Original Research Article

PREVALENCE OF ACUTE SARS COV-2 INFECTION AMONG HEALTHCARE WORKERS AND THEIR ASSOCIATED RISK FACTORS IN A TERTIARY CARE CENTRE OF NORTH INDIA

ABSTRACT

Background: Study on the SARS COV-2 and its associated risk factors among the Health care workers who are being in the frontline of the SARS COV-2 pandemic are facing a substantial risk of infection from Corona-virus disease 2019 outbreak.

Study: Hospital-based cross-sectional study.

Place of Study: Postgraduate Department of Microbiology, Government Medical College, Srinagar, Kashmir.

Duration: One year.

Methodologies: This is a hospital-based cross-sectional study design conducted in the Department of Microbiology, Covid Lab, where the participants were the HCW's from GMC & associated hospitals along with many districts of Kashmir division suffering from acute respiratory infection suspected of COVID-19. All the participants provided information on demographic factors, medical history, and subsequently any COVID-19 symptoms along with the contact details before testing. And the test results for SARS-CoV-2 were obtained using real-time reverse transcription-polymerase chain reaction (rRT-PCR).

Results: Between March 2020 and March 2021, 7141 HCWs were tested for COVID-19 at Covid Lab, GMC Srinagar. A total of 913 (12.7%) HCW tested positive for Covid-19. Males 629 (68.8%) were affected more in comparison to females 284 (31.2%). The highest positivity was observed among the age group between 26-35 years of age 346 (37.8%) followed by 36-45 years 221 (24.2%). Among the positive 698(76.4%) were symptomatic. Doctors comprise a total of 533 (58.3%) of the total SARS COV-2 infected health care workers.

Conclusion: As apparent from the study, HCWs play a vital role in fighting the SARS-CoV-2 pandemic. The analysis along with the rapid and reliable access to testing of the infection status of HCWs is essential to preserve the health, safety, and availability of the healthcare workforce and to facilitate the rapid return of SARS-CoV-2 negative HCWs to work.

Keywords: SARS COV-2, pandemic, (RT-PCR), health care workers

INTRODUCTION:

Covid-19 is a pandemic of acute respiratory disease that was first detected and identified in a number of patients that presented with pneumonia of an unknown etiology in late December 2019 in Wuhan, China [1]. As of January 12th, 2020, the World Health Organization (WHO) named the disease Coronavirus disease 2019 (COVID-19). On 11th March 2020, WHO declared COVID-19 a pandemic [2]. In India, the first case was reported on 30th January 2020 [3]. Slowly, the pandemic spread to various states and union territories in India including the union territory of Jammu & Kashmir. On March 7th, A 63-year-old woman, who had a travel history to Iran, tested positive for corona-virus, making her the first confirmed case in Jammu and Kashmir [4]. As of 6th March 2021, the total number of positive cases in Jammu and Kashmir was 126932, including 882 active cases, 124089 cures, and 1961 deaths.[2] SARS-CoV-2 is a Betacoronavirus belonging to the family of Coronaviridae that infects humans and the disease presented mostly with fever, dry cough, dyspnea, fatigue, and myalgia. Other symptoms include diarrhea, nausea, vomiting, and new-onset anosmia or ageusia [5]. COVID-19 is transmitted efficiently from person to person through respiratory droplets, close contact, as was previously seen in severe acute respiratory syndrome Coronavirus (SARS-CoV) in 2003 and Middle East respiratory syndrome Coronavirus (MERS-CoV) in the 2014 outbreak [6,7]. In addition, elderly patients infected with COVID-19 with underlying comorbidities including hypertension, diabetes, cardiovascular disease, and cerebrovascular disease are more likely to have adverse outcomes. Moreover, a considerable proportion of around 80% of the SARS-CoV-2-infected individuals was able to transmit the infection even without any noticeable symptoms [8]. Meta-genomics sequencing of RNA samples isolated from bronchoalveolar lavage (BAL) fluid from the patients suffering from a severe acute respiratory illness (SARI) in the city of Wuhan, China identified a novel RNA virus as the causative pathogen.SARS-COV2 virion structure consists of four structural proteins, including spike(S) with S1 and S2 subunits, (E) envelope, (M) membrane, and (N) nucleoprotein that encapsulates the virus positive sense single-stranded genome (+ssRNA)[9,10,11]. It has been demonstrated that the isolated positive-sense single-stranded RNA had a genome size of 29.9 KB.[9,12] The SARS-CoV-2 genome contains 12 functional open reading frames (ORFs) expressing 12 proteins from 11 protein-coding genes. After entry of SARS-CoV-2 into host cells, the viral genome act as messenger RNA (mRNA) and is translated by host ribosomes. Sixteen non-structural proteins (NSPs) are encoded via two large polyproteins, pp1a/pp1ab, from the 5′ two-third end of the COVs genome. Two viral proteases named 3c-like protease and papain-like protease are responsible for processing these polypeptides to produce NSPs. Four structural proteins and accessory proteins are encoded by open reading frames (ORFs) from the 3′ one-third end of the genome form a set of nested sub genomic RNAs (sgRNAs) beginning from a negative-sense RNA intermediate. [13,14,15]. From December 2019 to October 30, 2021, more than 3,215,645 SARS-CoV-2 genomic sequences have been reported by different countries. Phylogenetic analysis of SARS-CoV-2 genomes showed that they are under evolutionary selection in the human host across different regions of the world [16].In India INSACOG (Indian SARS-CoV-2 Genetics Consortium), established on 30 December 2020,is the forum set up under the Ministry of Health and Family Welfare , to study and monitor genome sequencing and virus variation of circulating strains of COVID-19 . [17,18, 19]

Healthcare workers (HCWs) are at the front-line of the COVID-19 outbreak, and their constant occupational exposure to infected patients and contaminated surfaces can put them at risk of acquiring and transmitting the infection [20].
Overall multiple factors contributing to the risk of infections in HCWs include lack of awareness regarding the infection during the early weeks of the outbreak, inadequate personal protective equipment supply, and training in using personal protective measures including hand hygiene and proper donning and doffing of PPE, hesitancy for testing by some healthcare workers, long work hours in high-risk environments, and community acquisition [21,22, 23]. COVID-19 pandemic has a marked impact on the physical and mental health of HCWs across the globe.
It leads to a double burden on the healthcare system if an HCW acquires the infection, as not only does the HCW become unavailable to work as well as the one who now needs to be cared for. In addition, the morale of other HCWs could take a toll. Hence, it is imperative to do all that it takes to prevent infection to the HCWs. So, Optimal hand hygiene, use of personal protective equipment, and other Covid protective measures along with early and high-throughput testing for SARS-CoV-2 is of paramount importance in the prevention of COVID-19 among the HCWs [24].

AIMS AND OBJECTIVES:
1. To determine the prevalence of Covid-19 infection among the HCWs in the tertiary care hospital and associated hospitals of GMC primarily.
2. To determine prevalent risk factors associated with SARS-COV2 infection among the healthcare workers.

METHODS & MATERIALS:

1. Study setting and design:

This is a hospital based cross-sectional study that was conducted in the Covid Lab of the Postgraduate Department of Microbiology GMC Srinagar, a tertiary care center that is a teaching hospital and carters to a large population in the Kashmir division. The participants were the healthcare workers of GMC primarily and the associated hospitals who delivered care in various departments of associated hospitals and GMC itself. Health care workers in these settings comprised of medical doctors, nurses, laboratory technicians, pharmacists, midwives, and others who were either symptomatic with an acute respiratory infection (influenza-like illness or severe acute respiratory infection) suspected of Covid19 or high-risk contacts and asymptomatic close contacts of COVID-19 positive patients. A total of 7141 healthcare workers were tested for SARS-CoV-2 using real-time reverse transcription-polymerase chain reaction (rRT-PCR) over a period of one year.

2. METHODS:
The study was conducted in the Covid lab, CD that comes under the VRDL division of the Department of Microbiology, Government Medical College Srinagar, J&K between March, 2020 and March 2021. The study of HCWs began in mid-march 2020,

RT-PCR testing was performed on symptomatic HCWs with an acute respiratory infection (influenza-like illness and severe acute respiratory infection) suspected of Covid-19 and those with a history of any contact with a confirmed or suspected case. After obtaining informed consent, data with regard to demographic variables including age, sex and occupation, clinical history with regard to symptomatology, history of associated risk factors like hypertension, Diabetes Mellitus, COPD, asthma, chronic liver disease etc. prevalent in these suspected cases of acute respiratory infection were also collected along with the infection prevention and control measures adopted were captured on to a structured performa.

2.1 Specimen collection:

Before beginning the procedure, a proper PPE comprising of N95 mask, face shield, gown, goggles, shoe cover, and the cap was worn. Since sample collection is an aerosol-generating procedure we followed the pertinent respiratory and contact precautions certified by the Centre for Disease Control and Prevention. Testing for COVID-19 was performed using a deep nasopharyngeal and a concomitant oropharyngeal swab. Nasopharyngeal swabs were taken by gently tilting the patient's head back 70 degrees while holding the person's head with one hand and the swab in another. The swab was inserted through the nostril parallel to the palate (not upwards) until resistance was encountered or the distance is equivalent to that from the ear to the nostril of the patient, indicating contact with the nasopharynx. When the tip of the swab reached the posterior wall of the nasopharyngeal cavity it was rotated gently once (paused for a moment in case of reflex cough), then slowly removed. If a deviated septum or blockage created difficulty in obtaining the specimen from one nostril, the same swab was used to obtain the specimen from the other nostril. Then this swab tip containing the specimen was gently dipped into a tube containing 2-3ml viral transport medium (VTM) after breaking the applicator stick and the cap is tightened and the labeled specimen was transferred to our laboratory at the earliest possible maintaining cold chain (2-4°C) throughout [25,26,27].

2.2 Laboratory methods:

Molecular tests were performed by the qualified clinical laboratory personnel specifically instructed and trained in the techniques of real-time PCR. In vitro diagnostic procedures were done on the specimen of healthcare workers at negative pressure BSL-III Covid Lab, GMC. Real time RT-PCR assay was used to analyze the specimen, looking for genetic material (ribonucleic acid or RNA) of SARS-CoV-2that causes COVID-19. The first step in RT-PCR was the RNA extraction and purification that was done either by using manual RNA extraction kits that is Chromus RNA, Invitrogen, Pure link viral, Qiagen, Genetex, RNA Sure, Higenomics and Path kits or the automated kits Genolution, Higinome (Himedia) and GeneMag (Genetix). The Extracted RNA was reverse transcribed to c DNA and amplified using the RT-PCR thermocycler.

Initially, RT-PCR assay targeted at specific SARS-CoV-2 E-gene regions using National Institute of Virology (NIV), Pune-developed kits as per the ICMR recommendations [28]. These kits were a two-step kit wherein the E gene was used for the initial screening test. All those specimens that came out to be positive by screening test were confirmed by a second reaction targeting the ORF and Rd-RP genes as per the NIV protocol [29]. Later the test kits used were TaqPath (Thermo Fisher Scientific) RT-PCR COVID-19 Kit detecting ORF1ab, N, and S gene (2) Allplex (Seegene)2019-

nCOV Assay detecting E, N, RdRP, S and IC (3) LabGun (Lab Genomics, Korea) COVID-19 RT-PCR Kit detecting RdRP, E, and IC and recently Meril COVID-19 One-Step RT-PCR Kit that gets the specific conserved sequence encoding the ORF 1ab gene and the nucleoprotein N gene was used to confirm the Covid 19 infection. All test controls were examined prior to the interpretation of the results. When the cycle threshold value (Ct value) was 35 and less results were considered as positive (+) and the Ct value of >35 was considered as negative (-).

RESULTS:

A total of 7141 HCWs working primarily in GMC and in various associated hospitals and a few district hospitals of health services in J&K were tested for SARS-CoV-2 between March 2020 to March 2021 with 913 (12.7%) testing positive and 629(68.8%) affected were male and 284(31.2%) were females. 346(37.8%) Healthcare workers were positive between 26 to 35 years of age followed by 221 (24.2%) between 36 to 45 years, 110(12.0%) between 46 to 55 years,99(10.8%) <25 years, and 89(9.7%) that were above 56 years of age. The median age (IQR) was 31 years. Doctors comprise 58.3% of all the infected HCWs. Others including nurses, midwives, non-clinical support service staff, administrative staff, allied health professionals, and other clinical support staff include (64.4%). Among the positive cases in HCW's fever and chills was the most common symptom 611(66.9%) followed by cough 568(62.2%), fatigue 520(56.9%), myalgia 496(54.3%), congestion and runny nose 387(42.3%) headache 325(35.5%), sore throat 216(23.6%), anosmia 156(17.0%), shortness of breath 121(13.2%), nausea &vomiting 114(12.4%) abdominal pain 73(7.9%) and diarrhea 52(5.6%). 133(14.5%) healthcare workers that were positive for COVID-19 were having other associated comorbidities including hypertension 42(4.6%) the most common followed by Diabetes mellitus 39(4.2%), COPD 21(2.3%), and asthma 17(1.8%). 879(96.2%) healthcare workers had reported the proper use of personal protective equipment . 828 (90.6%) healthcare workers followed recommended hand hygiene practices.574(62.8%) healthcare workers were reported from GMC Srinagar & allied hospitals and 339(37.1%) healthcare workers were from a few other district hospitals of the Kashmir division[table1,2][chart1].

table1: Baseline Characteristics Of The Healthcare Workers

S.no	DEMOGRAPHIES	COVID-19 POSITIVES N=913	COVID-19 NEGATIVE N=6228	Total no. Of participants N=7141
1.	Gender			
	Male	629(68.8%)	3659(58.7%)	4572(64.02 %)
	Female	284(31.2%)	1656(26.5%)	2569(35.9%)
2	Age groups years (n=7141)			
	<25	99(10.8%)	900(14.4%)	999(13.9%)

	26-35	346(37.8%)	2428(38.9%	2774(38.8%)
	36-45	221(24.2%)	1342(21.5%)	1563(21.8%)
	46-55	110(12%)	714(11.4%)	824(11.5%)
	>56	89(9.7%)	337(5.4%)	426(5.9%)
3.	Occurrence			
	Symptomatic	698(76.4%)	5167(72.3%)	5865(82.1%)
	Asymptomatic	215(23.5%)	1061(17.03%)	1276(17.8%)
4.	Occupation			
	Doctors	533(58.3%)	2959(47.5%)	3492(48.9%)
	Others (Nurses, technicians, hospital &sanitary attendants)	380(41.6%)	3269(52.4%)	3649(51.09 %)
5	Follow IPC standard precautions: Hand hygiene			
	Always, as recommended Most of the time Occasionally/rarely	828(90.6%) 78(8.5%) 7(0.7%)		
6	Wear PPE when indicated?			
	Always, according to the risk assessment Most of the time, according to the risk assessment Occasionally/rarely	879(96.2%) 26(2.8%) 8(0.87%)		
7	Presenting Symptoms			

	Fever or chills	611(66.9%)			
	Cough.	568(62.2%)			
	Fatigue.	520(56.9%)			
	Muscle or body aches.	496(54.3%)			
	Congestion or runny nose.	387(42.3%)			
	Headache	325(35.5%)			
	Sore throat	216(23.6%)			
	New loss of taste or smell.	156(17.0%)			
	Shortness of breath or difficulty breathing.	121(13.2%)			
	Nausea/Vomiting	114(12.4%)			
	Abdominal pain	73(7.9%)			
	Diarrhea	52(5.6%)			
8.	COMORBIDITIES	N=913	GENDER Male	Female	
	1. **Cardiovascular disease:** Hypertension Coronary artery disease	42(4.6%) 11(1.2%)	28(3.0%) 8(0.8%)	14(1.5%) 3(0.3%)	
	2. Chronic respiratory disease: Asthma Chronic obstructive pulmonary disease (COPD)	21(2.3%) 17(1.8%)	13(1.4%) 6(0.65%)	8(0.8%) 11(1.20%)	
	3. Endocrine disorder Diabetes mellitius Hypothyroidism	39(4.2%) 7(0.76%)	21(2.3%) 2(0.21%)	18(1.9%) 5(0.54%)	
	4. Liver disease Cirrhosis	9(0.9%)	6(0.65%)	3(0.3%)	
	5. Chronic Kidney disease (CKD)	4(0.43%)	3(0.3%)	1(0.10%)	
	6.Multiple Comorbidities	62(6.7%)	41(4.4%)	21(2.3%)	

Table 2: Distribution of positive healthcare workers

S.no	Variable	Total positive (n=913)	Percent-age %
1.	**Occupation n=913**		
	Doctors	533	58.3 %
	Nursing staff	125	13.6%
	Technicians (including dental)	83	9.09%
	Sanitary attendants	104	11.3%
	Others (administration staff, hospital attendants, security etc.)	212	23.2%
2.	SPECIALITY n=533		
	Medical specialties [MICU, Emergency, medicine wards}	156	29.2%
	Diagnostic specialties (laboratory pri-marily microbiology followed by other labs, and radiology)	94	17.6%
	Surgical specialties {SICU]	63	11.8%
	ICU & Anesthesia	54	10.1%
	Gynecology/obstetrics	28	5.2%

Other departments	138	25.8%

DISCUSSION:

This study found an overall prevalence of COVID-19 among the HCWs in GMC and associated hospitals over for one year was 12.7%. The prevalence of SARS-CoV-2 infection among HCWs in our study is higher than the study conducted by Mahajan et al where the total prevalence of SARS COV2 infection among the HCWs was11% [30]. The present study will give an insight into the socio-demographic determinants, the clinical presentation and, the proportion of asymptomatic and symptomatic HCWs along with the other associated risk factors with COVID-19. Majority 68.8% (629/913) of HCWs infected with SARS-CoV-2 were male and 31.2% (284/913) were female. Various studies have also examined the gender dimension of COVID-19 infection and the epidemiological findings reports have found that male individuals represent in general a higher proportion of the infected COVID-19 patients due to biological, social, and economic factors between the genders [31]. In our study, 37.8% of young individuals between 26 to 35 years were predominantly affected which is consistent with national data on HCWs with COVID-19.

Out of the total 913 positive cases, 698(76.4%) HCWs were symptomatic. This data is similar to the study done by Niraj et al where the majority (85%) of the HCWs with COVID-19 were symptomatic and 15% were asymptomatic [27]. Fever and chills 611(66.9%) are the most common symptom followed by cough, fatigue, myalgia, running nose, and headache. Co-morbidities were reported in 16.4% (150/913) of HCWs with COVID-19. Hypertension and Diabetes Mellitus were the most common co-morbidities reported in our study. That implies Impaired glucose metabolism i.e., type 2 diabetes, as well as hypertension as in most other diseases are the important risk factors for COVID-19. Our study results are similar to the study by Wang et al where common co-morbidities such as hypertension, COPD, diabetes, and cardiovascular disease were observed to be the more significant risk factors in subjects when compared with other underlying disease states [32].
Based on current information and clinical expertise multiple co-morbidities like uncontrolled medical conditions such as diabetes, hypertension, lung, liver, and kidney disease are associated with the severity of COVID-19 disease progression and many of the poorer outcomes for COVID-19 have been related to various co-morbid conditions [33,34]. Therefore, patients with co-morbidities should take all necessary precautions to avoid getting infected with SARS CoV- 2, as they usually have the worst prognosis.

Since hand hygiene is very important to prevent transmission of Covid-19 infection and our study focused on the importance of hand hygiene during caring of the COVID-19 patients, similar to another research done previously [35]. In our study, 90.6% of HCWs followed recommended hand hygiene practices. Such high compliance in hand hygiene practices may be attributable to continuous training of HCWs as a part of good infection prevention and control measures. These observations are in line with the results of a study done in a tertiary care center in Pune where compliance to adequate hand hygiene was also found to be higher (91.0%) among the HCWs [36].

This study shows that if health care workers take adequate precautions and infection prevention and control training then they can minimize the risk of getting an infection. Proper donning and doffing practice of PPE by HCWs is a must to prevent their exposure to the pathogen as there are high chances of contamination while doffing and donning PPE. In our study 879(96.2%) healthcare workers were wearing full personal protective equipment (PPE) always, according to the risk assessment.
The prevalence of SARS-CoV2- infection among HCWs can inform infection prevention policies within the healthcare systems, including the availability and proper use of PPE, particularly if the patient to HCW transmission is suspected despite PPE use. Training in knowledge and skills is important for healthcare providers for the prevention and control of SARS COV-2 [37].
We observed that doctors 58.3% had the highest frequency of positive test results as compared with nursing staff and technicians (13.6% and 9.09%, respectively) and 11.3% for sanitation workers. Our observations are similar to those of an Italian cohort of 1573 HCWs in which physicians had the highest frequency of positive tests 61/582 (10.5%), whereas clerical workers and technicians had the lowest frequency 5/137 (3.6%)[38]. Our findings of higher occupational risk of COVID-19 infection among the clinical healthcare provider roles as compared with HCP working in healthcare support and infrastructure roles likely reflects the high-risk job duties performed within these occupations, often involving extended close physical contact with patients, exposure to higher viral load through aerosol-generating procedures, and work with patients who may be extremely ill and infectious[39,40]. However, various other studies have found no consistent difference in the risk between physicians and other HCW categories.
Since the researchers believed that SARS-CoV-2 may turn into chronic disease and concomitantly coexist with humans like the flu [41]. Therefore, to cope with the long-term existence of SARS-Cov-2 and possible public health emergencies health care workers should receive annual training on the use of personal PPE and additional education during surge events [42]. Since the virus is infecting at a fast rate and the unavailability of vaccines for Covid -19 until recently so all the age groups are susceptible. Newer variants of the virus are emerging so the necessary measures should be taken to reduce the spread of infection, including getting a COVID-19 vaccine the best way to slow the emergence of new variants. as proven from various studies Vaccines reduce the risk of severe illness, hospitalization, and death from COVID-19.
The study based on the prevalence of SARS CoV-2 among HCWs from London and a study from China strongly suggests that policies are needed urgently for regular testing and surveillance which will protect both HCWs and patients. [43,44]. Last, the actual prevalence of SARS-CoV-2 infection may be higher than reported here, due to less routine screening in asymptomatic or pre-symptomatic HCWs

CONCLUSION:

The present study provides the first insight into the infection status of HCWs in north India, UT of J&K during the COVID-19 pandemic. The results of this study will be useful for determining the impact of COVID-19, adverse outcomes in HCWs, and thus identifying the probable modes of acquiring SARS-CoV-2 infection in HCWs. We presented a representative sample of 7141 employees of a large healthcare system who underwent nasopharyngeal testing for SARS-CoV-2 and observed a prevalence of 12.7%. This report identified factors related to COVID-19 among HCWs, with inferences to curb the infection spread among HCPs in probably resource-limited countries.

Rapid and high-throughput testing of HCWs for COVID-19 using the drive-through and walk-through testing clinic models, facilitating the rapid return of SARS-CoV-2 negative HCWs to work. Ensuring the adequate supply of PPE to the Healthcare professionals is just the first step followed by providing adequate rest time, societal, familial, and psychological support. Thus, the protection of HCWs from infection is critical for the resilience of the health system facing a major pandemic like COVID-19.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

Références:

1. World Health Organization. WHO director-general's opening remarks at the media briefing on COVID-19. 11 March 2020. Available at: https://www.who.int/dg/speeches/detail/who-director-general-s-opening-remarks-at-the-mediabriefing-on-covid-19---11-march-2020. Accessed 5 May 2020.

2. "MoHFW-GOI". Ministry of Health and Family Welfare. Retrieved 23 May 2020

3. Indian Council of Medical Research. [cited 2020 May 22]. Available from: https://www.icmr.gov.in

4. J&K, Health & Medical Education Department (8 March 2020). "One case of a patient admitted in isolation at GMC tested positive for Coronavirus, patient had travel history to Iran, second patient's sample being sent for retest". jkhealth.org. Retrieved 31 May 2020.

5. Chatterjee P, Nagi N, Agarwal A, Das B, Banerjee S, Sarkar S, et al. The 2019 novel coronavirus disease (COVID-19) pandemic: A review of the current evidence. Indian J Med Res 2020; 151: 147-59

6. Ramadan N, Shaib H. Middle East respiratory syndrome coronavirus (MERS-CoV): A review. Germs 2019; 9: 35-42.

7. Zhong NS, Zheng BJ, Li YM, Poon , Xie ZH, Chan KH, et al. Epidemiology and cause of severe acute respiratory syndrome (SARS) in Guangdong, People's Republic of China, on 6,7 February, 2003. Lancet 2003; 362: 1353-8.

8. Huang L, Zhang X, Zhang X, Wei Z, Zhang L, Xu J, et al. Rapid asymptomatic transmission of COVID-19 during the incubation period demonstrating strong infectivity in a cluster of youngsters aged 16-23 years outside Wuhan and characteristics of young patients with COVID-19: A prospective contact-tracing study. J Infect 2020; 80: e1-13.

9. Tang X., Wu C., Li X., Song Y., Yao X., Wu X., Duan Y., Zhang H., Wang Y., Qian Z. On the origin and continuing evolution of SARS-CoV-2. Natl. Sci. Rev. 2020;7(6):1012–1023. [Google Scholar]

10. Wang W., Xu Y., Gao R., Lu R., Han K., Wu G., Tan W. Detection of SARS-CoV-2 in different types of clinical specimens. JAMA. 2020;323(18):1843–1844. [PMC free article] [PubMed] [Google Scholar]

11. Dos Santos W.G. Impact of virus genetic variability and host immunity for the success of COVID-19 vaccines. Biomed. Pharmacother. 2021;111272 [PMC free article] [PubMed] [Google Scholar]

12. Michel C.J., Mayer C., Poch O., Thompson J.D. Characterization of accessory genes in coronavirus genomes. Virol. J. 2020;17(1):131. [PMC free article] [PubMed] [Google Scholar]

13. Liu W., Li H. COVID-19: attacks the 1-beta chain of hemoglobin and captures the porphyrin to inhibit human heme metabolism. Preprint revised on. 2020;10(04) [Google Scholar]

14. Guo Y.-R., Cao Q.-D., Hong Z.-S., Tan Y.-Y., Chen S.-D., Jin H.-J., Tan K.-S., Wang D.-Y., Yan Y. The origin, transmission and clinical therapies on coronavirus disease 2019 (COVID-19) outbreak–an update on the status. Mil. Med. Res. 2020;7(1):1–10. [PMC free article] [PubMed] [Google Scholar]

15. Bar-On Y.M., Flamholz A., Phillips R., Milo R. SARS-CoV-2 (COVID-19) by the numbers. Elife. 2020;9 [PMC free article] [PubMed] [Google Scholar]

16. Julia L Mullen, Ginger Tsueng, Alaa Abdel Latif, Manar Alkuzweny, Marco Cano, Emily Haag, Jerry Zhou, Mark Zeller, Emory Hufbauer, Nate Matteson, Kristian G Andersen, Chunlei Wu, Andrew I Su, Karthik Gangavarapu, Laura D Hughes, SARS-CoV-2 (hCoV-19) Mutation Reports, 2020. https://outbreak.info/.

17."Genome Sequencing by INSACOG shows variants of concern and a Novel variant in India". Ministry of Health and Family Welfare. 24 March 2021. Retrieved 17 May 2021.

18. *Das, Krishna N (16 May 2021). "Top Indian virologist quits government panel after airing differences". Reuters. Retrieved 17 May 2021.*

19. *Pulla, Priyanka (28 February 2021). "India's Genome Sequencing Program Is Finally Good To Go – So What's the Hold Up?". The Wire. Retrieved 17 May 2021*

20. Nguyen LH, Drew DA, Joshi AD, Guo C-G, Ma W, Mehta RS, et al. Risk of COVID-19 among frontline healthcare workers and the general community: A prospective cohort study. medRx 2020. doi: https://doi. org/10.1101/2020.04.29.2008411

21..Zhou P, Huang Z, Xiao Y, Huang X, Fan XG. Protecting Chinese healthcare workers while combating the 2019 novel coronavirus. Infect Control Hosp Epidemiol 2020:1–4. doi:10.1017/ice.2020.60.

22.Wang J, Zhou M, Liu F. Reasons for healthcare workers becoming infected with novel coronavirus disease 2019 (COVID-19) in China. J Hosp Infect 2020:S0195670120301018. doi:10.1016/j.jhin.2020.03.002.

23..Ran L, Chen X, Wang Y, Wu W, Zhang L, Tan X. Risk factors of healthcare workers with coronavirus disease 2019: a retrospective cohort study in a designated hospital of Wuhan in China. Clin Infect Dis 2020. doi:10.1093/cid/ciaa287.

24.Centers for Disease Control and Prevention. Priorities for testing patients with suspected COVID-19 infection. Available at: https://www.cdc.gov/ coronavirus/2019-ncov/downloads/priority-testing-patients.pdf. Accessed 5 May 2020.

25. Marty FM, Chen K, Verrill KA. How to Obtain a Nasopharyngeal Swab Specimen. N Engl J Med. 2020;382(22):e76. [PubMed]

26.Tang YW, Schmitz JE, Persing DH, Stratton CW. Laboratory diagnosis of COVID-19: Current issues and challenges. J Clin Microbiol. 2020;58(6):1-22. [Full Text]

27.Centers for Disease Control and Pevention. Interim Guidelines for Collecting, Handling, and Testing Clinical Specimens from Per- sons for Coronavirus Disease 2019 (COVID-19). [Full Text]

28. Choudhary ML, Vipat V, Jadhav S, Basu A, Cherian S, Abraham P, et al. Development of in vitro transcribed RNA SONI et al: CLINICAL PROFILE OF COVID-19 PATIENTS 11 as positive control for laboratory diagnosis of SARS-CoV-2 in India. Indian J Med Res 2020; 151: 251-4.

29.ICMR-National Institute of Virology (ICMR-NIV), Pune. Standard Operating Procedure for Detection of 2019 novel coronavirus (2019-nCoV) in suspected human cases by rRTPCR: First Line Screening assay. Document No.: SP.01.

30.Mahajan NN, Mathe A, Patokar GA, Bahirat S, Lokhande PD, Rakh V, Gajbhiye R, Rathi S, Tilve A, Mahajan K, Mohite SC. Prevalence and Clinical Presentation of COVID-19 among Healthcare Workers at a Dedicated Hospital in India. J AssocPhysicians India. 2020 Dec;68(12):16-21. PMID: 33247637

31.Kopel J, Perisetti A, Roghani A, Aziz M, Gajendran M, Goyal H. Racial and gender-based differences in COVID-19. Front Public Health. (2020) 8:418. doi:10.3389/fpubh.2020.0

32.Wang B, Li R, Lu Z, Huang Y. Does comorbidity increase the risk of patients with COVID-19: Evidence from meta-analysis. Aging (Albany NY). 2020;12(7):6049–57. https://doi.org/10.18632/ aging.103000 [Accessed May 30, 2020,https://pubmed.ncbi.nlm. nih.gov/32267833/].

33.*W-Jie G, Liang W-H, He J-X, Zhong N-S. Cardiovascular comorbidity and its impact on patients with COVID-19. Eur Respir J. 2020;55:2001227. https://doi.org/10.1183/13993003.01227-2020. [Accessed May 30, 2020, https://erj.ersjournals.com/content/early/ 2020/04/20/13993003.01227-2020*

34. CDC. Coronavirus (COVID-19): symptoms of coronavirus. Centers for Disease Control and Prevention. 2020. [Accessed April 18, \2020,https://www.cdc.gov/coronavirus/2019-ncov/ symptoms-testing/symptoms.html].

35.Ran L, Chen X, Wang Y, Wu W, Zhang L, Tan X. Risk factors of healthcare workers with corona virus disease 2019: a retrospective cohort study in a designated hospital of Wuhan in China. Clin Infect Dis. 2020; 71:2218-222

63.Anargh V, Singh H, Kulkarni A, Kotwal A, Mahen A. Hand hygiene practices among health care workers (HCWs) in a tertiary care facility in Pune. Med J Armed Forces India. 2013; 69:54-56.

37. Chen Q, Liang M, Li Y, Guo J, Fei D, Wang L, et al. Mental health care for medical staff in China during the COVID-19 outbreak. Lancet Psychiatry. 2020;7(4): e15–

6.20. CCTV-13. [CCTV segment onNews1+1: OutbreakResponseinToday]. 2020.http://tv.cntv.cn/video/C10586/3f3144db134c4586a717f8950e28c82a (accessed 19 February 2020).

38..Lombardi A, Consonni D, Carugno M, et al. Characteristics of 1573 healthcare workers who underwent nasopharyngeal swab testing for SARS-CoV-2 in Milan, Lombardy, Italy. Clin Microbiol Infect. 2020;26(10): 1413.e9–13.

36. Chou R, Dana T, Buckley DI, Selph S, Fu R, Totten AM. Epidemiology of and risk factors for coronavirus infection in health care workers: a living rapid review. Ann Intern Med 2020; 173:120–1.

39. CDC COVID-19 Response Team, Burrer SL, et al. Characteristics of health care personnel with COVID-19—United States, February 12–April 9, 2020. MMWR Morb Mortal Wkly Rep 2020; 69:477–81. doi:10.15585/mmwr.mm6915e6.

40.Mason DJ, Friese CR. Protecting health care workers against COVID-19—and being prepared for future pandemics. 2020. https://jamanetwork.com/ chanels/health-forum/fullarticle/2763478 (accessed 21 March 2020)

41. Hughes MM, Groenewold MR, Lessem SE, et al. Update: characteristics of health care personnel with COVID-19 - United States, February 12-July 16, 2020. MMWR Morb Mortal Wkly Rep 2020; 69:1364–1368.

42..Houlihan CF, Vora N, Byrne T, et al. Pandemic peak SARS-CoV- 2 infection and seroconversion rates in London frontline health-care workers. Lancet 2020; 396:e6-e7

43.Lai X, Wang M, Qin C, Tan L, Ran L, Chen D, Zhang H, Shang K, Xia C, Wang S, Xu S, Wang W. Coronavirus Disease 2019 (COVID-2019) Infection Among Health Care Workers and Implications for Prevention Measures in a Tertiary Hospital in Wuhan, China. JAMA Netw Open 2020; 3:e209666.