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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COVID-19 in Health Care Personnel: Significance of Health Care Role, Contact History, and Symptoms in Those Who Test Positive for SARS-CoV-2 Infection

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Abstract

Objective: To identify significant factors that help predict whether health care personnel (HCP) will test positive for severe acute respiratory coronavirus 2 (SARS-CoV-2).

Patients and Methods: We conducted a prospective cohort study among 7015 symptomatic HCP from March 25, 2020, through November 11, 2020. We analyzed the associations between health care role, contact history, symptoms, and a positive nasopharyngeal swab SARS-CoV-2 polymerase chain reaction test results, using univariate and multivariable modelling.

Results: Of the symptomatic HCP, 624 (8.9%) were positive over the study period. On multivariable analysis, having a health care role other than physician or advanced practice provider, contact with family or community member with known or suspected coronavirus disease 2019 (COVID-19), and seven individual symptoms (cough, anosmia, ageusia, fever, myalgia, chills, and headache) were significantly associated with higher adjusted odds ratios for testing positive for SARS-CoV-2. For each increase in symptom number, the odds of testing positive nearly doubled (odds ratio, 1.93; 95% CI, 1.82 to 2.07, $P<.001$).

Conclusion: Symptomatic HCP have higher adjusted odds of testing positive for SARS-CoV-2 based on three distinct factors: (1) nonphysician/advanced practice provider role, (2) contact with a family or community member with suspected or known COVID-19, and (3) specific symptoms and symptom number. Differences among health care roles, which persisted after controlling for contacts, may reflect the influence of social determinants. Contacts with COVID-19–positive patients and/or HCP were not associated with higher odds of testing positive, supporting current infection control efforts. Targeted symptom and contact questionnaires may streamline symptomatic HCP testing for COVID-19.

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For editorial comment, see page 2295

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Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the causative agent of coronavirus disease 2019 (COVID-19), continues to surge globally. Health care personnel (HCP) are vital to the response, necessitating a healthy workforce. Sources of transmission to HCP can include patients, health care visitors, other HCP, and close contacts such as family and community members. Within each contact type, the risk of transmission may vary based on use of personal protective equipment, hand hygiene, physical distancing, aerosol exposure, ventilation management, and frequency and duration of contact. Severe acute respiratory syndrome coronavirus 2 acquisition among HCP may also be driven by social determinants, especially outside of the health care environment.

Monitoring for COVID-19 symptoms in HCP is important for early diagnosis and isolation, preventing spread in the health

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care system and among vulnerable populations. However, signs and symptoms can be subtle and mimic other common respiratory viral illnesses.[1] Therefore, health care systems have struggled to balance screening HCP for possible COVID-19, promoting illness absenteeism, and ensuring appropriate staffing for patient care, especially during surges. Data on prevalence of, and risk factors for, COVID-19 in HCP exist[2-6]; however, there is little information on the relationship between (1) health care role, (2) contact history, and (3) symptoms with subsequent SARS-CoV-2 polymerase chain reaction (PCR) testing results for symptomatic HCP.[7-11] We performed a prospective cohort study of symptomatic HCP at a large, tertiary care center to determine these associations.

METHODS

Study Design and Data Collection

We constructed a prospective cohort of symptomatic HCP working in a large, integrated health system serving more than 600,000 patients annually in the Upper Midwest. The system employed approximately 13,000 personnel at four hospitals and more than 80 outpatient sites. Data collection took place between March 25, 2020, and November 11, 2020.

Starting March 25, 2020, Employee Health Services offered SARS-CoV-2 nasopharyngeal swab PCR testing for any symptomatic HCP at no cost to employees. All HCP were eligible and encouraged to use the testing site if they had symptoms compatible with COVID-19. Employee Health Services—trained staff prospectively collected HCP self-reported symptoms, sociodemographics, contact history, and duration of contact using a standardized telephone survey performed at the time of testing. All data collection was performed before test results to prevent recall bias. Queried symptoms included cough, chills, shortness of breath, chest tightness, fever, anosmia (loss of smell), ageusia (loss of taste), pharyngitis (sore throat), rhinorrhea (runny nose), nasal congestion, headache, fatigue, myalgia (muscle pain), nausea and/or vomiting, and diarrhea. Ten questions focused on potential contacts with SARS-CoV-2—infected individuals including patients, health care visitors, other HCP, and family or community members. Specifically, Employee Health Services staff inquired about whether HCP had any known contact with a patient, another HCP member, or family/community member with (1) known COVID-19, (2) suspected or presumptive COVID-19 (ie, based on symptoms or clinical characteristics), or (3) a concurrent respiratory illness within the last 14 days. Contact was defined as being within 6 feet of this person who did not wear a surgical mask for any portion of the contact time. Additionally, contact with a nonmasked health care visitor was ascertained. If there was reported contact, the estimated duration was recorded (<10 minutes, 10-20 minutes, >20 minutes, or indeterminate). Additional variables included date of testing, test result, work location (inpatient, ambulatory setting, home, affiliated health care facility), and health care role. Roles were grouped as follows: (1) physician or advanced practice provider (APP); (2) nurse, medical assistant (MA), or therapist; (3) other HCP involved in direct patient care (eg, radiology technician); (4) other HCP not involved in direct patient care (eg, custodian); (5) medical/nursing trainee (eg, medical student, resident, nursing student); and (6) pharmacy. Retesting a symptomatic HCP was restricted to the following criteria: (1) those who had a previous negative test, but the symptoms had resolved completely and they now had new symptoms; (2) those who had a previous negative test whose previous symptoms had not completely resolved but have developed new symptoms or significant worsening of previous symptoms; and (3) for situations outside of the previous two, the case was discussed with employee health nurse or APP. Health care personnel included in the dataset who had more than one test over the study period were considered independent observations for each lab test-data pair. Health care personnel who tested positive were not included if they

were tested again at a later period to avoid counting a single infection twice.

Institutional COVID-19 Standards of Practice

Throughout the study period, the health care system's infection control measures for confirmed COVID-19 included negative pressure room isolation and donning fit-tested N-95 respirators, gowns, gloves, and face shields for room entries.[12] For all other HCP-patient interactions, HCP wore surgical masks made to ASTM standards and face shield. Surgical masks were reused for up to 3 days and N-95 for 7 days. Health care personnel received in-person personal protective equipment (PPE) training and emails regarding best practices to reduce transmission. All hospital visitors were instructed to wear a mask, although some did not comply completely with this policy early in the pandemic. Universal masking of staff, patients, and visitors was instituted on April 24, 2020, and remained in effect throughout the remaining period. Hospital visitation became increasingly restricted over the study period; for a significant portion no visitors were allowed except under special circumstances such as end of life. This study was considered quality improvement and was exempt from institutional review board evaluation.

SARS-CoV-2 Testing Methods

Health care personnel reporting symptoms compatible with COVID-19 were referred to a single testing site. Nasopharyngeal swab samples were collected using standardized technique by trained health care staff. Samples underwent real-time PCR (RT-PCR) testing by a validated in-house RT-PCR assay using the Centers for Disease Control and Prevention (CDC)—published primer-probe design or Hologic Panther Fusion SARS-CoV-2 Assay (Hologic, Inc). All assays were performed and interpretations made according to manufacturer's instructions for use under the emergency use authorization.

Statistical Analysis

We used χ^2 and Fisher exact tests to summarize demographic information, HCP contact history, and symptoms. We conducted univariate logistic regression to identify factors associated with a positive SARS-CoV-2 PCR test. Factors with P values less than or equal to .05 in univariate analysis were entered into a multivariable model. We used a post-estimation odds plot with confidence intervals to graph the results of the multivariable model and robust standard error estimates.[13] We also constructed an unweighted symptom score (0-7) using the seven symptoms that remained positively correlated with a positive test result in our multivariable model. We created a second multivariable model to assess the association between testing positive for SARS-CoV-2 and the symptom score, controlling for factors that were statistically significant in the univariate model but excluding individual symptom variables to avoid collinearity. All analyses were conducted using STATA 16 (StataCorp, 2019. Stata Statistical Software: Release 16).

RESULTS

A total of 7015 SARS-CoV-2 RT-PCR tests were performed on symptomatic HCP with 624 (8.9%) testing positive over the study period. Trends in the number of HCP tested and positivity rate paralleled regional surges, with very low prevalence and relatively lower testing volume early, a modest surge in June and July, and a substantial surge in September through November (Figure 1).

Testing, demographic, contact, and symptom data stratified by HCP role are presented in Table 1. Those in the nursing, MA, or therapist group comprised the largest subset of HCP tested (n=2968, 42.3%), followed by other HCP not involved in direct patient care, physician/APP, other HCP involved in direct patient care, medical/nursing trainees, and pharmacy. The proportion of symptomatic HCP testing positive differed across health care roles. Those serving in pharmacy roles had the highest proportion of positive tests (12.6%), followed by those not involved in direct patient care (11.2%). Physicians/APPs had the smallest proportion of positive tests (4.0%).

The majority of HCP worked in inpatient (n=3120, 44.5%) or ambulatory settings (n=3296, 47.0%). HCP not involved in direct patient care frequently worked from home.

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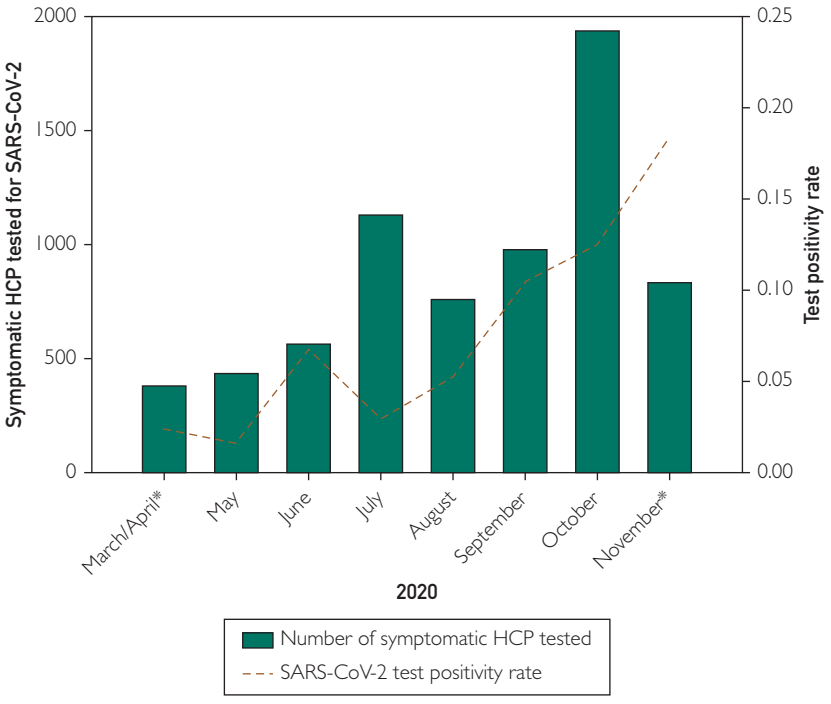

FIGURE 1. Monthly numbers of health care personnel (HCP) tested for severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) (bars) and proportion who tested positive (dashed line) over the study period. *March was combined with April as testing began March 25, 2020. November encompasses results from only the first 11 days.

Four thousand fourteen HCP (57.2%) reported 7080 contacts. Contact with an individual known to have COVID-19 was reported 2507 times, whereas contact with an individual suspected to have COVID-19 was reported 1654 times. Patient contacts were highest among those expected to have more patient interactions (eg, physician/APP and nurse/MA/therapist groups). Contact with another HCP with suspected or known COVID-19 was similar across health care roles. Physicians/APPs had fewer contacts with family members with known COVID-19 compared with other health care roles. When contact time could be estimated, a majority (n=2435, 69.9%) recalled spending more than 20 minutes within 6 feet of the index person. The proportion reporting this contact duration was similar across health care roles. Finally, the most common symptoms, in descending order, included pharyngitis, headache, and nasal congestion. All were reported in more than 50% of symptomatic HCP. Rhinorrhea, cough, fatigue, myalgia, chills, chest tightness, nausea/vomiting, diarrhea, shortness of breath, and fever were reported in 10% to 50% of cases; whereas loss of smell or loss of taste as a symptom were rare (<10%) (Figure 1). Symptoms were reported with similar frequency across HCP roles.

Univariate Analysis

On univariate analysis, all health care roles had significantly higher odds of testing positive compared with the referent physician/APP group (Table 2). Working from home and contact with a family or community member with known or suspected COVID-19 were associated with higher odds of testing positive for SARS-CoV-2. In the health care environment, contact with a patient who had a respiratory illness or nonmasked visitor was protective. Contact times longer than 20 minutes were associated with increased odds of positive test results. Nine symptoms

TABLE 1. Cohort Characteristics Stratified by HCP Role[a,b]

Characteristic	Total cohort	Nurse/MA/ therapist	Other HCP not involved in direct patient care	Physician/APP	Other HCP involved in direct patient care	Medial/ nursing trainee	Pharmacy
Symptomatic HCP	7015	2968	1739	910	862	361	175
Test positive for SARS-CoV-2	624 (8.9)	252 (8.5)	195 (11.2)	36 (4.0)	86 (10.0)	33 (9.1)	22 (12.6)
Work location							
Inpatient	3120 (44.5)	1708 (57.6)	364 (20.9)	367 (40.3)	349 (40.5)	261 (72.3)	71 (40.6)
Ambulatory	3196 (45.6)	1129 (38.0)	981 (56.4)	447 (49.1)	458 (53.1)	89 (24.7)	92 (53.1)
Home	511 (7.3)	58 (2.0)	349 (20.1)	36 (4.0)	49 (5.7)	8 (2.2)	11 (6.3)
Affiliated health care facility	188 (2.7)	73 (2.5)	45 (2.6)	60 (6.6)	6 (0.7)	3 (0.8)	1 (0.6)
Reported contacts with							
Patient with known COVID-19	950 (13.5)	506 (17.1)	57 (3.3)	141 (15.5)	154 (17.9)	86 (23.8)	6 (3.4)
Patient with suspected COVID-19	746 (10.6)	360 (12.1)	64 (3.7)	107 (11.8)	149 (17.3)	59 (16.3)	7 (4.0)
Patient with respiratory illness	1064 (15.2)	567 (19.1)	69 (4.0)	164 (18.0)	163 (18.9)	91 (25.2)	10 (5.7)
Nonmasked health care visitor	879 (12.5)	386 (13.0)	134 (7.7)	140 (15.4)	137 (15.9)	71 (19.7)	11 (6.3)
HCP with known COVID-19	712 (10.2)	350 (11.8)	123 (7.1)	65 (7.1)	113 (13.1)	35 (9.7)	26 (14.9)
HCP with suspected COVID-19	284 (4.1)	136 (4.6)	57 (3.3)	18 (2.0)	51 (5.9)	14 (3.9)	8 (4.6)
HCP with respiratory illness	228 (3.3)	105 (3.5)	50 (2.9)	29 (3.2)	29 (3.4)	12 (3.3)	3 (1.7)
Family/community member with known COVID-19	847 (12.1)	367 (12.4)	256 (14.7)	61 (6.7)	110 (12.8)	33 (9.1)	20 (11.4)
Family/community member with suspected COVID-19	624 (8.9)	232 (7.8)	165 (9.5)	87 (9.6)	88 (10.2)	30 (8.3)	21 (12.0)
Family/community member with respiratory illness	747 (10.7)	307 (10.3)	175 (10.1)	141 (15.5)	71 (8.2)	41 (11.4)	12 (6.9)
Contact duration							
Not recalled or applicable	3531 (50.3)	1346 (45.4)	1082 (62.2)	444 (48.8)	404 (46.9)	150 (41.6)	105 (60.0)
<10 min	704 (10.0)	309 (10.4)	137 (7.9)	93 (10.2)	108 (12.5)	47 (13.0)	10 (5.7)
10-20 min	345 (4.9)	147 (5.0)	47 (2.7)	65 (7.1)	44 (5.1)	34 (9.4)	8 (4.6)
>20 min	2435 (34.7)	1166 (39.3)	473 (27.2)	308 (33.9)	306 (35.5)	130 (36.0)	52 (29.7)
Symptoms							
Cough	2926 (41.7)	1189 (40.1)	802 (46.1)	351 (38.6)	373 (43.3)	132 (36.6)	79 (45.1)
Chills	1445 (20.6)	603 (20.3)	402 (23.1)	149 (16.4)	189 (21.9)	67 (18.6)	35 (20.0)
Shortness of breath	864 (12.3)	357 (12.0)	280 (16.1)	60 (6.6)	120 (13.9)	22 (6.1)	25 (14.3)
Chest tightness	1218 (17.4)	511 (17.2)	349 (20.1)	92 (10.1)	193 (22.4)	42 (11.6)	31 (17.7)
Fever	787 (11.2)	344 (11.6)	227 (13.1)	74 (8.1)	90 (10.4)	30 (8.3)	22 (12.6)
Anosmia	431 (6.1)	192 (6.5)	113 (6.5)	45 (5.0)	52 (6.0)	20 (5.5)	9 (5.1)
Ageusia	399 (5.7)	174 (5.9)	113 (6.5)	41 (4.5)	47 (5.5)	15 (4.2)	9 (5.1)
Pharyngitis	4361 (62.2)	1846 (62.2)	1044 (60.0)	583 (64.1)	545 (63.2)	245 (67.9)	98 (56.0)
Rhinorrhea	3344 (47.7)	1403 (47.3)	819 (47.1)	474 (52.1)	411 (47.7)	160 (44.3)	77 (44.0)
Nasal congestion	4115 (58.7)	1775 (59.8)	988 (56.8)	537 (59.0)	505 (58.6)	208 (57.6)	102 (58.3)
Headache	4265 (60.8)	1885 (63.5)	1076 (61.9)	465 (51.1)	545 (63.2)	197 (54.6)	97 (55.4)
Fatigue	2026 (28.9)	876 (29.5)	560 (32.2)	198 (21.8)	237 (27.5)	107 (29.6)	48 (27.4)
Myalgia	1910 (27.2)	791 (26.7)	520 (29.9)	221 (24.3)	243 (28.2)	90 (24.9)	45 (25.7)
Nausea/vomiting	1172 (16.7)	539 (18.2)	293 (16.9)	102 (11.2)	152 (17.6)	52 (14.4)	34 (19.4)
Diarrhea	897 (12.8)	381 (12.8)	266 (15.3)	93 (10.2)	103 (12.0)	34 (9.4)	20 (11.4)

[a]APP, advanced practice provider; COVID-19, coronavirus disease 2019; HCP, health care personnel; MA, medical assistant; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.

[b]Values shown are n (%).

(cough, chills, fever, anosmia, ageusia, nasal congestion, headache, fatigue, and myalgia) were associated with increased odds of testing positive for SARS-CoV-2, whereas two (pharyngitis and nausea/vomiting) were associated with decreased odds. The proportion of HCP

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TABLE 2. Odds Ratios of Testing Positive for SARS-CoV-2 PCR Test by Univariate Analysis of HCP Role, Contact History, and Symptoms[a]

	Tested positive (N=624) n (%)	Tested negative (N=6391) n (%)	Unadjusted odds ratio (95% CI)	*P*
Healthcare role				
Physician/APP	36 (5.8)	874 (13.7)	Ref	
Nurse/MA/therapist	252 (40.4)	2716 (42.5)	2.25 (1.58-3.22)	**<.001**[b]
Other HCP not involved in direct patient care	195 (31.3)	1544 (24.2)	3.07 (2.13-4.42)	**<.001**
Other HCP involved in direct patient care	86 (13.8)	776 (12.1)	2.69 (1.80-4.02)	**<.001**
Medical/nursing trainee	33 (5.3)	328 (5.1)	2.44 (1.50-3.98)	**<.001**
Pharmacy	22 (3.5)	153 (2.4)	3.49 (2.00-6.10)	**<.001**
Work location				
Inpatient	278 (44.6)	2842 (44.5)	Ref	
Ambulatory	261 (41.8)	2935 (45.9)	0.90 (0.76-1.08)	.290
Home	67 (10.7)	444 (6.9)	1.54 (1.16-2.05)	**.003**
Affiliated health facility	18 (2.9)	170 (2.7)	1.08 (0.66-1.79)	.757
Reported contacts with				
Patient with known COVID-19	97 (15.5)	853 (13.3)	1.19 (0.95-1.50)	.13
Patient with suspected COVID-19	61 (9.8)	685 (10.7)	0.90 (0.68-1.19)	.47
Patient with respiratory illness	77 (12.3)	987 (15.4)	0.77 (0.60-0.99)	**.04**
Nonmasked health care visitor	58 (9.3)	821 (12.9)	0.69 (0.53-0.92)	**.01**
HCP with known COVID-19	69 (11.1)	643 (10.1)	1.11 (0.85-1.44)	.43
HCP with suspected COVID-19	24 (3.9)	260 (4.1)	0.94 (0.62-1.44)	.92
HCP with respiratory illness	16 (2.6)	212 (3.3)	0.77 (0.46-1.28)	.35
Family/community member with known COVID-19	212 (34.0)	635 (9.9)	4.66 (3.88-5.61)	**<.001**
Family/community member with suspected COVID-19	106 (17.0)	517 (8.1)	2.32 (1.85-2.92)	**<.001**
Family/community member with respiratory illness	72 (11.5)	675 (10.6)	1.10 (0.85-1.43)	.45
Contact duration				
Not recalled or applicable	245 (39.3)	3286 (51.4)	Ref	
<10 min	37 (5.9)	667 (10.4)	0.74 (0.52-1.06)	.103
10-20 min	19 (3.0)	326 (5.1)	0.78 (0.48-1.26)	.315
>20 min	323 (51.8)	2112 (33.0)	2.05 (1.72-2.44)	**<.001**
Symptoms				
Cough	417 (66.8)	2509 (39.3)	3.10 (2.6-3.7)	**<.001**
Chills	234 (37.5)	1211 (18.9)	2.57 (2.2-3.1)	**<.001**
Shortness of breath	88 (14.1)	776 (12.1)	1.19 (0.94-1.51)	.16
Chest tightness	117 (18.8)	1101 (17.2)	1.11 (0.90-1.37)	.34
Fever	155 (24.8)	632 (9.9)	3.01 (2.47-3.68)	**<.001**
Anosmia	127 (20.3)	304 (4.8)	5.12 (4.08-6.42)	**<.001**
Ageusia	123 (19.7)	276 (4.3)	5.43 (4.32-6.85)	**<.001**
Pharyngitis	357 (57.2)	4004 (62.7)	0.80 (0.67-0.94)	**.007**
Rhinorrhea	310 (49.7)	3034 (47.5)	1.09 (0.93-1.29)	.29
Nasal congestion	417 (66.8)	3698 (57.9)	1.47 (1.23-1.75)	**<.001**
Headache	453 (72.6)	3812 (59.7)	1.79 (1.49-2.15)	**<.001**
Fatigue	246 (39.4)	1780 (27.9)	1.68 (1.42-1.99)	**<.001**
Myalgia	286 (45.8)	1624 (25.4)	2.48 (2.10-2.94)	**<.001**
Nausea/vomiting	77 (12.3)	1095 (17.1)	0.68 (0.53-0.87)	**.002**
Diarrhea	88 (14.1)	809 (12.7)	1.13 (0.89-1.44)	.30

[a]APP, advanced practice provider; COVID-19, coronavirus disease 2019; HCP, health care personnel; MA, medical assistant; PCR, polymerase chain reaction; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.
[b]Bold values indicate statistically significant values.

who tested positive versus negative for SARS-CoV-2 for each symptom is shown in Figure 2.

Multivariable Analysis

In multivariable analysis (Table 3), health care role remained a strong predictor of

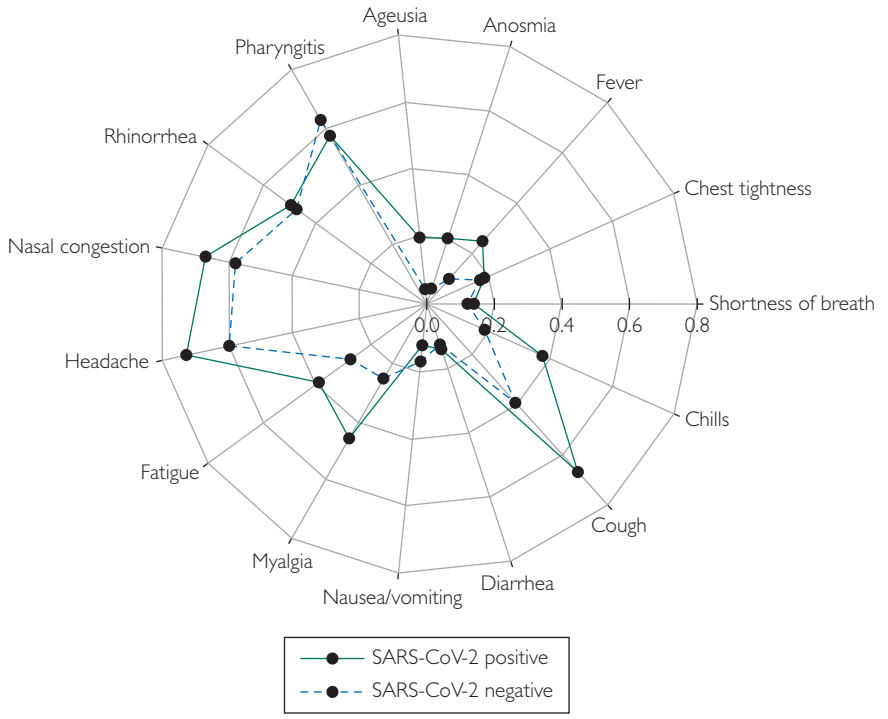

FIGURE 2. Radar plot showing the proportion of health care personnel with each symptom stratified by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) polymerase chain reaction test result.

testing results, with all health care roles having significantly higher odds of testing positive for SARS-CoV-2 compared with the physician/APP group. Pharmacy had the highest odds (odds ratio [OR], 3.06; 95% CI, 1.69 to 5.52), followed by medical/nursing trainees (OR, 2.76; 95% CI, 1.63 to 4.67), other HCP not involved in direct patient care (OR, 2.21; 95% CI, 1.49 to 3.29), other HCP involved in direct patient care (OR, 2.18; 95% CI, 1.41 to 3.35), and nurse/MA/therapist group (OR, 1.79; 95% CI, 1.23 to 2.60). In the adjusted model, there was no significant difference in the odds of a positive test across work locations or contact duration, nor was there a significant difference based on contact with a patient who had a respiratory illness or contact with a nonmasked visitor. However, contact with a family or community member with known or suspected COVID-19 remained highly associated with a positive SARS-CoV-2 test (OR, 4.03; 95% CI, 3.13 to 5.18; and OR, 1.65; 95% CI, 1.24 to 2.19; respectively). Seven symptoms remained statistically significant in the multivariable model. These included, in descending order, cough, anosmia, ageusia, fever, myalgia, chills, and headache. The two symptoms that were negatively correlated were pharyngitis and nausea/vomiting.

We created a second multivariable model using the composite symptom score based on the seven symptoms that were associated with increased odds of testing positive in the main multivariable model (cough, anosmia, ageusia, fever, myalgia, chills, and headache). Among HCP with none of the seven symptoms, 3.1% (n=35) tested positive. More than 40% of HCP with five or more of the seven symptoms tested positive (Table 4). The odds of testing positive almost doubled (OR, 1.93; 95% CI, 1.82 to 2.07) for each additional symptom.

DISCUSSION

We report relationships between (1) health care role, (2) contact history, and (3) symptoms and testing positive for SARS-CoV-2 in

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a large, prospective cohort of symptomatic HCP. The odds of a positive test differed by job role and were associated with family or community exposures, but not with exposures within the health care environment. There may be several explanations for this finding and it is important to acknowledge we could not definitively distinguish between SARS-CoV-2 infection acquired occupationally or from the community. A possibility we theorize, but could not test, was whether differences in sociodemographics and/or socioeconomic status played a role. For example, symptomatic physicians and APPs had significantly reduced odds of testing positive for SARS-CoV-2 compared with all other health care roles. The one exception to the trend was pharmacy. This may reflect the extremely high volume of interactions many pharmacy personnel have with persons who have an unknown infectious (ie, COVID-19) history, as well as PPE, hand hygiene, and physical distancing challenges that are unique to their specific work environment. Pharmacists may also work at multiple locations with variation in community SARS-CoV-2 transmission. However, pharmacy was the smallest group with a wide confidence interval around our point estimate. Therefore, the true odds may be aligned with our hypothesized socioeconomic trend and poorly estimated in our model.

Numerous studies have reported an association between COVID-19 and social disadvantage.[14-21] The health care system can serve as a unique microcosm for understanding COVID-19 disparities. In our study population, all HCP received email reminders of best practices to remain safe in and out of the health care environment. Testing for symptomatic individuals was accessible and free regardless of specific job roles. Therefore, better education or access to testing is unlikely to explain the lower odds of a positive test among physicians/APPs compared with other HCP groups. Instead, we suspect physicians/APPs may have increased resources to more effectively reduce their risk of SARS-CoV-2 infection. For example, higher earning individuals may be more likely to live in detached, single-dwelling homes where distancing is feasible. They may be able to afford in-home care or education options for their dependents, which may reduce exposure risk. Lower earners may have additional risk due to second jobs or dependence on public services such as transportation. Additionally, social behaviors and interactions that are independent of economic factors may differ between these

TABLE 3. Odds Ratios of Testing Positive for SARS-CoV-2 PCR Test by Multivariable Analysis of HCP Role, Contact History, and Symptoms[a]

	Adjusted odds ratio	95% CI	*P*
Healthcare role			
Physician/APP	Ref		
Nurse/MA/Therapist	1.79	1.23-2.60	**.002**[b]
Other HCP not involved in direct patient care	2.21	1.49-3.29	**<.001**
Other HCP involved in direct patient care	2.18	1.41-3.35	**<.001**
Medical or nursing trainee	2.76	1.63-4.67	**<.001**
Pharmacy	3.06	1.69-5.52	**<.001**
Work location			
Inpatient	Ref		
Ambulatory	0.84	0.69-1.04	.108
Home	0.80	0.56-1.15	.231
Affiliated health facility	0.86	0.47-1.57	.625
Reported contacts with			
Patient with respiratory illness	0.79	0.58-1.06	.120
Nonmasked health care visitor	0.75	0.53-1.04	.084
Family/community member with known COVID-19	4.03	3.13-5.18	**<.001**
Family/community member with suspected COVID-19	1.65	1.24-2.19	**.001**
Contact duration			
Not recalled or applicable	Ref		
<10 min	0.79	0.54-1.17	.236
10-20 min	0.62	0.37-1.05	.074
>20 min	1.25	0.97-1.59	.080
Symptoms			
Cough	2.88	2.36-3.50	**<.001**
Chills	1.71	1.37-2.14	**<.001**
Fever	2.34	1.82-3.00	**<.001**
Anosmia	2.86	2.10-3.89	**<.001**
Ageusia	2.77	2.02-3.78	**<.001**
Sore throat	0.60	0.50-0.73	**<.001**
Nasal congestion	1.16	0.94-1.42	.161
Headache	1.26	1.02-1.55	**.030**
Fatigue	0.93	0.75-1.15	.480
Myalgia	1.82	1.48-2.24	**<.001**
Nausea/vomiting	0.52	0.39-0.70	**<.001**

[a]APP, advanced practice provider; COVID-19, coronavirus disease 2019; HCP, health care personnel; MA, medical assistant; PCR, polymerase chain reaction; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.
[b]Bold values indicate statistically significant values.

TABLE 4. Number of Symptoms, Positivity Rate, and Odds Ratio of Testing Positive Associated With Increasing Symptom Number by Multivariable Analysis[a]

Number of symptoms[b]	Total	Tested positive n (%)	Multivariable adjusted OR (95% CI) of test result by number of symptoms
0	1116	35 (3.1)	For each additional symptom, adjusted[c] OR of testing positive was 1.94 (1.82-2.07), $P<.001$
1	2393	81 (3.4)	
2	1770	152 (8.6)	
3	1009	135 (13.4)	
4	497	127 (25.6)	
5	178	72 (40.4)	
≥6	52	22 (42.3)	

[a]COVID-19, coronavirus disease 2019; OR, odds ratio.
[b]Symptoms included cough, chills, fever, anosmia, ageusia, headache, and myalgia.
[c]Adjusted for health care role, contact with patient with respiratory illness, contact with nonmasked visitor, contact with family/community member with known COVID-19, contact with family/community member with suspected COVID-19, duration of contact, and work location.

groups. Further studies incorporating income and other social determinants are necessary to examine the influence of these factors on differences in SARS-CoV-2 infection across health care roles.

Our study and others suggest that SARS-CoV-2 transmission to HCP within the hospital environment is relatively rare if strict infection control practices are followed.[12,21-24] Neither patients nor HCP contacts were associated with higher odds of testing positive for SARS-CoV-2. However, HCP who had contact with a COVID-19–positive family or community member experienced a greater than four-fold increased odds of a positive test. Given that SARS-CoV-2 is highly contagious, and contact with a family or community member is not likely to occur under the same PPE standards as in the health care environment, one would expect these interactions to lead to transmission. In addition, the protective association on univariate analysis between contact with a patient with a respiratory illness and contact with a nonmasked visitor is logical when put into context. First, if HCP reported contact with a patient who had a respiratory illness, but not known or suspected COVID-19, it most often meant that the patient had a negative SARS-CoV-2 test result. Secondly, nonmasked visitors were primarily an event of the first few months of the pandemic when the local prevalence was very low and mask mandates were not strictly enforced. For the rest of study period, hospital visitation was more restrictive. Thus, the odds of HCP getting COVID-19 from either of these two contact situations should be low.

In our cohort, many specific symptoms were associated with a symptomatic HCP testing positive for SARS-CoV-2, including cough, anosmia, ageusia, fever, myalgia, chills, and headache. We also demonstrated the importance of multiple symptoms from this group; as for each additional symptom, the odds of testing positive for SARS-CoV-2 doubled. We believe this data is helpful to health care institutions that would like to create streamlined symptom questionnaires, prioritize testing queues, and triage HCP before definitive PCR testing. However, we do not think that symptoms alone may be a substitute for testing.

A number of other publications found similar associations between symptoms and SARS-CoV-2 testing for symptomatic HCP.[7-11] Most demonstrated the presence of fever, cough, ageusia, or anosmia are associated with a higher odds of testing positive; few have similarly shown gastrointestinal symptoms and pharyngitis may be associated with significantly lower odds. However, prior results have been hampered by: (1) limited

power, with on average 752 symptomatic HCP (range, 295-1698); (2) brief study durations over relatively small portions of the pandemic period (average 7.5 weeks, all between March and June 2020); and (3) limited prevalence. The latter two may skew symptom reporting toward common mimicker illnesses that were temporally and geographically associated at that time. These limitations are not present in our study, which corroborates earlier findings.

Despite our study's strengths, including the size and breadth of the population, the duration of evaluation through periods of low, moderate, and high COVID-19 activity within our local community, the prospective approach to symptom and contact data collection, and equal and free access to testing, we also acknowledge limitations. Contact and symptom data are self-reported and we cannot conclusively determine all contact events. Likewise, genome sequencing was not performed routinely to link specific contacts with infection events. There is heterogeneity within some health care role groups in terms of job title, responsibilities, experience, and income. We were unable to examine specific socioeconomic status and sociodemographic factors such as race. Finally, this is a single-center cohort study, which may limit generalizability. Future studies incorporating social, behavioral, and economic determinants will be important to elucidate why we observed differences in SARS-CoV-2 infection across health care roles.

CONCLUSION

We demonstrated significant factors associated with positive SARS-CoV-2 testing in symptomatic HCP across three distinct areas: health care role, contact history, and symptoms. Our findings of different risk across HCP roles, after controlling for known contacts, reinforce the need for further investigations into COVID-19 disparities. They suggest equal education and testing will not be enough to overcome differences. Our findings emphasize that existing infection control practices limit transmission to HCP within the health care environment. Lastly, the association between seven symptoms and positive test results, as well as the increased odds of testing positive with each additional symptom, may be useful in augmenting HCP testing strategies. Whereas this study limited the analysis to HCP, it may be reasonable to apply some of our findings, including contact history with family/community members with known or suspected COVID-19 and the seven symptoms, to the screening process for other populations.

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Abbreviations and Acronyms: **APP** = advanced practice provider; **ASTM** = American Society for Testing and Materials (formerly); **CDC** = Centers for Disease Control and Prevention; **COVID-19** = coronavirus disease 2019; **HCP** = health care personnel; **IRB** = institutional review board; **MA** = medical assistant; **NP** = nasopharyngeal; **OR** = odds ratio; **PCR** = polymerase chain reaction **PPE** = personal protective equipment; **RT-PCR** = real-time polymerase chain reaction; **SARS-CoV-2** = severe acute respiratory syndrome coronavirus 2

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