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Diagnosed and Undiagnosed COVID-19 in US Emergency Department Health Care Personnel: A Cross-sectional Analysis

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Study objective: We determine the percentage of diagnosed and undiagnosed severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection among a sample of US emergency department (ED) health care personnel before July 2020.

Methods: This was a cross-sectional analysis of ED health care personnel in 20 geographically diverse university-affiliated EDs from May 13, to July 8, 2020, including case counts of prior laboratory-confirmed coronavirus disease 2019 (COVID-19) diagnoses among all ED health care personnel, and then point-in-time serology (with confirmatory testing) and reverse transcriptase–polymerase chain reaction testing in a sample of volunteers without a previous COVID-19 diagnosis. Health care staff were categorized as clinical (physicians, advanced practice providers, and nurses) and nonclinical (clerks, social workers, and case managers). Previously undiagnosed infection was based on positive SARS-CoV-2 serology or reverse transcriptase–polymerase chain reaction result among health care personnel without prior diagnosis.

Results: Diagnosed COVID-19 occurred in 2.8% of health care personnel (193/6,788), and the prevalence was similar for nonclinical and clinical staff (3.8% versus 2.7%; odds ratio 1.5; 95% confidence interval 0.7 to 3.2). Among 1,606 health care personnel without previously diagnosed COVID-19, 29 (1.8%) had evidence of current or past SARS-CoV-2 infection. Most (62%; 18/29) who were seropositive did not think they had been infected, 76% (19/25) recalled COVID-19–compatible symptoms, and 89% (17/19) continued to work while symptomatic. Accounting for both diagnosed and undiagnosed infections, 4.6% (95% confidence interval 2.8% to 7.5%) of ED health care personnel were estimated to have been infected with SARS-CoV-2, with 38% of those infections undiagnosed.

Conclusion: In late spring and early summer 2020, the estimated prevalence of severe acute respiratory syndrome coronavirus 2 infection was 4.6%, and greater than one third of infections were undiagnosed. Undiagnosed SARS-CoV-2 infection may pose substantial risk for transmission to other staff and patients. [Ann Emerg Med. 2021;78:27-34.]

Please see page 28 for the Editor's Capsule Summary of this article.

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INTRODUCTION

Background

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) spreads primarily through close personal contact,[1,2] and an analysis of self-reported US and UK data identified that health care personnel had higher risk of coronavirus disease 2019 (COVID-19) than non–health care personnel (hazard ratio 3.4). As of November 1, 2020, the Centers for Disease Control and Prevention had identified greater than 200,000 US health care personnel who had contracted COVID-19.[2,3] These findings parallel data from the 2003 severe acute respiratory syndrome 1 outbreak that documented health care personnel transmission, especially for those performing aerosol-generating airway procedures.[4]

Importance

Emergency department (ED) health care personnel may be at particularly high risk because they perform resuscitation procedures and frequently treat patients with unknown infection status.[5] Population-based seroprevalence studies provide evidence that SARS-CoV-2

*All members are listed in the Appendix.

Editor's Capsule Summary

What is already known on this topic

Coronavirus disease 2019 (COVID-19) infection in health care workers, diagnosed and undiagnosed, can create risk to them and others.

What question this study addressed

What was the frequency of current or previous COVID-19 infection in emergency department (ED) workers in the May to July 2020 period and did they work during the interval?

What this study adds to our knowledge

In a multisite volunteer sample of 6,788 ED workers, 4.6% had evidence of COVID-19 infection, with 38% of those infections undiagnosed outside of this trial. In individuals without diagnosis, 89% of those who recalled symptoms also continued to work.

How this is relevant to clinical practice

ED worker COVID-19 acquisition exists, requiring directed strategies for the safety of all.

infection is frequently undiagnosed.[6-8] Undiagnosed infection among health care personnel may pose a threat of infection transmission to patients and other health care personnel.

Goals of This Investigation

We describe the prevalence of diagnosed and undiagnosed COVID-19 among US health care personnel working at 20 geographically diverse US EDs before July 2020.

MATERIALS AND METHODS

Study Design, Setting, and Selection of Participants

COVID-19 Evaluation of Risk in Emergency Departments is a multicenter prospective surveillance of health care personnel for SARS-CoV-2 infection at 20 geographically diverse, high-volume, university-affiliated, US, hospital EDs (in 15 states; all sites are listed in the acknowledgments) that included assessment of baseline cross-sectional seroprevalence between May 13, 2020 and July 8, 2020. We collected total COVID-19 case counts identified from among all health care personnel in participating EDs, and then we enrolled a sample of physicians, nurses, advanced practice providers, and nonclinical health care personnel (clerks, social workers, case managers, and others without routine patient contact who worked in the ED) not previously having received a diagnosis of COVID-19. This activity was determined to meet the requirements of public health surveillance because it was authorized by a public health authority for assessing risk to health care personnel during the COVID-19 pandemic as defined in 45 CFR 46.102(l)(2),[9] and participating health care personnel provided informed consent. This article is reported in accordance with Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement.[10]

Selection of Participants and Data Collection and Processing

We collected ED facility-level data, including counts of employees' COVID-19 diagnoses from occupational health reports. Additionally, 20 local teams recruited approximately 80 volunteer health care personnel at each site who had not received a diagnosis of COVID-19: 40 physicians/advanced practice providers, 20 nurses, and 20 nonclinical staff (20.8% of eligible employees). The sample size was determined from the parent study to detect an attributable risk of COVID-19 acquisition of 4% (α=.05; power=0.9). Participants completed a survey about their job and COVID-19 exposures[11] and provided a blood sample and a proctored self-collected nasal swab for baseline serology and SARS-CoV-2 reverse transcriptase–polymerase chain reaction (PCR) testing, respectively. After these initial results were reported, we asked participants with positive results to provide information about symptoms and exposures since December 31, 2019. We collected COVID-19 community cumulative incidence from public health reports for the health service area of each facility as of June 29, 2020.

Nasal swabs were analyzed by SARS-CoV-2 reverse transcriptase–PCR (limit of detection 0.009 median tissue culture infectious dose/mL). Anti–SARS-CoV-2 immunoglobulin G (nucleocapsid phosphoprotein; sensitivity 100% and specificity 99.6%) was measured with the Architect i2000 (Abbott Laboratories, Chicago, IL), with positive serology results confirmed by orthogonal testing using a spike glycoprotein (sensitivity 90% and specificity 100%) enzyme-linked immunosorbent assay (EUROIMMUN, Lubeck, Germany). We designated health care personnel as testing positive for prior SARS-CoV-2 infection if they had positive results on both the nucleocapsid and spike immunoglobulin G assays, or positive nasal PCR result.

Primary Data Analysis

We calculated summary statistics as counts and percentages (with 95% confidence intervals [CIs], adjusted for clustering by site) for categoric variables, and we used medians and interquartile ranges for continuous variables. We calculated odds ratios with adjusted 95% CIs adjusted for clustering by site to compare COVID-19 prevalence between strata of interest. We calculated the percentage of diagnosed infections (documented by testing before the start of this project) as the ratio of the number of occupational health–reported infections among all ED health care personnel (from December 31, 2019, to site enrollment) and the total number of ED health care personnel at participating sites. We calculated the

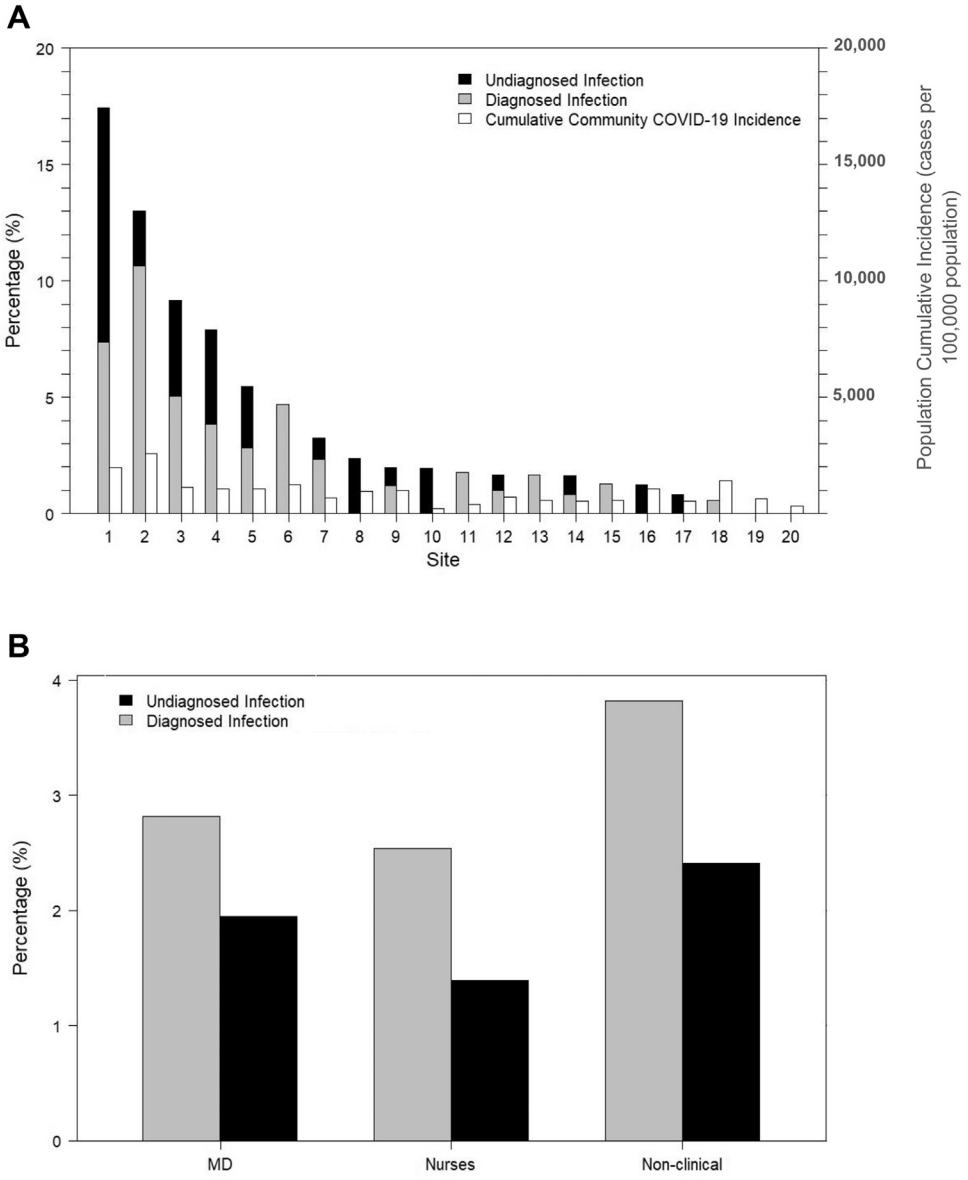

Figure. Prevalence of diagnosed and estimated undiagnosed SARS-CoV-2 infections in US ED health care personnel, July 2020, by site. *A*, The percentage of health care personnel with diagnosed and undiagnosed infections in a sample of 20 US EDs at enrollment (May 13 to July 8, 2020). Gray bars represent the percentage of diagnosed infections as recorded in occupational health reports at the beginning of the enrollment period. Black bars represent undiagnosed infections estimated from a sample of previously undiagnosed disease in volunteer health care personnel in whom serology and nasal reverse transcriptase–PCR testing was performed (Table 2). White bars show the cumulative community COVID-19 incidence (June 29, 2020; right vertical axis). In total, 38% of all infections among ED health care personnel were undiagnosed before surveillance PCR and serology testing. *B*, The relationship between the percentage of recognized and estimated unrecognized infections in this sample, stratified by job classification. Gray bars represent diagnosed infections, and black bars represent undiagnosed ones.

Table 1. Characteristics of 1,606 US ED health care personnel, stratified by baseline SARS-CoV-2 serology results.

Category	Baseline Negative Serology Result (n=1,577), No. (%)	Baseline Positive Serology Result (n=29), No. (%)
Job classification		
Attending physician	360 (23)	6 (21)
Resident physician	264 (17)	8 (28)
Advanced practice provider (physician assistant, nurse practitioner)	155 (10)	1 (3)
Nurse	404 (26)	6 (21)
Nonclinical staff	394 (25)	8 (28)
Gender		
Men	569 (36)	12 (41)
Women	1,001 (64)	17 (59)
Transgender/nonconforming	7 (0.4)	0
Race		
White	1,264 (80)	16 (55)
Black	118 (7)	13 (45)
Asian	132 (8)	2 (7)
Other	76 (5)	1 (3)
Ethnicity		
Hispanic/Latino	148 (10)	4 (14)
Age, y		
≤30	368 (23)	8 (28)
31–40	613 (39)	9 (31)
41–50	313 (20)	6 (21)
51–60	216 (14)	6 (21)
≥61	67 (4)	0
Suspected infection with COVID-19		
Yes (includes presumed positive result regardless of whether testing was conducted)	179 (11)	11 (38)

Depicted is the percentage of health care personnel in each category at project enrollment (May 13 to July 8, 2020).

conditional percentage of undiagnosed infections as the ratio of participants in the prospective seroprevalence project with positive test results and the number of tested health care personnel participants at their baseline evaluation. We estimated the number of ED health care personnel with undiagnosed infection by multiplying the percentage of test-positive participants in each job classification at each site by the number of site-specific ED health care personnel in that classification (including nonparticipating personnel) not previously having received a diagnosis of COVID-19. We estimated the community population cumulative incidence across all sites as the mean of the health service area–specific population cumulative incidence weighted by the total number of employees in each participating ED. We estimated unadjusted odds ratios to describe the probability of infection by job category.

RESULTS

The Figure shows the percentage of health care personnel with diagnosed and undiagnosed infections in the 20 US EDs at enrollment (May 13 to July 8, 2020). Across all centers, the aggregate number of ED health care personnel with previously diagnosed COVID-19 from December 31, 2019, to enrollment was 193 of 6,788 (2.8%). Diagnosed COVID-19 was reported to occupational health clinics in 3.8% of nonclinical staff (38/993) versus 2.7% of clinical staff (155/5,795) (odds ratio 1.5). During this period, the population cumulative incidence of diagnosed COVID-19 ranged from 214 to 2,778 per 100,000 population, with a weighted population cumulative incidence of 1,058 per 100,000 (1.1%) (Figure).

Among 1,606 selected participants without prior COVID-19 diagnosis who had baseline serology and PCR testing, 29 (1.8%) had evidence of undiagnosed SARS-CoV-2 infection (28 by serology and 1 by PCR) (Figure). Table 1 shows factors associated with severe acute respiratory syndrome coronavirus 2 infection. Across all sites, the estimated combined prevalence of diagnosed and undiagnosed COVID-19 was 4.6% (95% CI 2.8% to 7.5%), with 38% of infections being undiagnosed. Two sites had prevalence of prior infection greater than 10%. Total estimated infections were highest for nonclinical staff and lowest for nursing staff (6.2% versus 4.0%, respectively; odds ratio 1.6; 95% CI 1.1 to 2.4) (Table 2).

Participants who tested negative for COVID-19 were more likely to believe that they had not been infected (88% [1,398/1,577] seronegative versus 62% [18/29] seropositive). Among 25 respondents with evidence of undiagnosed SARS-CoV-2 infection (86% response rate to additional survey), 19 (76%) reported prior symptoms compatible with COVID-19. Six participants (24%) had nasopharyngeal testing performed (all results negative) (Table 3), and 17 (89%) of those who reported symptoms worked in the ED while symptomatic (median 3 days; interquartile range 2 to 4).

LIMITATIONS

Our most significant limitation was the risk of applying an estimate of undiagnosed infection from a sample of

Table 2. Diagnosed and projected undiagnosed cases in 20 US EDs.

Category	Physicians/APPs (%; 95% CI)	Nurses (%; 95% CI)	Nonclinical Staff (%; 95% CI)	Total (%; 95% CI)
Diagnosed, cases/total HCP	71/2,506 (2.8; 2.0–4.1)	84/3,289 (2.6; 1.2–5.4)	38/993 (3.8; 1.3–10.5)	193/6,788 (2.8; 1.6–5.0)
Undiagnosed, projected cases/total HCP	49/2,506 (2.0; 0.9–4.0)	46/3,289 (1.4; 0.6–3.1)	24/993 (2.4; 1.3–4.6	119/6,788 (1.8; 1.0–3.1)
Total diagnosed+ undiagnosed/total HCP	120/2,506 (4.8; 3.1–7.3)	130/3,289 (4.0; 2.0–7.7)	62/993 (6.2; 2.9–12.9)	312/6,788 (4.6; 2.8–7.5)
Projected undiagnosed cases/total projected cases	49/120 (40.8; 26.0–57.5)	46/130 (35.4; 20.2–54.3)	24/62 (38.7; 17.8–64.8)	119/312 (38.1; 25.9–52.1)

APP, advanced practice provider; HCP, health care personnel.

volunteers to the entire health care personnel population. Because we did not randomly select health care personnel for participation in our surveillance testing, our volunteer participants may have been more likely or less likely to include the highest-risk health care personnel. Our estimates of the burden of undiagnosed infection came from extrapolation to the larger ED health care personnel population, but this sampling method introduces uncertainty into our estimate of disease.

Additionally, participating sites were academic centers with infection control programs in place, which may not be fully representative of all US EDs. Our project is further limited by the occupational health data used to tabulate diagnosed COVID-19 cases. Our reliance on occupational health records may have undercounted infections among the nonparticipating health care personnel. Recall bias may have affected the quality of data in seropositive participants. The strengths of this project include geographic diversity and rigorous high-accuracy testing procedures.

DISCUSSION

SARS-CoV-2 infection occurred among an estimated 4.6% of US ED health care personnel and many infections were undiagnosed. Single-site studies of US health care personnel have shown SARS-CoV-2 seropositivity rates between 0.4% and 46%,[5,12] and a recent multisite seroprevalence survey of frontline health care personnel conducted from April 13 to June 19, 2020 estimated a seropositivity at 6%.[13] Our methods differ from those of the prior multisite study in that we enrolled both clinical and nonclinical staff in EDs only, reported occupational health data, and used an orthogonal serology testing strategy specifically designed to limit false-positive test results. That one third of infections were undiagnosed highlights the importance of infection control strategies not only to prevent health care personnel infections (eg, use of personal protective equipment [PPE]) but also to limit spread from health care personnel to others (eg, universal use of masks).[14]

Recognition of SARS-CoV-2 infection by health care personnel was unreliable, with greater than 60% of those infected unaware that they had COVID-19. Many of these health care personnel worked during a period when they had COVID-compatible symptoms because their infection was early in the pandemic, symptoms were perceived as trivial, or negative PCR testing reassured them it was safe to work. Additionally, approximately one quarter of infections appeared to be asymptomatic. Enhanced PPE use by health care personnel, health care personnel surveillance for infection, nonpunitive workplace illness measures, and priority access to potential vaccine may decrease the risk of viral transmission from health care personnel to vulnerable patients and help maintain an effective frontline health care workforce. Ultimately, COVID-19 Evaluation of Risk in Emergency Departments is an ongoing prospective surveillance project determining rates of new infections among clinical and nonclinical ED health care personnel that will collect information on specific exposures, infection control practices, PPE use, and community and household contacts to better determine the attributable risk of ED patient care.

We did not find a higher prevalence of infection in clinical compared with nonclinical staff, suggesting that the risk from direct ED patient care in these sites may be relatively small. The nonclinical infection risk suggests that either reduced PPE use put them at risk or there are additional nonoccupational community risks. Nonfrontline health care personnel have previously

Table 3. Recall of symptoms and work behaviors among US ED health care personnel with undiagnosed SARS-CoV-2 infection (n=25).*

Question	No. (%)
Since December 31, 2019, have you had any symptoms that could be consistent with COVID-19? Yes	19 (76)
Since December 31, 2019, have you had a fever (a temperature >100.4°F or 38°C)? Yes	2 (8)
To which of the following did you attribute your symptoms (select all that apply)?	
COVID-19	8 (42)
Common cold	8 (42)
Influenza	5 (26)
Seasonal allergies	7 (36)
Gastroenteritis/stomach flu	1 (5)
Exacerbation of a chronic medical condition	1 (5)
Medications	1 (5)
Asthma	2 (10)
Inadequate sleep, overwork, schedule changes, or stress	7 (36)
Other	1 (5)
Did you seek care from any health care provider for any of these symptoms? Yes	1 (5)
During the period(s) that you had any symptoms (even minimal, minor, oratypical symptoms), did you work at your place of employment? Yes	17 (89)†
Did you have any COVID-19 testing (nasal test, blood test, or any other test) before participation in this project? Yes	6 (24)
Since December 31, 2019, estimate how many patients with confirmed COVID-19 infection you cared for at work without mask and gloves.	
0	9 (36)
1–5	9 (36)
6–10	2 (8)
>10	5 (20)
Since December 31, 2019, have you traveled outside the United States? Yes	2 (8)

Participants responded to this survey after results of their serology testing had been reported, in early July 2020.
*Among 29 participants with evidence of undiagnosed SARS-CoV-2 infection, 28 had positive serology results and 1 had positive nasal PCR results.
†The percentage of individuals who worked while they had symptoms was calculated from among only those who had symptoms (17/19=89%).

been shown to have higher rates of COVID-19 infection, possibly related to less infection control vigilance and PPE use.[15]

In conclusion, the estimated percentage of SARS-CoV-2 infection among health care personnel in a sample of 20 high-volume US EDs in the late spring and early summer of 2020 was approximately 4.6%, with 38% of those infections undiagnosed.

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APPENDIX

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