoms of any acute viral illness since March 2020. However, among HCWs with a definite history of exposure significantly higher numbers were seronegative (p = 0.034). Table 2.

Univariate and Multivariate analysis both demonstrated that security staff (OR 5.589, P < 0.001) and sanitary workers (OR 3.946, P < 0.001) were at significantly higher risk of seropositivity even when they had

Table 2
Univariate analyses to identify potential factors associated with COVID-19 seropositivity.

	n (%)	Seropositive, n (%)	Seronegative, n(%)	Seroprevalence (%)	p value
Total	1033	267	766	25.8	
Median Age	39 (20–89)	37 (23–69)	39 (20–89)		0.001
Sex					
Male	488 (47.2)	153 (57.3)	335 (43.7)	31.4	<0.001
Female	545 (52.8)	114 (42.6)	431 (56.2)	20.9	
Clinical Role					
Administrative Staff	83 (8)	14 (5.2)	69 (9.1)	16.8	0.051
Ward boys	68 (6.6)	28 (10.5)	40 (5.2)	41.2	0.003
Doctor	240 (23.2)	16 (6)	224 (29.2)	6.7	<0.001
Nurse	297 (28.8)	53 (19.8)	244 (31.8)	17.8	<0.001
Sanitary Workers	203 (19.7)	112 (41.9)	91 (11.9)	55.2	<0.001
Security	53 (5.1)	32 (12)	21 (2.7)	60.4	<0.001
Technical Staff	89 (8.6)	12 (4.5)	77 (10)	13.4	0.005
Primary location of clinical work					
COVID-19 ICU	45 (4.4)	17 (6.3)	28 (3.6)	37.8	0.062
COVID-19 ward	77 (7.5)	23 (8.6)	54 (7)	29.9	0.402
Emergency Department	29 (2.8)	10 (3.7)	19 (2.5)	34.5	0.281
Fever Clinic	7 (0.7)	2 (0.7)	5 (0.6)	28.6	1
ICU	131 (12.7)	25 (9.3)	104 (13.5)	19.1	0.058
Laboratories	63 (6.1)	4 (1.5)	59 (7.7)	6.3	<0.001
OPD	172 (16.6)	48 (18)	124 (16.2)	27.9	0.499
Offices	39 (3.8)	2 (0.7)	37 (4.8)	5.1	<0.001
OT	23 (2.2)	2 (0.7)	21 (2.7)	8.7	0.088
Other	21 (2)	3 (1.1)	18 (2.3)	14.3	0.004
Ward	426 (41.2)	130 (48.7)	296 (38.6)	30.5	0.618
PPE Type					
Type 1	338 (32.7)	98 (36.7)	240 (31.3)	29	0.107
Type 2	337 (32.6)	79 (29.6)	258 (33.7)	23.4	0.219
Type 3	358 (34.7)	90 (33.7)	268 (35)	25.1	0.705
Any History of Past exposure to SARS-COV-2					
History of exposure to SARS-COV-2	162 (15.7)	31(11.6)	131 (17.1)	19.1	0.034
Not sure	26 (2.5)	8 (3)	18 (2.3)	30.8	0 .562
No History of exposure	845 (81.8)	228 (85.4)	617 (80.5)	27.7	0.077
Any History of Co-morbidities					
History of Co-morbidities	170 (16.5)	35 (13.1)	135 (17.6)	20.6	0 .087
No History of Co-morbidities	863 (83.5)	232 (86.9)	631 (82.3)	26.9	0 .087
Any previous History of symptoms suggestive of COVID-19					
previous History of symptoms suggestive of COVID-19	5 (0.5)	0	5 (0.6)	0	0.336
No previous History of symptoms suggestive of COVID-19	1028 (99.5)	267 (100)	761 (99.3)		0.336
Residence in Containment zone					
History of Residence in Containment zone	9(0.9)	2 (0.7)	7 (0.9)	22.2	1.000
No History of Residence in Containment zone	1024 (99.1)	265 (99.2)	759 (99.1)	25.9	1.000

Table 3

Effect of PPE on sero-positivity in different professional categories.

Staff Category (n)	Type 1 PPE		Type 2 PPE		Type 3 PPE		p value
	Total (%)	Seropositive (%)	Total (%)	Seropositive (%)	Total (%)	Seropositive (%)	
Adminstrative Staff (83)	51 (61.5)	8 (15.7)	28 (33.7)	5 (17.9)	4 (4.8)	1 (25)	0.879
Ward boys (68)	37 (54.5)	13 (35.1)	13 (19.1)	5 (38.5)	18 (26.5)	10 (55.6)	0.344
Doctor (240)	68 (28.3)	2 (2.9)	82 (34.2)	4 (4.9)	90 (37.5)	10 (11.1)	0.091
Nurse (297)	24 (8.1)	3 (12.5)	110 (37)	18 (16.4)	163 (54.9)	32 (19.6)	0.61
Sanitary workers (203)	116 (57.2)	61 (52.6)	23 (11.3)	15 (65.2)	64 (31.5)	36 (56.2)	0.527
Security (53)	22 (41.5)	10 (45.5)	31 (58.5)	22 (71)	0	NA	0.061
Technical Staff (89)	20 (22.5)	1 (5)	50 (56.2)	10 (20)	19 (21.3)	1 (5.3)	0.125

Table 4

Multiple logistic regression model incorporating seropositivity as the dependent variable and age, sex, clinical role, location of work and history of exposure to SARS-COV-2 as independent variables.

	95% C.I.(Confidence Interval)		OR (Odds Ratio)	p value
	Lower	Upper		
Age	0.969	1.003	0.986	0.111
Sex(1)	0.72	1.673	1.629	0.702
Clinical Role				
Ward boys	0.995	5.441	2.326	0.051
Doctor	0.134	0.705	0.279	0.005
Nurse	0.319	1.386	0.665	0.276
Sanitary Workers	1.924	8.094	3.946	<0.001
Security	2.381	13.123	5.589	<0.001
Technical Staff	0.269	1.635	0.663	0.373
Laboratories	0.15	1.449	0.466	0.187
Offices	0.046	0.963	0.210	0.045
Wards	0.786	1.573	1.112	0.550
History of exposure to SARS-COV-2	0.45	1.144	0.718	0.163
Constant			0.461	0.098

used PPE used whereas doctors had significantly lower risk of seropositivity (OR 0.307, P = 0.005) than other professional category of HCW. (Table 4). Similarly personnel working in the office areas were also found to be associated with low seropositivity (OR 0.21, P = 0.045).

4. Discussion

The present cross-sectional study was performed in asymptomatic HCWs among a wide spectrum of professional categories, working across different areas in the hospital and using different levels of PPE based on the modified guidelines of the hospital were found to be adequate.

Overall, 25.8%, i.e. 267 of the HCWs were positive for anti SARS-COV-2 antibodies. Shields et al. [9] have reported similar SARS-COV-2 seroprevalence of 24.4% among asymptomatic HCWs. In contrast, Singhal et al. [10] reported much lower rate of 4.3% seropositivity among asymptomatic HCWs in a hospital in Mumbai, India in June 2020. The present study was performed later in September, when the pandemic was at its peak. Siddiqui et al. [11] also reported increasing SARS-COV-2 seroprevalence among HCW in a hospital at New Delhi from April (2.3%) to July (50.65%) with a cumulative seroprevalence of 16.5% and a seroprevalence of 23.5% in community which is quite similar to the seroprevalence in HCWs found in our study. Similar seroprevalence in HCW and community settings has also been reported in the USA [12,13] indicating that local epidemiology is important factor to consider when evaluating infection and transmission risks among HCW. HCW being a part of the general population do participate in social activities and gatherings, and are subject to similar risks as other members in the community in addition to the place of work. Among the HCW at our centre, seropositivity was more in men, a scenario which has been reported in other studies too [9,14].

None of the HCWs with positive SARS-COV-2 antibody could recall any symptoms consistent with an acute respiratory viral illness or any history of definite exposure to patients with Covid 19 disease. Other researchers have also reported such silent infections [15,16], re-emphasising that undetected COVID-19 infections in HCW may be a source of spread of the disease. This highlights the importance of universal screening of HCW.

Interestingly doctors who are at the highest risk by virtue of being in close contact with the COVID-19 patients had the lowest seropositivity supporting the efficacy of PPE practices in this group. Siddiqui et al. [11] in a study from another tertiary care centre in Delhi also reported low seroprevalence (10.2%) among doctors. Similar rates of seropositivity ranging from 5.6 to 10.8% have been reported from centres in USA, UK and Spain [15–17]. It is likely that a combination of measures including use of Type 3 PPE, training, adequate staffing levels, provision of dedicated space for donning and doffing in high risk areas may have contributed to lower risk of infection among doctors. It is also possible that doctors being most well informed are expected to use appropriate PPE and strictly following all guidelines and appropriate Covid behaviour.

We also found that personnel assigned to work in office areas were associated with significantly lowest risk of infection. The seroprevalence of 16.8% in this category of HCW was lower than 23% reported in general population despite having a risk level comparable to the general community. So the use of modified guidelines for PPE in this category of workers was perceived well and bore results. In contrast, much higher rates of seropositivity were seen among sanitary workers, security staff and ward boys than that reported in general population despite the availability of appropriate PPE. These findings indicate that education and behavioral patterns of the staff are very important factors associated with infection & seropositivity especially among this category of HCW apart from the provision of appropriate PPE. Lower rates of adherence to hand hygiene protocols have been reported among hospital cleaners [18]. Highest seroprevalence in housekeeping staff among the HCWs has been reported by Siddiqui et al. [11] and Schields et al. [9]. Higher rates of SARS-COV-2 infection have also been reported in outsourced ancillary HCWs including cleaning staff, security officers, and maintenance services compared to medical and nursing staff [19]. Eyre et al. [20] have also reported that porters and cleaners had the highest SARS-COV-2 infection rates among the HCW in a prospective observational study in the United Kingdom. Improper use of PPE and failure to follow social distancing norms have been found to be significant risk factors for transmission of SARS-COV-2 among HCW [21]. Hence, such staff should not be overlooked in infection prevention and control efforts. Having common lunch breaks at the place of work mostly in poorly ventilated spaces appears to be the most common mode of spread & seroconversion in HCW.

Another important fact is that the security staff and sanitary workers, on an average, live in small houses in semi-urban areas with increased crowding where social distancing is difficult to maintain. It has been reported that the higher the size of the household, the higher the odds of being seropositive, potentially because household exposure is an added source of infection among HCW [17].

The strength of our study was that subjects were recruited from the entire hospital workforce with different levels of risk of exposure provided with appropriate PPE had achieved protection when used appropriately reposing faith in our modified guidelines. We could also identify potential risk factors for acquiring infection despite near ideal conditions and find ways to limit the transmission by way of continuous awareness drives and rigorous employee trainings regarding appropriate use of PPE, especially among the lesser educated staff. Limitations of the study included its single centre setting, its Cross-sectional design wherein only association and no causation can be inferred and failure to do follow up serology in the same cohort which could help us better understand the dynamics and stability of SARS-COV-2 antibody response among HCW. It also created a scope to determine whether the infection among seropositive HCW was hospital acquired or community acquired thereby breaking the myth that HCW can get infection from their places of work only.

In conclusion, we document high seroprevalence of SARS-COV-2 antibodies in asymptomatic HCW, particularly among ancillary workers despite the availability of adequate PPE as per the guidelines due to their unsafe Covid behaviour. More studies are needed to better understand the risks and infection transmission in different healthcare settings. Determining such prevalence among HCW in healthcare settings across varied geographical areas may help in risk stratification, establish better policies and procedures to protect the HCWs and limit transmission across healthcare settings.

5. Declarations of interest

None.

Funding

None.

Ethics approval

The study was approved by the institutional review board of the hospital vide letter number EC/05/20/1691 dated 26th June 2020.

Consent to participate

Written informed consent was taken from each included individual.

Availability of material/data

The data supporting the findings of the study are available within the article.

CRediT authorship contribution statement

Chand Wattal: Conceptualization, Supervision, Writing – review & editing, Conception & design, supervision of the procedures, manuscript review. **Jaswinder Kaur Oberoi:** Data curation, Formal analysis, Data collection, compilation, analysis & intepretation, manuscript preparation. **Neeraj Goel:** Writing – review & editing, manuscript preparation & review. **Sanghamitra Datta:** Formal analysis, Writing – review & editing, Sample analysis, manuscript preparation & review. **Reena Raveendran:** Writing – review & editing, manuscript preparation & review. **Brijendra Kumar Rao:** Conceptualization, Conception & design. **Reena Kumar:** Conceptualization, Project administration, Conception & design, administrative support. All authors of this paper have read and approved the final version submitted.

Declaration of competing interest

None declared.

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