Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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Major Article

The prevalence of COVID-19 in healthcare personnel in an adult and pediatric academic medical center

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Background: It is vital to know which healthcare personnel (HCP) have a higher chance of testing positive for severe acute respiratory syndrome coronavirus 2 (COVID-19).

Methods: A retrospective analysis was conducted at Stanford Children's Health (SCH) and Stanford Health Care (SHC) in Stanford, California. Analysis included all HCP, employed by SCH or SHC, who had a COVID-19 reverse transcriptase polymerase chain reaction (RT-PCR) test resulted by the SHC Laboratory, between March 1, 2020 and June 15, 2020. The primary outcome was the RT-PCR percent positivity and prevalence of COVID-19 for HCP and these were compared across roles.

Results: SCH and SHC had 24,081 active employees, of which 142 had at least 1 positive COVID-19 test. The overall HCP prevalence of COVID-19 was 0.59% and percent positivity was 1.84%. Patient facing HCPs had a significantly higher prevalence (0.66% vs 0.43%; $P = .0331$) and percent positivity (1.95% vs 1.43%; $P = .0396$) than nonpatient facing employees, respectively. Percent positivity was higher in food service workers (9.15%), and environmental services (5.96%) compared to clinicians (1.93%; $P < .0001$) and nurses (1.46%; $P < .0001$), respectively.

Discussion and Conclusion: HCP in patient-facing roles and in support roles had a greater chance of being positive of COVID-19.

BACKGROUND

The safety and wellbeing of healthcare personnel (HCP) is paramount to caring for patients and communities affected by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). Previous research suggests that HCP may be at increased risk of exposure when caring for patients and family members with SARS-CoV-2 infections (COVID-19).[1-5] Early outbreaks of COVID-19 had HCPs in the United States concerned with the 20% rate of infection experienced in Italy.[1,2] The Centers for Disease Control (CDC) reports that the percentage of respiratory specimens testing positive for SARS-CoV-2 in the United States was 5.1%.[6] While local data from Santa Clara County in California, which includes Stanford Health Care (SHC) and Stanford Children's Health (SCH), had a percent positivity of 2.60% with 293 deaths as of September 2020.[7]

Caring for patients with COVID-19 may put HCPs at risk for transmission or infection. To reduce risk, healthcare facilities have invested in personal protective equipment (PPE) and implemented infection control protocols to minimize transmission within the hospital.[8-10] The CDC recommends prioritizing gowns and other PPE for HCPs engaging in "high-contact patient care activities" and for

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"patient-facing HCPs and those where splashes and sprays are anticipated."[9] The CDC prioritized N95 and eye protection for physicians, advanced practice providers (APP), registered nurses, and respiratory therapists (RT) who perform aerosol generating procedures and universal masking and eye protection for all other HCP.

It is easy to assume that the greatest risk of infection or transmission to HCP is due to their role in patient care. However, possibly of equal importance, may be the risk of exposure that HCPs face in the community. HCPs represent a broad diversity not only in range of professions, but also in terms of demographic and socio-economic circumstances. Social and economic factors, not related directly to patient care, have been associated with a higher risk of having COVID-19, and worse outcomes.[11]

To understand the positivity rates of the SARS-CoV-2 reverse transcriptase polymerase chain reaction (RT-PCR) test and the prevalence of COVID-19 in HCPs, a retrospective analysis was performed to compare rates between patient facing HCPs vs nonpatient facing HCPs. Extrapolating from previous research,[1,2] we hypothesized that patient-facing HCPs would have a higher percent positivity and prevalence than nonpatient facing HCPs. Differences between different HCP occupational roles were also examined. Study results will provide insights on how to further target and tailor efforts to protect HCPs.

METHODS

A retrospective analysis was performed utilizing electronic health record data at SCH, a 361 licensed bed pediatric acute care hospital and at SHC, a 613 licensed bed adult acute care hospital, in Stanford, CA. Study participants were all active HCPs, employed at SCH or SHC, who were voluntarily tested for COVID-19 using SARS-CoV-2 RT-PCR nasopharyngeal sample between March 1, 2020 and June 15, 2020. Along with the testing date and the result, the extracted data included whether the individual was symptomatic or asymptomatic at the time of their RT-PCR test. All the lab specimens included in the study were tested at the SHC Laboratory in Stanford, CA and stored in our Epic 2020 (Epic Inc, Wisconsin) electronic health record. Occupational Health collected the job role, organization, age, sex, and COVID-19 collection date during testing registration. The clinical data was extracted from EPIC 2018 Clarity database (Epic Inc, Wisconsin) using SQLDBX (AngStream LLC., LSistema UAB).

There were 2,262 job roles identified amongst the HCP analyzed in the study. Utilizing a manual review, each job role was categorized into 15 job categories and divided into patient facing or non-patient facing roles. Moving forward "clinicians" are defined as: medical doctors, physician assistant, nurse practitioners, medical postgraduates, and APPs. Registered nurse and certified nursing assistants will be referenced in the "nursing" population.

The job categories were further subdivided into patient-facing and nonpatient facing. Patient-facing roles completed most of their shift on an inpatient unit, diagnostic or procedural area, or clinic, and had direct contact with patients; whereas, nonpatient-facing roles did not. Nine job categories were defined as patient facing: clinical support, clinical tech, clinician, dietitian, environmental services, nursing, pharmacist, RT, and transporter. There were 6 job categories defined as nonpatient facing roles: administration, food preparation, information technology, laboratory, nonclinical support, and all "other" roles that did not align with the 15 categories previously described. (Appendix A1).

Outcomes

To investigate how COVID-19 positivity differed between HCP roles, RT-PCR test percent positivity and prevalence were used as the primary outcomes. Test percent positivity was defined as total number of positive COVID-19 tests divided by the total number of COVID-19 tests resulted, positive or negative. HCP prevalence was defined as the total number of unique individuals who tested positive for COVID-19 divided by the total number of unique individuals in the HCP population.

Statistical analysis

The age (mean ± standard deviation) and sex (% female) are provided for HCP who were tested for COVID-19. Statistical tests on the primary outcomes were conducted in R and RStudio.[12,13] To test for differences between two groups, the R package Exact for Boschloo's test (1970), an exact unconditional test was employed as it is a conservative binomial test to account for the rarity of positive individuals and positive tests in the tested population. First, differences in outcomes between nonpatient facing and patient-facing roles were determined. Within the HCP population, the following stratifications were analyzed: employees presenting as symptomatic or asymptomatic at the time of the test; clinicians vs nurses vs all other employees; and other post hoc, pairwise comparisons.

Differences in proportion and *P* values from Boschloo's exact test are reported. To determine if the outcomes differed between the 15 job categories, a G likelihood-ratio test was employed with the R package DescTools.[14] The G test statistic, degrees of freedom, and p-values were reported. *P* values < .05 were considered significant. The project was conducted as a quality improvement initiative and was determined to be nonresearch by the Stanford University School of Medicine Internal Review Board.

RESULTS

Between March 1, 2020 and June 15, 2020, there were a total of 24,081 HCPs employed at SCH and SHC. 13,001 HCPs were tested, 142 employees were positive, for a prevalence of 0.59%. HCPs had 16,219 total tests resulted, 298 positive tests, and 15,921 negative tests, for a RT-PCR percent positivity of 1.84%. The average age of the HCPs tested was 41.31 years (±11.48 standard deviation) and 68.03% were female.

As shown in Table 1, the patient-facing HCPs had a prevalence of 0.66% (112/17,040) and a percent positivity of 1.95% (248/12,714), which was significantly higher than the nonpatient facing prevalence of 0.43% (30/7,041) (*P*= .0331) and percent positivity of 1.43% (50/3,505; *P*= .0396), respectively. The average age of patient-facing employees tested was 40.89 years with 69.31% female vs 42.79 years with 63.59% identified as female in the nonpatient facing employee population.

As shown in Table 2, testing asymptomatic HCPs started, on a voluntary basis, on April 20, 2020. Symptomatic employees had a percent positivity of 4.11% (264/6,417) vs asymptomatic had a percent positivity of 0.35% (34/9,802; *P*< .0001). The average age of positive asymptomatic employees was 38.84 years with 67.27% female vs 40.79 years with 64.37% identified as female in the symptomatic employee population.

As shown in Table 3, clinicians and nurses had a COVID-19 prevalence of 0.58% (64/11,030) and percent positivity of 1.68% (149/8,874). This was lower, though not significantly lower, than the prevalence of 0.60% (78/13,051; *P*= .8663) and percent positivity of 2.04% (149/7,345; *P*= .09998) for all other employees, respectively.

When stratified by the 15 derived job categories, 5 job categories: Administration, Clinical Technician, Dietician, Laboratory, and Pharmacist had 5 or less positive individuals. These 5 job categories were combined into the Other job category to protect confidentiality as shown in Table 4. The proportion of positive RT-PCR tests to negative tests differed significantly by HCP role ($G = 104.37$, df = 9, $P < .0001$). Similarly, proportion of positive employees to negative employees also

Table 1
Prevalence of COVID-19, SARS-CoV-2 RT-PCR percent positivity, age, and gender in non-patient facing versus patient facing healthcare personnel

		Non-patient facing employees	Patient facing employees	Difference in proportion (Boschloo's exact test)	*P* value (Boschloo's exact test)
Characteristics of Positive Individuals	Number of Positive Individuals	30	112	-	-
	Gender of Positive Individuals (% Female)	76.67%	62.50%	-	-
	Average Age In Years of Positive Individuals (Standard Deviation)	42.00 (11.20)	39.51 (10.99)	-	-
Characteristics of Individuals tested at least once	Number of Individuals Tested	2,911	10,090	-	-
	Gender of Individuals Tested (% Female)	63.59%	69.31%	-	-
	Average Age In Years of Individuals Tested (Standard Deviation)	42.79 (11.90)	40.89 (11.32)	-	-
Prevalence among total population of HCP	Number of Positive Individuals	30	112	0.23%	0.0331
	Total Individuals in the Population	7,041	17,040		
	Total Prevalence (Positive/Total Employee)	0.43%	0.66%		
Test Positivity	Total Number of Positive PCR Tests	50	248	0.52%	0.0396
	Total Number of PCR Tests Results	3,505	12,714		
	Percent Positivity of Tests	1.43%	1.95%		

Table 2
SARS-CoV-2 RT-PCR percent positivity, age, and gender in healthcare personnel symptomatic and asymptomatic at the time of RT-PCR testing

		Symptomatic employees	Asymptomatic employees	Difference in proportion (Boschloo's exact test)	*P* value (Boschloo's exact test)
Characteristics of HCP who received a PCR Test	Total Number of Positive PCR Tests	264	34	-	-
	Gender of Positive Individuals (% Female)	64.37%	67.27%	-	-
	Average Age In Years of Positive Individuals (Standard Deviation)	40.79 (11.81)	38.84 (9.69)	-	-
Characteristics of HPC who had a positive PCR test	Total Number of PCR Test Results	6,417	9,802	-	-
	Gender of Individuals Tested (% Female)	63.54%	69.65%	-	-
	Average Age In Years of Individuals Tested (Standard Deviation)	41.46 (11.38)	41.26 (11.52)	-	-
Test Positivity	Total Number of Positive PCR Tests	264	34	**3.77%**	**<.0001**
	Total Number of PCR Test Results	6,417	9,802		
	Percent Positivity of Tests	4.11%	0.35%		

differed significantly by job role ($G = 46.797$, df = 9, $P < .0001$). Prevalence ranged from 1.89% amongst environmental services (n = 635) and food preparation workers at 1.83% (n = 382) down to 0% for transporters (n = 151) and respiratory therapy (n = 285). The employee population in total had a prevalence of 0.59% (n = 24,081) which was similar to nurses at 0.53% (n = 6,040) and clinicians at 0.64% (n = 4,990).

The test percent positivity ranged from 0.0% for respiratory therapists (n = 207 tests) and transporters (n = 81 tests) up to 9.15% for food preparation workers (n = 164 tests) and 5.96% for environmental services (n = 403 tests). Total employee percent positivity was 1.84%, which was close to nurses at 1.46% (n = 4,721) and clinicians at 1.91% (n = 4,142). Clinical support staff including social workers, case managers, and physical therapists had a percent positivity of 3.17% (n = 1,925).

As shown in Table 5, test percent positivity and prevalence were higher in staff employed in food preparation and environmental services than clinicians and nursing. Food service workers had higher percent positivity and prevalence than clinicians (9.15% vs 1.93%, $P < .0001$ and 1.83% vs 0.64%, $P < .0001$), respectively. Food service workers had higher percent positivity and prevalence than nursing staff (9.15% vs 1.46%, $P < .0001$ and 1.83% vs 0.53%, $P < .0001$), respectively. Environmental services staff had higher percent positivity and prevalence than

Table 3
Prevalence of COVID-19, SARS-CoV-2 RT-PCR percent positivity, age, and gender in Clinicians and Nurses versus all other healthcare personnel

		All other employees	Clinicians* and nurses†	Difference in proportion (Boschloo's exact test)	*P* value (Boschloo's exact test)
Characteristics of Positive Individuals	Number of Positive Individuals	78	64	-	-
	Gender of Positive Individuals (% Female)	66.67%	64.06%	-	-
	Average Age In Years of Positive Individuals (Standard Deviation)	41.59 (11.46)	38.14 (10.28)	-	-
Characteristics of Individuals tested at least once	Number of Individuals Tested*	5,973	7,028	-	-
	Gender of Individuals Tested (% Female)	65.58%	70.11%	-	-
	Average Age In Years of Individuals Tested (Standard Deviation)	41.96 (11.71)	40.76 (11.26)	-	-
Prevalence among total population of HCP	Number of Positive Individuals	78	64	0.02%	.8663
	Total Individuals in the Population	13,051	11,030		
	Total Prevalence (Positive/Total Employee)	0.60%	0.58%		
Test Positivity	Total Number of Positive PCR Tests	50	248	0.36%	.09998
	Total Number of PCR Tests Results	149	149		
	Percent Positivity of Tests	7,345	8,874		

*Clinicians defined as medical doctors, physician assistant, nurse practitioners, medical postgraduates, and advanced practice provider.
†Nursing defined as registered nurses, clinical nurse specialists, nurse educator, nurse coordinator, and nursing assistants.

Table 4
SARS-CoV-2 RT-PCR percent positivity, characteristics, and prevalence among healthcare personnel

	Characteristics of individuals tested at least once			Characteristics of positive individuals			Prevalence among total population of HCP			Test positivity		
	Number of individuals	Gender (% female)	Average age, years (Standard deviation)	Number positive individuals	Gender (% female)	Average age, years (Standard deviation)	Number positive individuals	Total individuals in the population	Prevalence total (Positive/total employee)	Number of positive PCR tests	Number of resulted PCR tests	Percent positive
Clinical support	1,511	77.50%	40.57 (11.19)	29	68.97%	39.62 (10.48)	29	2,964	0.98%	61	1,925	3.17%
Clinicians*	3,211	65.33%	35.13 (11.45)	32	43.75%	39.59 (10.89)	32	4,990	0.64%	80	4,153	1.93%
Food preparation	124	50.00%	46.48 (11.62)	7	57.14%	39.42 (13.58)	7	382	1.83%	15	164	9.15%
Environmental services	335	56.12%	43.18 (12.31)	12	33.33%	43.16 (13.48)	12	635	1.89%	24	403	5.96%
Information technology	234	36.75%	45.31 (10.95)	0	N/A	N/A	0	890	0.00%	0	258	0.00%
Nonclinical support	1,254	55.40%	40.10 (12.18)	14	0.00%	42.92 (10.83)	14	3,611	0.39%	21	1,448	1.45%
Nursing†	3,817	60.53%	48.10 (11.05)	32	85.71%	36.68 (9.59)	32	6,040	0.53%	69	4,721	1.46%
Other‡	2,279	67.62%	41.77 (11.59)	16	75.00%	43.75 (11.89)	16	4,133	0.39%	28	2,859	0.98%
Respiratory therapy	173	59.54%	42.82 (10.89)	0	N/A	N/A	0	285	0.00%	0	207	0.00%
Transporter	63	11.11%	37.33 (12.42)	0	N/A	N/A	0	151	0.00%	0	81	0.00%
G likelihood-ratio test results							G = 46.797, x-squared df = 9, *P*< .0001			G = 104.37, x-squared df = 9, *P*< .0001		

*Clinicians defined as medical doctors, physician assistant, nurse practitioners, medical postgraduates, and advanced practice provider.
†Nursing defined as registered nurses, clinical nurse specialists, nurse educator, nurse coordinator, and nursing assistants.
‡Other job category utilized for any roles with <5 positive individuals. Other defined as administrative, clinical tech, dietitian, laboratory, pharmacists.

Table 5
Prevalence and test positive rates of SARS-CoV-2 RT-PCR selected pairwise comparisons between healthcare personnel

	Prevalence			Test positivity		
	Total individuals in the population	Prevalence (%)	*P* value	Number of resulted PCR tests	Positive tests (%)	*P* value
Food preparation	382	1.83%		164	9.15%	
vs Clinicians*	4,990	0.64%	.0179	4,153	1.93%	<.0001
vs Nurses†	6,040	0.53%	.0071	4,721	1.46%	<.0001
Environmental services	635	1.89%		403	5.96%	
vs Clinicians*	4,990	0.64%	.0085	4,153	1.93%	<.0001
vs Nurses†	6,040	0.53%	.0006	4,721	1.46%	<.0001

*Clinicians defined as medical doctors, physician assistant, nurse practitioners, medical postgraduates, and advanced practice provider.
†Nursing defined as registered nurses, clinical nurse specialists, nurse educator, nurse coordinator, and nursing assistants.

clinicians (5.96% vs 1.93%; $P < .0001$ and 1.89% vs 0.64%; $P < .0001$), respectively. Environmental services staff had higher percent positivity and prevalence than nursing staff (5.96% vs 1.46%; $P < .0001$ and 1.89% vs 0.53%; $P < .0001$), respectively.

DISCUSSION

Healthcare systems are critical infrastructures that depend on the safety of their workforce. During a pandemic this locus of control expands beyond the healthcare facility, and it is imperative to monitor HCP rates of infection to understand which employees are at highest risk. Having robust infection control measures in place and access to PPE should reduce disease transmission within the healthcare setting. Even so, HCP continue to face the risks of community exposure when they leave the healthcare facility. Given the propensity for COVID-19 to disproportionately affect low income communities, HCP with lower paying jobs may also be at higher risk of infection from the community.[11]

The <1% prevalence among the front-line clinical staff further substantiate the effectiveness of implementing evidence-based infection control protocols to improve HCP safety. Of concern, however, is the relatively high rate of positivity among the nonpatient facing support roles such as food preparation. Given the initial infection rates and associated mortality cited in Italy and China, it was reasonable to assume providers coming into direct contact with known COVID-19 positive patients would have the highest percent positivity.[1,2] Our data did support this assumption, with patient-facing employees having 136% higher percent positivity than non-patient facing employees, which was statistically significantly. However, jobs associated with direct contact with confirmed COVID-19 patients and performing aerosol generating procedures, such as respiratory therapists, had 0 positive RT-PCR tests. Additionally, other high-risk groups such as physicians/APPs and nurses had a lower percent positivity and prevalence than food preparation and environmental services.

Despite the higher percent positivity amongst patient facing HCP, further analysis of the roles and job categories showed our data differed considerably from previous studies. When stratifying the employees into the 15 job roles, there was a statistically significant difference in the prevalence and percent positivity of COVID-19. Prevalence in environmental services, food preparation, laboratory workers, dieticians, and clinical support were higher than the clinicians, nurses, and respiratory therapists. These findings are notable given previous research suggesting that physicians and proceduralists are at a high risk of being positive.[1,5] However, it is unclear if the support roles have a higher rates of infection than clinicians due to hospital onset or due to greater propensity of exposure in the community.

The source of transmission is beyond the scope of this study, but our findings suggest further analysis is warranted to delineate hospital onset vs community onset transmission. Case control studies should be conducted to determine risk factors and better ascertain sources of transmission among support roles. These findings will help guide infection control strategies to mitigate spread, source control, and contact tracing.

LIMITATIONS

Our study was limited since we were unable to evaluate whether COVID-19 transmission was community or hospital onset. We were unable to evaluate HCP access to PPE, training, or compliance to infection control protocols based on job role or category. In addition, we manually assigned job roles to patient facing or nonpatient facing

based on the job description. This manual assignment may have led to misallocation of certain staff categories. We acknowledge these limitations and support additional research on this topic.

CONCLUSION

The need for data-driven policies and implementation of protocols to protect healthcare workers is essential. The COVID-19 pandemic has exposed the vulnerability of the healthcare workforce. Unlike data seen from Italy,[1] the results of this study suggest that HCPs in key nonprovider roles, need to be considered with the same level of caution as providers performing high risk procedures.

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SUPPLEMENTARY MATERIALS

Supplementary material associated with this article can be found in the online version at https://doi.org/10.1016/j.ajic.2021.01.004.

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