Tracheostomies of Patients With COVID-19: A Survey of Infection Reported by Health Care Professionals

By Constance S. Harrell Shreckengost, PhD, MD, Limeng Wan, MSPH, Alexandra W. Reitz, MD, MPH, Alice Lin, MPH, Rohan K. Dhamsania, MS, Julia Spychalski, J. Miller Douglas, Andrea Lane, Dina Amin, DDS, Steven Roser, DMD, MD, David Berkowitz, MD, Jorge Esteban Foianini, MD, Renée Moore, PhD, Jithin K. Sreedharan, MScRT, FiSqua, Abesh Niroula, MD, Randi Smith, MD, MPH, Onkar V. Khullar, MD MSc; PTS-COVIDTrach Collaborative

Background Health care professionals (HCPs) performing tracheostomies in patients with COVID-19 may be at increased risk of infection.
Objective To evaluate factors underlying HCPs' COVID-19 infection and determine whether tracheostomy providers report increased rates of infection.
Methods An anonymous international survey examining factors associated with COVID-19 infection was made available November 2020 through July 2021 to HCPs at a convenience sample of hospitals, universities, and professional organizations. Infections reported were compared between HCPs involved in tracheostomy on patients with COVID-19 and HCPs who were not involved.
Results Of the 361 respondents (from 33 countries), 50% (n = 179) had performed tracheostomies on patients with COVID-19. Performing tracheostomies on patients with COVID-19 was not associated with increased infection in either univariable (P = .06) or multivariable analysis (odds ratio, 1.48; 95% CI, 0.90-2.46; P = .13). Working in a low- or middle-income country (LMIC) was associated with increased infection in both univariable (P < .001) and multivariable analysis (odds ratio, 2.88; CI, 1.50-5.53; P = .001).
Conclusions Performing tracheostomy was not associated with COVID-19 infection, suggesting that tracheostomies can be safely performed in infected patients with appropriate precautions. However, HCPs in LMICs may face increased infection risk. (*American Journal of Critical Care.* Published online September 6, 2022.)

doi:https://doi.org/10.4037/ajcc2022337

SARS-CoV-2, the virus responsible for COVID-19, had claimed more than 6 million lives by early August 2022.[1] Health care professionals (HCPs) who treat patients who test positive for COVID-19 are at increased risk of infection relative to the general population, with the incidence of HCP infection as high as 38%.[2–5] However, the factors associated with risk of COVID-19 infection among HCPs overall, and specifically among HCPs involved in aerosol-generating procedures such as tracheostomy, remain poorly characterized.[6]

Between 17% and 24% of patients admitted for COVID-19 treatment require invasive mechanical ventilation.[7–9] Early tracheostomy in intubated patients has been associated with shorter stays in the intensive care unit outside the context of the pandemic and shorter duration of invasive mechanical ventilation in patients who test positive for COVID-19 specifically.[10-13] Optimizing utilization of scarce resources has been critical to health care system stability during the pandemic, and appropriately timed tracheostomy may facilitate this goal as COVID-19 shifts to an endemic problem.[14,15]

Factors associated with risk of COVID-19 infection among health care providers, especially those involved in tracheostomy procedures, remain poorly characterized.

SARS-CoV-2 is transmitted through inhalation or mucous membrane contact with droplets and aerosols.[16,17] Because of the nature of the tracheostomy procedure, HCPs involved in tracheostomy procedures for patients who test positive for COVID-19 may face additional risks because of aerosolization of viral particles.[6] For this reason, experts have proposed numerous aerosol-minimizing techniques, although evidence regarding the efficacy of those techniques remains scant.[15,18-26] Given concern about the added risk of infection among HCPs, several expert organizations have recommended delaying tracheostomy 14 to 21 days after intubation or deferring procedures entirely,[27-31] despite reports of low rates of COVID-19 infection among tracheostomy providers.[32,33]

Considering the knowledge gaps surrounding HCP COVID-19 infections, particularly among HCPs involved in tracheostomy procedures, we sought to determine what clinical factors are associated with risk of COVID-19 infection in a global HCP population. We hypothesized that HCPs involved in tracheostomy procedures would report greater rates of COVID-19 infection than other HCPs.

Materials and Methods

Survey Development and Dissemination

After a review of the existing literature on the performance of tracheostomy procedures during the COVID-19 pandemic and other respiratory pandemics, the research team developed an online survey for HCPs caring for patients who test positive for COVID-19. This survey was drafted on the basis of existing guidelines and literature on tracheostomies in patients who test positive for COVID-19, reviewed in fall 2020. The survey draft was shared with teams of surgeons, intensivists, and nurses in North America and South America. After incorporating feedback from all draft reviewers, the survey was submitted

About the Authors

Constance S. Harrell Shreckengost is a resident physician, Department of Surgery, Emory University, Atlanta, Georgia. **Limeng Wan** is a student, Rollins School of Public Health, Emory University. **Alexandra W. Reitz** is a resident physician, Department of Surgery, Emory University. **Alice Lin** is a student, Rollins School of Public Health, Emory University. **Rohan K. Dhamsania** is a student, Philadelphia College of Osteopathic Medicine, Suwanee, Georgia. **Julia Spychalski** is a student, Rollins School of Public Health, Emory University. **J. Miller Douglas** is a student, Department of Surgery and Rollins School of Public Health, Emory University. **Andrea Lane** is a student, Rollins School of Public Health, Emory University. **Dina Amin** is an assistant professor, Department of Surgery, Emory University and a surgeon, Oral and Maxillofacial Surgery, Grady Memorial Hospital, Atlanta, Georgia. **Steven Roser** is a professor, Department of Surgery, Emory University and a surgeon, Oral and Maxillofacial Surgery, Grady Memorial Hospital, Atlanta, Georgia. **David Berkowitz** is a physician and professor, Department of Medicine, School of Medicine, Emory University. **Jorge Esteban Foianini** is a surgeon, Department of Surgery, Clínica Foianini, Bolivia. **Renée Moore** is a professor, Rollins School of Public Health, Emory University. **Jithin K. Sreedharan** is general secretary, Indian Association of Respiratory Care, Kochi, India. **Abesh Niroula** is a physician, Department of Medicine, School of Medicine, Emory University. **Randi Smith** is a surgeon, Department of Surgery, Emory University, a professor, Rollins School of Public Health, Emory University, and a surgeon, Trauma and Surgical Critical Care, Grady Memorial Hospital. **Onkar V. Khullar** is a surgeon, Department of Surgery, Emory University.

Corresponding author: Constance S. Harrell Shreckengost, Emory University Department of Surgery, 1364 Clifton Rd, NE, Ste B206, Atlanta, GA, USA 30322 (email: csharrell@gmail.com).

and approved for dissemination by the Emory University Institutional Review Board (Study 00001633) and research was carried out following the ethical standards set forth in the Helsinki Declaration. Study data were collected and managed with Research Electronic Data Capture (REDCap) tools.[34,35] Participation in the survey was voluntary, and all participants indicated their consent to be involved in the study. All participants identifying as adult HCPs were eligible for inclusion in the study. Those who did not indicate whether they had ever been infected with the SARS-CoV-2 virus were excluded from the study.

The English-language survey (Supplemental Table 1—available online only, at www.ajcconline.org) was made accessible to any visitor to the study website, www.covidtrach.org, starting November 20, 2020, and Spanish, French, and Portuguese versions were made openly accessible beginning in March 2021. The survey originally consisted of 19 questions targeted to all respondents. Those HCPs who indicated that they were involved in performing tracheostomies in patients with COVID-19 were asked 12 additional questions. These "tracheostomy providers" included a wide variety of health care team members, including those actively placing the tracheostomy tube; endoscopists; personnel monitoring patient safety; and other procedural assistants; but did not include those who cared for patients with tracheostomies without involvement in the procedure itself. Tracheostomy providers who indicated that they could describe details of how the tracheostomy procedure was performed were asked another 8 questions. Two additional questions pertaining to vaccination status were added to the survey on December 18, 2020, shortly after the beginning of COVID-19 vaccination availability for HCPs in the United States and after 25 participants had responded.

For recruitment, the survey was sent to 661 email addresses of individuals affiliated with a convenience sample of multinational hospitals, clinical academic departments, and professional organizations in critical care, pulmonology, respiratory care, and surgery (including general, trauma, thoracic, otorhinolaryngology, and oral and maxillofacial surgery; Supplemental Table 2—available online only). Social media recruitment included dissemination via moderated feeds and paid Facebook advertising.

Statistical Analysis

Survey responses were exported from REDCap for analysis, and surveys in which the respondent did not indicate completion of the survey by advancing through all questions were excluded. However, if the respondent advanced through the survey but skipped questions, these were included. Descriptive analysis was performed for providers reporting a history of COVID-19 infection ("infected") and those who reported no history of infection ("uninfected"). All categorical demographic and COVID-19–related data were compared using χ^2 or Fisher exact tests. Significance was set to $\alpha = .05$ (ie, a 95% CI).

Responses submitted before February 1, 2021, were separated from those entered on or after February 1 to assess the effect of pandemic time course. By this date, all North American and Western European countries, as well as the majority of South American and Asian countries, had made COVID-19 vaccines available to health care providers.[36] To assess COVID-19 pandemic severity, cumulative confirmed COVID-19 cases per million people were matched to survey respondents by response date and country of employment.[1] To assess country income, country of employment was linked to World Bank country income status.[37] High-income countries (HICs) were compared with low-income and middle-income countries (LMICs). Five-point Likert-scale responses were collapsed into 3 categories: "not at all" or "mildly", "somewhat", and "very" or "extremely."

> Survey responses from health care professionals reporting a history of COVID-19 infection were compared with responses from those not reporting infection.

Providers who reported having been involved in performing tracheostomies on patients who tested positive for COVID-19, including bronchoscopists, physicians, nurses, advanced practice providers, respiratory care practitioners, and other technicians working in critical care units involved in the procedure, were compared with those who reported that they had not been involved in performing tracheostomies on patients who tested positive for COVID-19. Multivariable logistic regression assessing reported COVID-19 infection as the outcome was performed with 3 variables selected a priori (tracheostomy provider status, COVID-19 prevalence, and pandemic timeline). Because of the large number of potentially clinically relevant variables, as well as the rapid flux in knowledge of the pertinence of those risk factors, we decided to consider all variables with $P < .20$ for potential inclusion. We then excluded colinear variables and those not clinically relevant.

Variables considered for inclusion in the adjusted model included country and country income level, gender, race, age, HCP type, years in practice,

Table 1
Respondent demographics, country factors, and timeline

Characteristic	No. (%) of respondents[a] Total 361 (100%)	Infected 90 (25%)	Uninfected 271 (75%)	*P*[b]
Country of employment				<.001
India	117 (33)	42 (47)	75 (28)	
United States	148 (41)	17 (19)	131 (49)	
Other countries[c]	92 (26)	30 (34)	62 (23)	
Missing	4	1	3	
Country income level				<.001
Low or middle	157 (44)	60 (67)	97 (36)	
High	199 (56)	29 (33)	170 (64)	
Missing	5	1	4	
Sex				.50
Female	199 (55)	47 (52)	152 (56)	
Male	161 (45)	43 (48)	118 (44)	
Missing	1	0	1	
Race				.02
Non-White	175 (54)	51 (65)	124 (50)	
White	152 (46)	28 (35)	124 (50)	
Missing	34	11	23	
Age				.01
≥45 y	78 (22)	11 (12)	67 (25)	
<45 y	283 (78)	79 (88)	204 (75)	
Date of survey response				.005
February 1, 2021, or later	264 (73)	76 (84)	188 (69)	
Before February 1, 2021	97 (27)	14 (16)	83 (31)	
COVID-19 country caseload[d]				<.001
> Median	178 (50)	28 (31)	150 (56)	
≤ Median	179 (50)	61 (69)	118 (44)	
Missing	4	1	3	

[a] All percentages are based on the number of respondents to each question. Because of rounding, percentages may not total 100.
[b] Determined by χ^2 or Fisher exact test.
[c] A complete list of respondents by countries of employment is listed in Supplemental Table 3.
[d] Median cumulative confirmed cases per million people based on country and date of survey response: 46 326 (range, 27-157 103).

frequency of caring for patients who tested positive for COVID-19, vaccination status, concern for contracting COVID-19 infection, and facility type.[2,4,38–44] Manual backward stepwise elimination was then used for variable selection. Because of complete separation with pandemic time course and country income level, individual country was excluded. The variables thus selected for the final adjusted model were tracheostomy provider status, country income level, pandemic timeline, and country's COVID-19 caseload.

Separate descriptive analyses were done regarding tracheostomy-specific factors reported by providers who described the procedure in detail. All statistical analyses were performed with SAS version 9.4 by Emory University's Biostatistics Collaboration Core staff.

Results

Survey Response

The survey link on the study website, www.covidtrach.org, was accessed from 370 unique internet protocol (IP) addresses according to the website service Squarespace. Individual single-use survey links were also shared directly with 661 email addresses. Unique IP addresses and single-use survey links were used to minimize the possibility of duplicate survey responses.

Of the 1031 people who received an email or clicked on the survey on the public website, 365 people completed the survey, a 35% completion rate. (Completion was defined as advancing through the entire survey, even if some questions were skipped.) Four of the participants who completed the survey did not respond to the question regarding history of COVID-19 infection and were excluded. Thus, 361 complete survey responses were included in the analysis.

HCP Demographics, Experience, and Facility Characteristics

The HCPs who responded to the survey represented 33 countries, with large proportions working in India (32%) and the United States (41%; Table 1 and Supplemental Table 3—available online only). Seventy-three percent of all HCPs responded to the survey after February 1, 2021, and 44% worked in LMICs. COVID-19 infection was significantly more frequently reported by HCPs who were based outside the United States ($P<.001$); in LMICs ($P<.001$); non-White ($P=.02$); younger than 45 years ($P=.01$); and responding February 1, 2021, or later during pandemic ($P=.005$; Table 1). Nurses, respiratory care practitioners, technicians, and therapists ($P=.005$) and those caring for patients who tested positive for COVID-19 at least weekly ($P=.03$) were also significantly more likely to report COVID-19 infection than other types of HCPs or those working less often with patients who tested positive for COVID-19 (Table 2).

The median cumulative number of confirmed cases of COVID-19 per million people by date of survey response and country (date-location) was 46 326 (range, 27 to 157 103).[1] Those HCPs responding at a date-location with a COVID-19 caseload below the median reported COVID-19 infection more frequently than did those responding from a date-location with a caseload above the median ($P<.001$, Table 1). Ninety-six percent of survey responses from LMICs, including 100% of responses from India, were associated with below-median caseloads.

Table 2
Health care professional and health care facility characteristics

Characteristic	No. (%) of respondents[a]			
	Total 361 (100%)	Infected 90 (25%)	Uninfected 271 (75%)	*P*[b]
Type of health care professional				.005
Physician	118 (33)	21 (24)	97 (36)	
APP or ICU provider (NOS)	43 (12)	5 (6)	38 (14)	
Nurse, RCP, technician, or therapist	175 (49)	56 (63)	119 (45)	
Other[c]	20 (6)	7 (8)	13 (5)	
Missing	5	1	4	
Years in practice				.26
≥10	106 (29)	22 (25)	84 (31)	
<10	254 (71)	67 (75)	187 (69)	
Missing	1	1	0	
COVID-19 tracheostomy provider				.06
No	181 (50)	37 (42)	144 (53)	
Yes	179 (50)	52 (58)	127 (47)	
Missing	1	1	0	
COVID-19 care frequency				.03
At least once weekly	206 (57)	60 (67)	146 (54)	
Less than once weekly	155 (43)	30 (33)	125 (46)	
HCP vaccination status				.10
Partially or fully vaccinated	304 (90)	74 (86)	230 (92)	
Unvaccinated	32 (10)	12 (14)	20 (8)	
Missing	25	4	21	
Concern for contracting COVID-19 infection				.008
Not at all/mildly	120 (33)	19 (21)	101 (37)	
Moderately	109 (30)	28 (31)	81 (30)	
Very/extremely	131 (36)	43 (48)	88 (33)	
Missing	1	0	1	
PPE availability				.32
<75% of needs met	53 (15)	16 (18)	37 (14)	
≥75% of needs met	306 (85)	73 (82)	233 (86)	
Missing	2	1	1	
Facility type			136 (50)	.001
Nonteaching	199 (55)	63 (70)	135 (50)	
Teaching	162 (45)	27 (30)		
Facility COVID-19 designation			55 (20)	.54
COVID-19 designated	76 (21)	21 (23)	216 (80)	
Not COVID-19 designated	285 (79)	69 (77)		

Abbreviations: APP, advanced practice provider; HCP, health care professional; ICU, intensive care unit; NOS, not otherwise specified; PPE, personal protective equipment; RCP, respiratory care practitioner.

[a] All percentages are based on the number of respondents to each question. Because of rounding, percentages may not total 100.
[b] Determined by χ^2 or Fisher exact test.
[c] Other types of health care professionals who responded to the survey included trainees, administrative health care workers, and those not otherwise specified.

Ninety percent of HCPs were partially or fully vaccinated at the time of survey response (Table 2), excluding the 25 individuals who responded to the survey before the vaccine-related questions were added on December 18, 2020. Among vaccinated HCPs who reported COVID-19 infection and indicated timing relative to vaccination, 69% indicated that they were infected before vaccination, with the remaining 31% becoming infected after partial or full vaccination. Thirteen of the vaccinated HCPs who reported COVID-19 infection did not indicate timing relative to vaccination status. The 4 HCPs who reported COVID-19 infection and responded to the survey before the vaccine-related questions were added were excluded from vaccine analysis.

Tracheostomy Provider Status and Reported COVID-19 Infection

Approximately half of respondents (n = 179) indicated involvement in performing tracheostomies

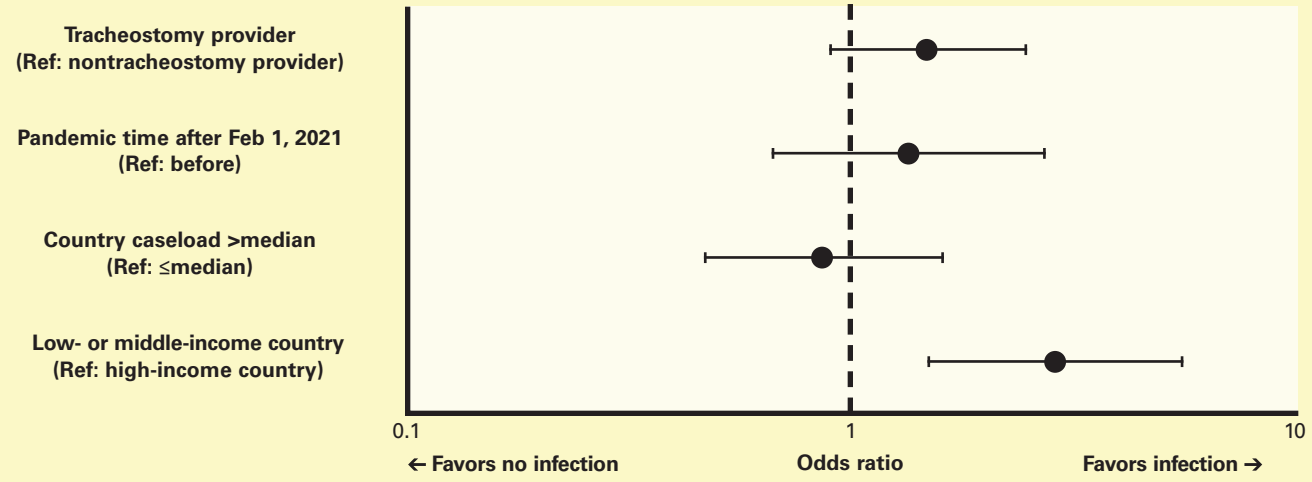

Figure Multivariable assessment of tracheostomy provider status with reported COVID-19 infection. Multivariable logistic regression of association between tracheostomy provider status and reported COVID-19 infection was performed. Pandemic time course and country COVID-19 prevalence were included a priori with additional variables in the final model determined by backward elimination. Tracheostomy provider status was not significantly associated with reported COVID-19 infection (odds ratio [OR], 1.48; 95% CI, 0.90-2.46; *P*=.13). Only country income level was independently associated with reported COVID-19 infection (OR, 2.88; 95% CI, 1.50-5.53; *P*=.001). X-axis displayed in logarithmic scale. Error bars represent 95% CI.

on patients who tested positive for COVID-19 (Table 2). COVID-19 tracheostomy providers represented 58% of the infected HCP population and 47% of the uninfected population (*P*=.06). Of the 53 infected tracheostomy providers, 76% reported infection more than 14 days after involvement in a tracheostomy on a patient who tested positive for COVID-19, whereas 6% reported infection within 14 days of a tracheostomy. Eighteen percent were unsure of timing; 2 providers did not respond to the question (Supplemental Table 4—available online only). Infection rates reported according to tracheostomy provider status and vaccination status were also examined and demonstrated that unvaccinated HCPs who were not involved with any tracheostomy procedures accounted for 22% of those reporting infection but only 8% of those not reporting infection (*P*=.02; Supplemental Table 5—available online only). This pattern was not observed among tracheostomy providers, with unvaccinated individuals accounting for similar proportions of infected and uninfected respondents (*P*=.94).

Providers in LMICs were significantly more likely to report COVID-19 infection than those in high income countries, even adjusting for country caseload.

COVID-19 tracheostomy providers were not more likely to report infection in the multivariable model (odds ratio [OR], 1.48; 95% CI, 0.90-2.46; *P*=.13; see Figure). However, after tracheostomy provider status, pandemic timeline, and COVID-19 caseload were adjusted for, HCPs from LMICs were significantly more likely to report a history of COVID-19 infection (OR, 2.88; 95% CI, 1.50-5.53; *P*=.001).

Descriptive data of the LMIC and HIC samples are available in Supplemental Table 6 (available online only). The LMIC population was majority non-White (87% vs 30% of the HIC population); younger than 45 years old (LMIC 90% vs HIC 70%); and nurses, respiratory care practitioners, technicians, or therapists (LMIC 73% vs HIC 31%). Moreover, 13% of LMIC respondents were unvaccinated, compared with 6% of HIC respondents, and 23% of LMIC respondents indicated that less than 75% of their needs for PPE were met, whereas only 8% of HIC respondents indicated this concern.

COVID-19 Tracheostomy Provider Subset

A subset analysis of the COVID-19 tracheostomy providers was performed to identify procedures that may have contributed to infection prevention. Of the 179 COVID-19 tracheostomy providers, 145 (81%) were able to describe procedural details and were included in the subset analysis. Demographics of this population are detailed in Supplemental Table 7 (available online only).

Most tracheostomies within this dataset were performed in an intensive care unit (81%), percutaneously (69%), and within 14 days of a patient's COVID-19 diagnosis (56%) (Table 3). Most COVID-19 tracheostomy providers also used some form of aerosol-reducing precautions (83%). These precautions

Table 3
Tracheostomy provider–specific factors and COVID-19 infections[a]

Provider factor	No. (%) of respondents[b]		
	Total 145 (100%)	Infected 42 (29%)	Uninfected 103 (71%)
Typical time to tracheostomy from patient COVID-19 diagnosis			
≤14 days	81 (56)	25 (60)	56 (54)
>14 days	64 (44)	17 (40)	47 (46)
No. of tracheostomies performed on patients with COVID-19			
1-6	71 (49)	21 (50)	50 (49)
7-14	25 (17)	5 (12)	20 (19)
≥15	49 (34)	16 (38)	33 (32)
Usually performs bronchoscopy			
No	121 (83)	37 (88)	84 (82)
Yes	24 (17)	5 (12)	19 (18)
Usually performs tracheotomy			
No	82 (57)	29 (69)	53 (51)
Yes	63 (43)	13 (31)	50 (49)
Procedure often in ICU			
No	27 (19)	8 (19)	19 (18)
Yes	118 (81)	34 (81)	84 (82)
Use of N95 or CAPR/PAPR			
No	3 (2)	1 (2)	2 (2)
Yes	142 (98)	41 (98)	101 (98)
Use of eye protection			
No	36 (25)	15 (36)	21 (20)
Yes	109 (75)	27 (64)	82 (80)
Use of paralytics			
No	10 (7)	7 (18)	3 (3)
Yes	127 (93)	33 (83)	94 (97)
Missing	8	2	6
Tracheostomy technique			
Mixed	11 (8)	2 (5)	9 (9)
Open	34 (24)	11 (26)	23 (23)
Percutaneous	98 (69)	29 (69)	69 (68)
Missing	2	0	2
Bronchoscopy used for anatomic identification			
No	84 (58)	31 (74)	53 (51)
Yes	61 (42)	11 (26)	50 (49)
Ultrasound used for anatomic identification			
No	117 (81)	34 (81)	83 (81)
Yes	28 (19)	8 (19)	20 (19)
Special precautions to minimize aerosols			
None	24 (17)	5 (12)	19 (18)
Any	121 (83)	37 (88)	84 (82)
Discontinuation of mechanical ventilation			
No	63 (43)	17 (40)	46 (45)
Yes	82 (57)	25 (60)	57 (55)

Abbreviations: CAPR, controlled air-purifying respirator; ICU, intensive care unit; PAPR, powered air purifying respirator.

[a] Data from the 145 tracheostomy providers who were able to provide procedural details of the 179 total health care professionals involved in tracheostomies.
[b] All percentages are based on the number of respondents to each question. Because of rounding, percentages may not total 100.

included minimizing bronchoscopy, discontinuing mechanical ventilation, and using additional barriers. Major complication rates were relatively low, with the most frequently reported complications being minor bleeding and significant desaturation (Supplemental Table 8—available online only). Given that performing tracheostomies on patients who tested positive for COVID-19 was not associated with increased reported COVID-19 infection in the provider and that most infections reported by

tracheostomy providers were identified more than 14 days after the procedure, statistical comparison of procedural factors was not performed.

Discussion

Minimizing HCP infection risk while maintaining an active workforce to care for patients has been critical to health care system stability throughout the COVID-19 pandemic.[45] Although tracheostomies are aerosol-generating procedures with theoretical risks to providers, these risks must be balanced against optimizing patient care and resource utilization during a pandemic.[6] This study indicates that providers who are involved in performing tracheostomies on patients who test positive for COVID-19 do not report greater rates of infection than other HCPs. However, the data suggest that HCPs working in LMICs are more likely to report COVID-19 infection than their counterparts who work in HICs, after adjusting for country COVID-19 caseload, pandemic timeline, and tracheostomy provider status.

Despite potential risks delineated in many tracheostomy guidelines, the lack of association between involvement in tracheostomies and reported COVID-19 infection is consistent with existing literature.[15,21,25,30,31,33,46-48] In a recent review of tracheostomy outcomes during the pandemic, only 3 of the 58 papers examined identified HCP infection within 4 weeks following tracheostomy involvement.[33] Although 1 study reported a COVID-19 infection rate of 7.7% among HCPs involved in tracheostomies, this rate did not significantly differ from the 11.5% overall HCP infection rate reported.[47] Nonetheless, several expert groups have recommended delaying tracheostomy or deferring procedures entirely on patients who test positive for COVID-19.[27-31] Such recommendations, although aiming to protect HCPs during a time of uncertainty, may have prevented optimal patient care or use of resources.

In addition to the absence of statistical association between involvement in tracheostomies and reported COVID-19 infection generally, only 3 tracheostomy providers reported being diagnosed with COVID-19 within 14 days of performing a tracheostomy on an infected patient. This finding is particularly notable considering that more than 50% of tracheostomy providers reported performing the procedure within 14 days of when the patient had been diagnosed with COVID-19. This frequency of such "early" tracheostomies is perhaps surprising given that more than 90% of protocols from the first several months of the pandemic suggested delaying the procedure until after 14 days of intubation.[49] Early tracheostomy may have multiple benefits for patients, including reduced ventilator dependence,[50] shorter stay in the intensive care unit,[51] decreased analgesia requirements,[52] and faster return to physical activity[53,54]; it is also cost-effective.[55,56] This suggests that, in appropriately selected patients, early tracheostomy may assist with both patient care and resource management during a crisis.[57]

Collectively, the data imply that tracheostomies can be safely performed on patients who test positive for COVID-19 with appropriate precautions and at the appropriate time. It must be noted that nearly all (98%) tracheostomy providers reported wearing particulate-filtering facepiece respirators during tracheostomies. Moreover, 83% reported using at least 1 aerosol-reducing maneuver, including discontinuation of mechanical ventilation, use of additional barriers, and minimizing bronchoscopy. As suggested above, tracheostomy timing may also be a factor affecting reported infection rates. Even patients undergoing "early" tracheostomy within 14 days of diagnosis or 10 days of intubation have typically developed antiviral antibodies and infectivity is much diminished.[26] Data were not collected regarding the use of specific facility-based protocols for tracheostomy timing or methods, but such guidelines may have also been protective. Further research should evaluate the specific factors that optimize safety of tracheostomy providers in greater depth.

The findings from this survey have important implications for HCP safety irrespective of involvement in tracheostomies. The 25% COVID-19 infection rate reported (Table 1) is consistent with existing data demonstrating that HCPs are at increased risk of infection relative to the general population.[2,3] Existing data point to multiple factors contributing to infection risk among HCPs, including use of personal protective equipment (PPE) , provider role, and race.[2,5,43,44,58,59] Similarly, this survey demonstrates associations between younger age, increased frequency of COVID-19 patient care, non-White race, and HCP role (nurse, respiratory care practitioner, technician, or therapist) with increased reported COVID-19 infection in univariable analysis. The data also highlight a protective role of COVID-19 vaccination among HCPs who are not involved with tracheostomies. Neither the fact that these additional factors, such as HCP role, were nonsignificant in multivariable analysis nor the lack of a significant protective effect of vaccination among tracheostomy providers indicates that these factors are unimportant for infection risk. The present study was neither designed nor powered to examine these factors fully, and additional

research is needed to understand these factors' contribution to COVID-19 risk among HCPs.

In univariable analysis, COVID-19 infection was also reported more often by HCPs located in LMICs, by those who responded to the survey later in the pandemic, and, counterintuitively, by HCPs from countries with below-median cumulative confirmed COVID-19 cases per million people. After adjusting for country caseload and pandemic timeline in multivariable analysis, LMIC status remained significantly associated with increased reported COVID-19 infection. Others have reported significant disparities in HCP safety at a global level, including inadequate access to PPE, reduced use of safety protocols, and disparity in vaccine access.[60,61] Given that this study was not designed to assess differences between respondents in LMICs and those in HICs, inferential statistical tests were not performed. However, descriptive analysis of the study sample by income status highlights the many differences between the populations, including age, race, vaccination status, and PPE availability. Further research designed to examine these and other factors that could contribute to increased HCP infection in LMICs is needed.

The counterintuitive finding in univariable analysis that lower COVID-19 caseload was linked to increased reported infection may be due to this variable's relationship with country income level. HCPs in LMICs accounted for 84% of the surveys associated with a caseload below the median and only 4% of surveys associated with a caseload above the median. COVID-19 cases may be dramatically underreported in LMICs such as India and elsewhere.[62-64] Thus, the impact of COVID-19 prevalence on HCP infection rates should not be dismissed. However, the data presented here indicate that additional country-specific factors play an important role in infection risk. The risks of working in a LMIC may outweigh the risks associated with high COVID-19 prevalence. These findings are consistent with existing literature providing evidence of significant disparities in HCP safety at a global level.[60]

This study has several limitations. All associations are correlative, and cause should not be inferred. The HCP COVID-19 infection rates are based on self-report without submission of laboratory testing or other confirmation of infection and are thus subject to recall bias. However, the frequency of COVID-19 infections reported in our study, both among all HCPs and among tracheostomy providers specifically, resembles that reported elsewhere.[2,33,59]

Selection bias is likely both in the targeted convenience sampling method used and in the self-selection of survey respondents. Recruitment methods involved highlighting the nature of the study and its relevance to tracheostomy care; the fact that nearly 50% of participants identified as being involved in tracheostomy care reflects these methods. Moreover, though data to this effect were not collected, many respondents not involved in the index procedure were most likely still involved in caring for patients with tracheostomies given the recruitment methods used. Given the publicly available nature of the survey and distribution at the organizational level in some cases, we are unable to estimate the full reach of study and thus we could not arrive at a conclusive response rate. The calculated survey completion rate (defined as those who completed the survey accessed either via email or via a public website) was 35% despite the wide distribution of the survey, which is similar to that reported from other surveys of HCPs on sensitive topics.[65,66] Nonetheless, the results should be interpreted cautiously given that the responses may not be generalizable to the complete population of HCPs worldwide.

Selection bias also most likely contributed to the geographic distribution of survey respondents. Although 33 countries are represented, 74% of the respondents worked in either the United States or India. Providers and facilities in the United States and India were heavily targeted during recruitment, given they are 2 of the countries with the greatest burden of patients who test positive for COVID-19 worldwide. However, these 2 countries accounted for only 34% of the global COVID-19 case burden as of July 16, 2021 (the date of survey closure).[1] This overrepresentation means that findings with respect to country income may be due to differences between the United States and India as opposed to differences between HICs and LMICs generally. Moreover, the use of the categories of HIC and LMIC as defined by the World Bank is also imperfect, as substantial variation in income level exists within countries. Further studies with greater representation from other HICs and LMICs, as well as more detailed analysis of regional income levels, are needed.

> This multinational survey demonstrates that tracheostomy providers do not report greater COVID-19 infection than other health care professionals.

The longer time frame during which the survey was made available is both a strength and a weakness of the study. The 7-month time frame allowed

us to target different countries at different times to account for global pandemic fluctuations. Non-English versions of the survey were distributed later during the study as well, corresponding to these fluctuations. This design, while intended to optimize response rates from HCPs at date-locations most affected by the pandemic, makes it difficult to evaluate the interrelationships between geography, time, language, and COVID-19 prevalence. Additional epidemiologic research will be necessary to understand the fluctuations in risk factors throughout the pandemic.

Conclusions

This multinational survey demonstrates that tracheostomy providers do not report greater COVID-19 infection than other HCPs. This suggests that, if adequate safety measures are in place, tracheostomies can be performed on patients who test positive for COVID-19 without putting HCPs at increased infection risk. This study should inform provider decision-making as COVID-19 shifts from a pandemic to an endemic problem. After adjusting for tracheostomy provider status, country caseload, and pandemic timeline, LMIC providers reported higher COVID-19 infection rates. Although overrepresentation of the United States and India may contribute to this finding, the results highlight global health care disparities and the impact of resource limitations. In conclusion, HCPs should continue to perform tracheostomies in patients who test positive for COVID-19 as indicated by standards of care and using adequate safety measures. However, additional research on infection risk in lower-resource settings is warranted.

ACKNOWLEDGMENTS

PTS-COVIDTrach Collaborative authors include Kerianne Allen, BA, CCRP, Riverside Health System, Newport News, Virginia; Marissa Boeck, MD, MPH, University of California, San Francisco; Christine A. Castater, MD, Emory University and Grady Memorial Hospital, Atlanta, Georgia; Michael Farrell, MD, MS, University of California, San Francisco; Vikas Pathak, MD, ATSF, DAABIP, Riverside Health System, Newport News, Virginia; Keriann Marie Van Nostrand, MD, Emory University, Atlanta, Georgia and University of South Florida, Tampa, Florida.

We are grateful for the assistance of colleagues in the Indian Association of Respiratory Care and the Multinational Council for Respiratory Care and our volunteer translators, including Daniela Farchi, Bahaa Kazzi, Eliana Lillivek, and Gustavo Moraes. We would also like to acknowledge funding support from the Emory University School of Medicine "Imagine, Innovate, Inspire" Nexus Award and Library Information Technology Services grant (UL1 TR000424) for REDCap.

Finally, we would like to acknowledge the support from all members of the PTS-COVIDTrach Collaborative: Katrina Abril, MD, MSc, Emory University, Atlanta, Georgia, and Spectrum Health System, Grand Rapids, Michigan; Sérgio S. Arap, MD, PhD, Hospital Das Clínicas, University of São Paulo, Brazil; Cindy L. Austin, MS, CCRP, Mercy Hospital, Springfield, Missouri; Mark Barry, MD, University of California, San Francisco; Ricardo F. Bento, MD, PhD, Hospital Das Clínicas, University of São Paulo, Brazil; Juan Blas, MD, MBBS-MBChB, Royo Villanova Hospital, Zaragosa, Spain; Maraya Camazine, MS, University of Missouri School of Medicine; Pedro P.D. Ciaralo, MD, Hospital Das Clínicas, University of São Paulo, Brazil; Jeffrey Coughenour, MD, University of Missouri School of Medicine; Deidre Dillon, BS, University of Missouri School of Medicine; Anya Greenberg, MBA, University of California, San Francisco; Rui Imamura, MD, PhD, Royo Villanova Hospital, Zaragosa, Spain; Wissam S. Jaber, MD, Emory University, Atlanta, Georgia; Or Kalchiem-Dekel, MD, Memorial Sloan Kettering Cancer Center, New York, New York; Hannah Kim, BS, ATC, University of California, San Francisco; Luiz P. Kowalski, MD, PhD, Hospital Das Clínicas, University of São Paulo, Brazil; Ali Mahmoud, MD, Hospital Das Clínicas, University of São Paulo, Brazil; Alessandro W. Mariani, MD, PhD, Hospital Das Clínicas, University of São Paulo, Brazil; Carlos A.M. Menegozzo, MD, Hospital Das Clínicas, University of São Paulo, Brazil; Phoebe Miller, MS, University of California, San Francisco; Hélio Minamoto, MD, PhD, Hospital Das Clínicas, University of São Paulo, Brazil; Fábio L.M. Montenegro, MD, PhD, Hospital Das Clínicas, University of São Paulo, Brazil; Jonathan Nguyen, DO, Grady Memorial Hospital and Morehouse University, Atlanta, Georgia; Paul Park, MS, University of California, San Francisco; Paulo M. Pêgo-Fernandes, MD, PhD, Hospital Das Clínicas, University of São Paulo, Brazil; Jennifer Randolph, BSN, RN, University of Missouri School of Medicine; Manu Sancheti, MD, Emory University, Atlanta, Georgia; Jones Santos Jr, MD, Hospital Das Clínicas, University of São Paulo, Brazil; Alejandro Sardi, MD, Emory University, Atlanta, Georgia; Matthew Schimmel, MD, Emory University, Atlanta, Georgia; Issa Talal, PhD, MSc, MD, MBBS-MBChB, Royo Villanova Hospital, Zaragosa, Spain; Gabriel Tirado, MD, MBBD-MBChB, Royo Villanova Hospital, Zaragosa, Spain; Edivaldo M. Utiyama, MD, PhD, Hospital Das Clínicas, University of São Paulo, Brazil; Thomas G. Weiser, MD, MPH, Stanford University, Palo Alto, California; Cheryl White, BSN, RN, Riverside Health System, Newport News, Virginia; Carlos Yánez Benitez, MD, MSc, Royo Villanova Hospital, Zaragosa, Spain.

FINANCIAL DISCLOSURES

Funding for this project was provided by an Emory University School of Medicine "Imagine, Innovate, Inspire" Nexus Award. Use of REDCap was supported by the Library Information Technology Services grant (UL1 TR000424).

REFERENCES

1. Ritchie H, Mathieu E, Rodés-Guirao L, et al. Coronavirus Pandemic (COVID-19). OurWorldInData.org. Accessed August, 20, 2022. https://ourworldindata.org/coronavirus
2. Nguyen LH, Drew DA, Graham MS, et al. Risk of COVID-19 among front-line health-care workers and the general community: a prospective cohort study. *Lancet Public Health.* 2020;5:e475-e483. doi:10.1016/S2468-2667(20)30164-X
3. World Health Organization. *Prevention, Identification and Management of Health Worker Infection in the Context of COVID-19: Interim Guidance.* Published 2020. Accessed May 26, 2022. https://apps.who.int/iris/rest/bitstreams/1313629/retrieve
4. Folgueira MD, Muñoz-Ruipérez C, Alonso-López MÁ, Delgado R. SARS-CoV-2 infection in health care workers in a large public hospital in Madrid, Spain, during March 2020. *medRxiv.* Published online April 7, 2020. doi:10.1101/2020.04.07.20055723
5. Calò F, Russo A, Camaioni C, De Pascalis S, Coppola N. Burden, risk assessment, surveillance and management of SARS-CoV-2 infection in health workers: a scoping review.

Infect Dis Poverty. 2020;9:139. Published online October 7, 2020. doi:10.1186/s40249-020-00756-6
6. Tran K, Cimon K, Severn M, Pessoa-Silva CL, Conly J. Aerosol generating procedures and risk of transmission of acute respiratory infections to healthcare workers: a systematic review. *PloS One.* 2012;7:e35797. Published online April 26, 2012. doi:10.1371/journal.pone.0035797
7. Monteiro AC, Suri R, Emeruwa IO, et al. Obesity and smoking as risk factors for invasive mechanical ventilation in COVID-19: a retrospective, observational cohort study. *medRxiv.* Preprint posted online August 14, 2020. doi:10.1101/2020.08.12.20173849
8. Potere N, Valeriani E, Candeloro M, et al. Acute complications and mortality in hospitalized patients with coronavirus disease 2019: a systematic review and meta-analysis. *Crit Care.* 2020;24:389. doi:10.1186/s13054-020-03022-1
9. Singer AJ, Morley EJ, Meyers K, et al. Cohort of four thousand four hundred four persons under investigation for COVID-19 in a New York hospital and predictors of ICU care and ventilation. *Ann Emerg Med.* 2020;76:394-404.
10. Mattioli F, Fermi M, Ghirelli M, et al. Tracheostomy in the COVID-19 pandemic. *Eur Arch Otorhinolaryngol.* 2020;277:2133-2135.
11. Andriolo BN, Andriolo RB, Saconato H, Atallah AN, Valente O. Early versus late tracheostomy for critically ill patients. *Cochrane Database Syst Rev.* 2015;1:CD007271.
12. Aviles-Jurado FX, Prieto-Alhambra D, González-Sánchez N, et al. Timing, complications, and safety of tracheotomy in critically ill patients with COVID-19. *JAMA Otolaryngol Head Neck Surg.* 2020;147:1-8. doi:10.1001/jamaoto.2020.3641
13. Glibbery N, Karamali K, Walker C, Fitzgerald O'Connor I, Fish B, Irune E. Tracheostomy in the coronavirus disease 2019 patient: evaluating feasibility, challenges and early outcomes of the 14-day guidance. *J Laryngol Otol.* 2020;134(8):688-695. doi:10.1017/S0022215120001759
14. Mahmood K, Cheng GZ, Van Nostrand K, et al. Tracheostomy for COVID-19 respiratory failure: multidisciplinary, multicenter data on timing, technique, and outcomes. *Ann Surg.* 2021;274:234-239.
15. Livneh N, Mansour J, Kassif Lerner R, Feinmesser G, Alon E. Early vs. late tracheostomy in ventilated COVID-19 patients: a retrospective study. *Am J Otolaryngol.* 2021;42:103102. doi: 10.1016/j.amjoto.2021.103102
16. World Health Organization. Coronavirus Disease (COVID-19) Situation Report—188. Published July 2020. Accessed May 26, 2022. https://www.who.int/emergencies/diseases/novel-coronavirus-2019/situation-reports
17. US Centers for Disease Control and Prevention. Scientific Brief: SARS-CoV-2 Transmission. Published May 7, 2021. Accessed May 26, 2022. https://www.cdc.gov/coronavirus/2019-ncov/science/science-briefs/sars-cov-2-transmission.html
18. Chiesa-Estomba CM, Lechien JR, Calvo-Henríquez C, et al. Systematic review of international guidelines for tracheostomy in COVID-19 patients. *Oral Oncol.* 2020;108:104844. doi:10.1016/j.oraloncology.2020.104844
19. Harrison L, Ramsden J. Guidance for Surgical Tracheostomy and Tracheostomy Tube Change During the COVID-19 Pandemic. Published 2020. Accessed August 20, 2022. https://www.ahns.info/wp-content/uploads/2020/03/Guidance-for-Surgical-Tracheostomy-and-Tracheostomy-Tube-Change-during-the-COVID.pdf
20. Heyd CP, Desiato VM, Nguyen SA, et al. Tracheostomy protocols during COVID-19 pandemic. *Head Neck.* 2020;42:1297-1302.
21. Sommer DD, Engels PT, Weitzel EK, et al. Recommendations from the CSO-HNS taskforce on performance of tracheotomy during the COVID-19 pandemic. *J Otolaryngol Head Neck Surg.* 2020;49:23. doi:10.1186/s40463-020-00414-9
22. Michetti CP, Burlew CC, Bulger EM, et al. Performing tracheostomy during the COVID-19 pandemic: guidance and recommendations from the Critical Care and Acute Care Surgery Committees of the American Association for the Surgery of Trauma. *Trauma Surg Acute Care Open.* 2020;5:e000482. doi:10.1136/tsaco-2020-000482
23. Yokokawa T, Ariizumi Y, Hiramatsu M, et al. Management of tracheostomy in COVID-19 patients: the Japanese experience. *Auris Nasus Larynx.* 2021;48:525-529.
24. Staibano P, Levin M, McHugh T, Gupta M, Sommer DD. Association of tracheostomy with outcomes in patients with COVID-19 and SARS-CoV-2 transmission among health care professionals: a systematic review and meta-analysis. *JAMA Otolaryngol Head Neck Surg.* 2021;147(7):646-655. doi:10.1001/jamaoto.2021.0930
25. Angel L, Kon ZN, Chang SH, et al. Novel percutaneous tracheostomy for critically ill patients with COVID-19. *Ann Thorac Surg.* 2020;110:1006-1011.
26. McGrath BA, Brenner MJ, Warrillow SJ, et al. Tracheostomy in the COVID-19 era: global and multidisciplinary guidance. *Lancet Respir Med.* 2020;8:717-725.
27. Bertroche JT, Pipkorn P, Zolkind P, Buchman CA, Zevallos JP. Negative-pressure aerosol cover for COVID-19 tracheostomy. *JAMA Otolaryngol Head Neck Surg.* 2020;146(7):672-674. doi:10.1001/jamaoto.2020.1081
28. Gosling AF, Bose S, Gomez E, et al. Perioperative considerations for tracheostomies in the era of COVID-19. *Anesth Analg.* 2020;131:378-386.
29. Lamb CR, Desai NR, Angel L, et al. Use of tracheostomy during the COVID-19 pandemic: American College of Chest Physicians/American Association for Bronchology and Interventional Pulmonology/Association of Interventional Pulmonology Program Directors Expert Panel Report. *Chest.* 2020;158:1499-1514. doi:10.1016/j.chest.2020.05.571
30. Lima DS, Ribeiro Junior MF, Vieira HM Jr, Campos T, Saverio SD. Alternatives for establishing a surgical airway during the COVID-19 pandemic. *Rev Col Bras Cir.* 2020;47:e20202549. doi:10.1590/0100-6991e-20202549
31. Niroula A, Van Nostrand KM, Khullar OV, et al. Percutaneous tracheostomy with apnea during coronavirus disease 2019 era: a protocol and brief report of cases. *Crit Care Explor.* 2020;2:e0134. doi:10.1097/CCE.0000000000000134
32. Pichi B, Mazzola F, Bonsembiante A, et al. CORONA-steps for tracheotomy in COVID-19 patients: a staff-safe method for airway management. *Oral Oncol.* 2020;105:104682.
33. Skoog H, Withrow K, Jeyarajan H, et al. Tracheotomy in the SARS-CoV-2 pandemic. *Head Neck.* 2020;42:1392-1396.
34. Harris PA, Taylor R, Minor BL, et al. The REDCap consortium: building an international community of software platform partners. *J Biomed Inf.* 2019;95:103208.
35. Harris PA, Taylor R, Thielke R, Payne J, Gonzalez N, Conde JG. Research electronic data capture (REDCap): a metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inf.* 2009;42:377-381.
36. Hale T, Angrist M, Goldszmidt R, et al. A global panel database of pandemic policies (Oxford COVID-19 Government Response Tracker). *Nat Hum Behav.* 2021;5:529-538.
37. World Bank. World development indicators: the world by income and region. Accessed May 26, 2022. https://datatopics.worldbank.org/world-development-indicators/the-world-by-income-and-region.html
38. World Health Organization. The impact of COVID-19 on health and care workers: a closer look at deaths. Published 2021. Accessed May 26, 2022. https://apps.who.int/iris/handle/10665/345300
39. El-Boghdadly K, Wong DJN, Owen R, et al. Risks to healthcare workers following tracheal intubation of patients with COVID-19: a prospective international multicentre cohort study. *Anaesthesia.* 2020;75:1437-1447.
40. Coppeta L, Ferrari C, Mazza A, Trabucco Aurilio M, Rizza S. Factors associated with pre-vaccination SARS-CoV-2 infection risk among hospital nurses facing COVID-19 outbreak. *Int J Environ Res Public Health.* 2021;18:13053. doi:10.3390/ijerph182413053
41. Gohil SK, Quan KA, Madey KM, et al. Infection prevention strategies are highly protective in COVID-19 units while main risks to healthcare professionals come from coworkers and the community. *Antimicrob Resist Infect Control.* 2021;10:163. doi:10.1186/s13756-021-01031-5
42. Waldman SE, Adams JY, Albertson TE, et al. Real-world impact of vaccination on coronavirus disease 2019 (COVID-19) incidence in healthcare personnel at an academic medical center. *Infect Control Hosp Epidemiol.* Published online July 21, 2021. doi:10.1017/ice.2021.336
43. Oda G, Sharma A, Lucero-Obusan C, Schirmer P, Sohoni P, Holodniy M. COVID-19 infections among healthcare personnel in the United States Veterans Health Administration, March to August, 2020. *J Occup Env Med.* 2021;63:291-295.
44. Lepak AJ, Buys A, Stevens L, et al. 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. *Mayo Clin Proc.* 2021;96,2312-2322.
45. Phillips, N. The coronavirus is here to stay—here's what that means. *Nature.* 2021;590:382-384.

46. Miles BA, Schiff B, Ganly I, et al. Tracheostomy during SARS-CoV-2 pandemic: recommendations from the New York Head and Neck Society. *Head Neck.* 2020;42:1282-1290.
47. Parker NP, Schiff BA, Fritz MA, et al. Tracheotomy recommendations during the COVID-19 pandemic. Revised April 2, 2020. Accessed May 26, 2022. https://www.entnet.org/resource/tracheotomy-recommendations-during-the-covid-19-pandemic-2
48. Rosano A, Martinelli E, Fusina F, et al. Early percutaneous tracheostomy in coronavirus disease 2019: association with hospital mortality and factors associated with removal of tracheostomy tube at ICU discharge: a cohort study on 121 patients. *Crit Care Med.* 2021;49:261-270.
49. Bier-Laning C, Cramer JD, Roy S, et al. Tracheostomy during the COVID-19 pandemic: comparison of international perioperative care protocols and practices in 26 countries. *Otolaryngol Head Neck Surg.* 2021;164:1136-1147.
50. Dochi H, Nojima M, Matsumura M, Cammack I, Furuta Y. Effect of early tracheostomy in mechanically ventilated patients. *Laryngoscope Investig Otolaryngol.* 2019;4:292-299.
51. Adly A, Youssef TA, El-Begermy MM, Younis HM. Timing of tracheostomy in patients with prolonged endotracheal intubation: a systematic review. *Eur Arch Otorhinolaryngol.* 2018;275:679-690.
52. Kapp CM, Latifi A, Feller-Kopman D, et al. Sedation and analgesia in patients undergoing tracheostomy in COVID-19, a multi-center registry. *J Intensive Care Med.* 2022;37:240-247.
53. Sutt AL, Tronstad O, Barnett AG, Kitchenman S, Fraser JF. Earlier tracheostomy is associated with an earlier return to walking, talking, and eating. *Aust Crit Care.* 2020;33:213-218.
54. Smailes S, Spoors C, da Costa FM, Martin N, Barnes D. Early tracheostomy and active exercise programmes in adult intensive care patients with severe burns. *Burns J Int Soc Burn Inj.* S0305-4179(21)00290–4. Published online October 27, 2021. doi:10.1016/j.burns.2021.10.005
55. Herritt B, Chaudhuri D, Thavorn K, Kubelik D, Kyeremanteng K. Early vs. late tracheostomy in intensive care settings: impact on ICU and hospital costs. *J Crit Care.* 2018;44:285-288.
56. Liu CC, Rudmik L. A cost-effectiveness analysis of early vs late tracheostomy. *JAMA Otolaryngol Head Neck Surg.* 2016;142:981-987.
57. Schultz MJ, Teng MS, Brenner MJ. Timing of tracheostomy for patients with COVID-19 in the ICU: setting precedent in unprecedented times. *JAMA Otolaryngol Head Neck Surg.* 2020;146:887-888.
58. D'Ascanio L, Pandolfini M, Capalbo M, Tempesta M. Minimizing healthcare worker contamination risk during tracheostomy. *J Am Coll Surg.* 2020;231:299-300.
59. Givi B, Schiff BA, Chinn SB, et al. Safety recommendations for evaluation and surgery of the head and neck during the COVID-19 pandemic. *JAMA Otolaryngol Head Neck Surg.* 146(6):579-584. doi:10.1001/jamaoto.2020.0780
60. Starr N, Capo-Chichi N, Moore J, et al. Perioperative provider safety in low-and middle-income countries during the COVID-19 pandemic: a call for renewed investments in resources and training. *Ann Surg.* 2021;274(6):e525-e627. doi:10.1097/SLA.0000000000005048
61. Peacocke EF, Heupink LF, Frønsdal K, Dahl EH, Chola L. Global access to COVID-19 vaccines: a scoping review of factors that may influence equitable access for low and middle-income countries. *BMJ Open.* 2021;11:e049505. doi:10.1136/bmjopen-2021-049505
62. Anand A, Sandefur J, Subramanian A. *Three New Estimates of India's All-Cause Excess Mortality during the COVID-19 Pandemic.* Center for Global Development (CGD). CGD Working Paper 589. Published 2021. Accessed May 26, 2022. https://cgdev.org/sites/default/files/three-new-estimates-indias-all-cause-excess-mortality-during-covid-19-pandemic.pdf
63. Karlinsky A, Kobak D. Tracking excess mortality across countries during the COVID-19 pandemic with the World Mortality Dataset. *Elife.* 2021;10:e69336. doi:10.7554/eLife.69336
64. Njenga MK, Dawa J, Nanyingi M, et al. Why is there low morbidity and mortality of COVID-19 in Africa? *Am J Trop Med Hyg.* 2020;103:564-569. doi:10.4269/ajtmh.20-0474
65. Cunningham CT, Quan H, Hemmelgarn B, et al. Exploring physician specialist response rates to web-based surveys. *BMC Med Res Methodol.* 2015;15:32. doi:10.1186/s12874-015-0016-z
66. Kannampallil TG, Goss CW, Evanoff BA, Strickland JR, McAlister RP, Duncan J. Exposure to COVID-19 patients increases physician trainee stress and burnout. *PloS One.* 2020;15:e0237301. doi:10.1371/journal.pone.0237301

Supplemental Table 1
Survey

We would like to gather information regarding the transmission of COVID-19 in the medical community. The aim of this study is to determine the frequency of transmission of COVID-19 to providers, particularly those involved in tracheostomies performed on COVID-19–positive patients. The information obtained is intended to help medical providers and researchers better understand the risks of COVID-19 transmission during tracheostomy and identify any risk-reducing strategies. Your participation is voluntary, and responses will be anonymized. Please take a moment to review our consent form before proceeding.	
Do you consent to proceed with this survey regarding COVID-19 infection in health care providers?	1, Yes | 2, No
In what country do you work?	1, Afghanistan | 2, Akrotiri | 3, Albania | 4, Algeria | 5, American Samoa | 6, Andorra | 7, Angola | 8, Anguilla | 9, Antarctica | 10, Antigua and Barbuda | 11, Argentina | 12, Armenia | 13, Aruba | 14, Ashmore and Cartier Islands | 15, Australia | 16, Austria | 17, Azerbaijan | 18, Bahamas | 19, Bahrain | 20, Bangladesh | 21, Barbados | 22, Bassas da India | 23, Belarus | 24, Belgium | 25, Belize | 26, Benin | 27, Bermuda | 28, Bhutan | 29, Bolivia | 30, Bosnia and Herzegovina | 31, Botswana | 32, Bouvet Island | 33, Brazil | 34, British Indian Ocean Territory | 35, British Virgin Islands | 36, Brunei | 37, Bulgaria | 38, Burkina Faso | 39, Burma | 40, Burundi | 41, Cambodia | 42, Cameroon | 43, Canada | 44, Cape Verde | 45, Cayman Islands | 46, Central African Republic | 47, Chad | 48, Chile | 49, China | 50, Christmas Island | 51, Clipperton Island | 52, Cocos (Keeling) Islands | 53, Colombia | 54, Comoros | 55, Cook Islands | 56, Coral Sea Islands | 57, Costa Rica | 58, Cote d'Ivoire | 59, Croatia | 60, Cuba | 61, Cyprus | 62, Czech Republic | 63, Democratic Republic of the Congo | 64, Denmark | 65, Dhekelia | 66, Djibouti | 67, Dominica | 68, Dominican Republic | 69, Ecuador | 70, Egypt | 71, El Salvador | 72, Equatorial Guinea | 73, Eritrea | 74, Estonia | 75, Ethiopia | 76, Europa Island | 77, Falkland Islands (Islas Malvinas) | 78, Faroe Islands | 79, Federated States of Micronesia | 80, Fiji | 81, Finland | 82, France | 83, French Guiana | 84, French Polynesia | 85, French Southern and Antarctic Lands | 86, Gabon | 87, Gambia | 88, Gaza Strip | 89, Georgia | 90, Germany | 91, Ghana | 92, Gibraltar | 93, Glorioso Islands | 94, Greece | 95, Greenland | 96, Grenada | 97, Guadeloupe | 98, Guam | 99, Guatemala | 100, Guernsey | 101, Guinea | 102, Guinea-Bissau | 103, Guyana | 104, Haiti | 105, Heard Island and McDonald Islands | 106, Holy See (Vatican City) | 107, Honduras | 108, Hong Kong | 109, Hungary | 110, Iceland | 111, India | 112, Indonesia | 113, Iran | 114, Iraq | 115, Ireland | 116, Isle of Man | 117, Israel | 118, Italy | 119, Jamaica | 120, Jan Mayen | 121, Japan | 122, Jersey | 123, Jordan | 124, Juan de Nova Island | 125, Kazakhstan | 126, Kenya | 127, Kiribati | 128, Kuwait | 129, Kyrgyzstan | 130, Laos | 131, Latvia | 132, Lebanon | 133, Lesotho | 134, Liberia | 135, Libya | 136, Liechtenstein | 137, Lithuania | 138, Luxembourg | 139, Macau | 140, Macedonia | 141, Madagascar | 142, Malawi | 143, Malaysia | 144, Maldives | 145, Mali | 146, Malta | 147, Marshall Islands | 148, Martinique | 149, Mauritania | 150, Mauritius | 151, Mayotte | 152, Mexico | 153, Moldova | 154, Monaco | 155, Mongolia | 156, Montserrat | 157, Morocco | 158, Mozambique | 159, Namibia | 160, Nauru | 161, Navassa Island | 162, Nepal | 163, Netherlands | 164, Netherlands Antilles | 165, New Caledonia | 166, New Zealand | 167, Nicaragua | 168, Niger | 169, Nigeria | 170, Niue | 171, Norfolk Island | 172, North Korea | 173, Northern Mariana Islands | 174, Norway | 175, Oman | 176, Pakistan | 177, Palau | 178, Panama | 179, Papua New Guinea | 180, Paracel Islands | 181, Paraguay | 182, Peru | 183, Philippines | 184, Pitcairn Islands | 185, Poland | 186, Portugal | 187, Puerto Rico | 188, Qatar | 189, Republic of the Congo | 190, Reunion | 191, Romania | 192, Russia | 193, Rwanda | 194, Saint Helena | 195, Saint Kitts and Nevis | 196, Saint Lucia | 197, Saint Pierre and Miquelon | 198, Saint Vincent and the Grenadines | 199, Samoa | 200, San Marino | 201, Sao Tome and Principe | 202, Saudi Arabia | 203, Senegal | 204, Serbia and Montenegro | 205, Seychelles | 206, Sierra Leone | 207, Singapore | 208, Slovakia | 209, Slovenia | 210, Solomon Islands | 211, Somalia | 212, South Africa | 213, South Georgia and the South Sandwich Islands | 214, South Korea | 215, Spain | 216, Spratly Islands | 217, Sri Lanka | 218, Sudan | 219, Suriname | 220, Svalbard | 221, Swaziland | 222, Sweden | 223, Switzerland | 224, Syria | 225, Taiwan | 226, Tajikistan | 227, Tanzania | 228, Thailand | 229, Timor-Leste | 230, Togo | 231, Tokelau | 232, Tonga | 233, Trinidad and Tobago | 234, Tromelin Island | 235, Tunisia | 236, Turkey | 237, Turkmenistan | 238, Turks and Caicos Islands | 239, Tuvalu | 240, Uganda | 241, Ukraine | 242, United Arab Emirates | 243, United Kingdom | 244, United States | 245, Uruguay | 246, Uzbekistan | 247, Vanuatu | 248, Venezuela | 249, Vietnam | 250, Virgin Islands | 251, Wake Island | 252, Wallis and Futuna | 253, West Bank | 254, Western Sahara | 255, Yemen | 256, Zambia | 257, Zimbabwe

Continued

Supplemental Table 1
Continued

In what city or town do you work?	
What is your gender?	0, Female | 1, Male | 2, Transgender | 3, Other
What is your ethnicity?	0, Hispanic or Latino | 1, NOT Hispanic or Latino | 2, I prefer not to respond
Race	0, American Indian/Alaska Native | 1, Asian | 2, Native Hawaiian or Other Pacific Islander | 3, Black or African American | 4, White | 5, More Than One Race | 6, Unknown/Not Reported
What is your age in years?	1, 18-34 | 2, 35-44 | 3, 45-54 | 4, 55-65 | 5, 65-74 | 6, 75+
How many years have you been working in health care in a nontrainee capacity?	0, 0 | 1, 1-3 | 2, 4-6 | 3, 7-9 | 4, 10-14 | 5, 15+
What type of health care provider are you? Select all that apply.[a]	1, Surgeon | 2, Anesthesiologist | 3, Physician, nonsurgeon/anesthesiologist | 4, Anesthetist, nonphysician | 5, Intensive care specialist | 6, Physician assistant or nurse practitioner | 7, Nurse | 8, Technician | 9, Respiratory therapist | 10, Administration | 11, Trainee | 12, None of these apply
How do you describe the health care facility at which you work most frequently? Select all that apply.	0, Public | 1, Private | 2, Primary/regional | 3, Secondary/general | 4, Tertiary/referral | 5, Quaternary/specialized | 6, Urban | 7, Semiurban | 8, Rural | 9, Teaching institution | 10, Designated COVID care center | 11, Charity-based | 12, None of these apply
How often do you take care of COVID-19–positive patients?	0, Never | 1, Rarely (a few times during the pandemic) | 2, Sometimes (1-3 times per month) | 3, Frequently (1-3 times per week) | 4, Nearly every day
Does your facility CURRENTLY have a shortage of personal protective equipment (PPE)?	0, Extreme shortage (~0%) | 1, Severe shortage (~25% | 2, Moderate shortage (~50%) | 3, Mild shortage (~75%) | 4, No shortage (~100%)
Has your facility EVER had a shortage of PPE during the COVID-19 pandemic? Please indicate the MOST SEVERE degree of shortage experienced.	0, Extreme shortage (~0%) | 1, Severe shortage (~25% | 2, Moderate shortage (~50%) | 3, Mild shortage (~75%) | 4, No shortage (~100%)
How concerned are you about contracting COVID-19 while taking care of COVID-19–positive patients?	0, Not at all concerned | 1, Mildly concerned | 2, Somewhat concerned | 3, Very concerned | 4, Extremely concerned
How is COVID-19 most frequently diagnosed at your facility?	1, Clinical suspicion without laboratory or radiological data | 2, Laboratory data (ie, PCR) | 3, Radiologic data (ie, CT scan) | 4, Other
Have you ever contracted COVID-19?	1, Yes | 2, No
If you have contracted COVID-19, how was it diagnosed?	1, Clinical suspicion without laboratory or radiological data | 2, Laboratory data (ie, PCR) | 3, Radiologic data (ie, CT scan)
If you have contracted COVID-19, do you believe this was due to exposure as a health care worker, or due to exposure unrelated to your work?	1, Due to exposure as a health care worker | 2, Due to exposure unrelated to work as a health care worker | 3, I'm not sure
If you have contracted COVID-19, what risk factors do you think may have contributed? Select all that apply.	0, Lack of PPE | 1, Lack of personal precaution | 2, Lack of precaution by coworkers | 3, Lack of precaution by patients | 4, Lack of precaution by others not involved in health care | 5, Did not know COVID-19–positive status of an individual | 6, My personal medical risk factors | 7, None of these
Have you received vaccination against COVID-19?	1, Yes, complete dose | 2, Yes, partial dose | 3, No
Did you contract COVID before or after being vaccinated?	0, Before | 1, After | 2, I don't know
How many times have you performed or been involved in performing tracheostomies in COVID-19–positive patients?[b]	0, Never | 1, 1-3 times | 2, 4-6 times | 3, 7-9 times | 4, 10-14 times | 5, 15+ times
(If ever involved with tracheostomies): Consider all the tracheostomies you have performed or been involved with performing on COVID-19–positive patients, and answer the following questions based on the most common situation you have encountered. "Provider" refers to any health care worker.	
On average, how many days after COVID-19 diagnosis do you perform tracheostomies?	0, 1-4 | 1, 5-7 | 2, 8-10 | 3, 11-14 | 4, 15-20 | 5, 21-28 | 6, 29+
On average, how many providers are in the room when tracheostomies are performed on COVID-19–positive patients?	0, 0 | 1, 1-3 | 2, 4-6 | 3, 7-9 | 4, 10+
Which providers are most commonly in the room when tracheostomies are performed on COVID-19–positive patients? Select all that apply.	1, Tracheostomy proceduralist | 2, Bronchoscopist | 3, Proceduralist - other | 4, Anesthesia provider | 5, Nurse | 6, Respiratory therapist or technician | 7, Trainee | 8, Observer | 9, Other
What is most often YOUR role during tracheostomies on COVID-19–positive patients? Select all that apply.	1, Tracheostomy proceduralist | 2, Bronchoscopist | 3, Proceduralist - other | 4, Anesthesia provider | 5, Nurse | 6, Respiratory therapist or technician | 7, Trainee | 8, Observer | 9, Other
Where are tracheostomies on COVID-19–positive patients most frequently performed? Select all that apply.	1, In the patient's ICU room | 2, In an operating room | 3, In a procedure room (non-OR) | 4, In a dedicated COVID-19 room | 5, In a negative pressure room | 6, Other

Continued

Supplemental Table 1
Continued

What type of PPE do you typically use during tracheostomies on COVID-19–positive patients? Select all that apply.	1, None | 2, N95 or filtering facepiece (FFP) mask | 3, Controlled air purifying respirator (CAPR) or powered air purifying respirator (PAPR) | 4, Surgical mask | 5, Cloth mask | 6, Cap | 7, Gown | 8, Nonsterile gloves | 9, Sterile gloves | 10, Eye protection | 11, Other
How concerned are you about contracting COVID-19 due to your involvement with tracheostomies in COVID-19–positive patients?	0, Not at all concerned | 1, Mildly concerned | 2, Somewhat concerned | 3, Very concerned | 4, Extremely concerned
Have you ever been diagnosed with COVID-19 within 14 days of being involved in a tracheostomy performed on a COVID-19–positive patient?	1, YES, I have contracted COVID-19 within 14 days of being involved in a tracheostomy | 2, NO, I have not contracted COVID-19 within 14 days of being involved in a tracheostomy | 3, I'm not sure
If you have contracted COVID-19 within 14 days of being involved in a tracheostomy, how was it diagnosed?	1, Clinical suspicion without laboratory or radiological data | 2, Laboratory data (ie, PCR) | 3, Radiologic data (ie, CT scan) | 4, Other
If you have contracted COVID-19 within 14 days of being involved in a tracheostomy on a COVID-19–positive patient, what risk factors do you think may have contributed? Select all that apply.	0, Lack of PPE | 1, Lack of personal precaution | 2, Lack of precaution by coworkers | 3, Lack of precaution by patients | 4, Lack of precaution by others not involved in health care | 5, Did not know COVID-19–positive status of an individual | 6, My personal medical risk factors | 7, None of these
Have any other providers at your facility become positive for COVID-19 within 14 days of involvement in a tracheostomy procedure?	1, Yes | 2, No | 3, I'm not sure
Are you able to describe procedural details about how tracheostomies are typically performed at your facility?	1, Yes | 2, No
(If YES) What technique is most often used to perform a tracheostomy on a COVID-19–positive patient at your facility?	0, Percutaneous | 1, Open | 2, Mixed (hybrid) | 3, I'm not sure | 4, Other
What type of tracheostomy tube is typically used? Select all that apply. (In the case of a tracheostomy tube with an inner cannula, if the inner cannula has no side ports it is considered nonfenestrated even if the outer cannula is fenestrated.)	1, Single-lumen tube | 2, Double-lumen tube | 3, Uncuffed tube | 4, Cuffed tube | 5, Fenestrated tube | 6, Nonfenestrated | 7, Unsure | 8, Other
How is the trachea typically identified for the procedure? Select the most common methods.	0, Anatomic reference | 1, Ultrasound | 2, Bronchoscopy | 3, I'm not sure | 4, Other
What techniques are typically used to minimize aerosolization during the procedure? Select all that apply.	1, No specific techniques | 2, Minimal or no use of bronchoscopy | 3, Minimal or no suctioning | 4, Minimal or no use of electrocautery | 5, Discontinuation of mechanical ventilation during key portions of procedure | 6, Use of additional sterile draping or other additional protective barrier | 7, Unsure | 8, Other
Are paralytic medications typically administered for the procedure? These medications include succinylcholine, cisatracurium, vecuronium, rocuronium, pancuronium, rapacuronium, doxacurium, pipecuronium, or mivacurium.	1, Yes | 2, No | 3, I'm not sure
What periprocedural complications occur most frequently? Select all that apply.	0, Complications occur very rarely | 1, False route | 2, Leakage or air loss | 3, Minor bleeding without transfusion requirement | 4, Major bleeding with transfusion requirement, | 5, Loss of airway | 6, Cardiac arrest | 7, Death | 8, I'm not sure | 9, Other
What other information would you like to share about your experience taking care of patients during the COVID-19 pandemic?	
How did you learn about this study?	1, Email invitation | 2, Facebook | 3, Friend or colleague | 4, Internet search | 5, Other

Abbreviations: CT, computerized tomography scan; OR, operating room; PCR, polymerase chain reaction; PPE, personal protective equipment.

[a] Respondents were asked to self-designate their position from among the following choices with the option to select more than one choice: "Surgeon", "Anesthesiologist", "Physician, nonsurgeon/anesthesiologist", "Anesthetist, nonphysician", "Intensive care specialist", "Physician assistant or Nurse practitioner", "Nurse", "Technician", "Respiratory therapist", "Administration", "Trainee", "None of these apply". Those who selected "Surgeon", "Anesthesiologist", "Physician, nonsurgeon/anesthesiologist", and those who identified as a medical doctor in free text were grouped as "physicians". Those who indicated "Anesthetist, nonphysician", "Physician assistant or Nurse practitioner," "Intensive care specialist" (without specifying another selection), and those who identified as an advanced practice provider in free text were grouped as "APP or ICU Provider (NOS)" signifying "advanced practice provider or intensive care unit provider (not otherwise specified)". Those selecting "Nurse", "Technician", or "Respiratory therapist" and who identified as a type of nurse, therapist, or technician in free text were grouped as "Nurse, therapist, or technician". Finally, those selecting any other option not falling into one of the previous categories were identified as "Other."

[b] The identification of whether a respondent was a "tracheostomy provider" was made separately in response to the question "How many times have you performed or been involved in performing tracheostomies in COVID-19–positive patients?", with those responding any number more than 0 categorized as "tracheostomy providers."

Supplemental Table 2
Organizations recruited for survey participation[a]

Alberta Health Services
American Association for the Surgery of Trauma
American College of Surgeons (national and international chapters)
Arizona Medical
Asociación Colombiana de Cirugía
Association for Academic Surgery
Atrium Health
Chiricahua Community Health Centers
ChristianaCare
Clínica Foianini
College of Surgeons of East Central and Southern Africa
Dartmouth University
Duke University
East, Central, and Southern Africa Health Community
Eastern Association for the Surgery of Trauma
Emirates Thoracic Society
Emory University
European Society of Intensive Care Medicine
Grady Memorial Hospital
Hammoud Hospital University Medical Center
Harvard University
Hôpitaux Universitaires de Strasbourg
Hospital Royo Villanova
InciSioN
Indian Association of Respiratory Care
Indian Society of Critical Care Medicine
Jefferson University
JHPIEGO
Lifebox
Madrid Salud
Maine Medical Center
Mayo Clinic
Memorial Sloan Kettering Cancer Center
Mercy Health
Mississippi State Medical Association
Morehouse School of Medicine
Nagoya University
National Cancer Center of Korea
National Health Service
National Health Service-United Kingdom
New Hanover Regional Medical Center
New Mexico Medical Society
New York University
Ochsner Health
Osakidetza
Panamerican Trauma Society
Phoebe Putney Medical Center
Physician Moms Group COVID19 Subgroup
Rambam Health Care Campus
Region Örebro Iän
Riverside Healthcare
Robotic Minimally Invasive Thoracic Surgery Community
Rural Area Medicine
Rural Health Information Hub
Saint Paul's Hospital Millennium Medical College
Sapienza Università di Roma
Saudi Critical Care Society
Saudi Society of Respiratory Care
Sidra Medicine
Smile Train
Sociedad de Cirugía de Uruguay
Society of Critical Care Medicine
Solidarity Bridge
South Carolina Medical Association
South Dakota State Medical Association
Stanford University
Temple University
Tulane University
University of California, San Francisco
University of Utah
Universidad Católica Boliviana-San Pablo
Universitätsklinikum Münster
Université Hôpital de Lyon
University of Alabama-Birmingham
University of California, Irvine
University of California, Davis
University of Cape Town
University of Hawaii
University of Kentucky
University of Michigan
University of Missouri
University of Pennsylvania
University of São Paolo
University of South Carolina
University of Virginia
University of Washington
Vermont Medical Society
Virginia Commonwealth University
Wake Forest University
Washington University of Saint Louis
Weill Consulting
West Virginia University

[a] Hospitals, universities, and professional and nongovernmental organizations contacted by email for survey distribution.

Supplemental Table 3

Health care worker participants by country of employment and infection status

Characteristic	No. (%) of participants[a]		
	Total 361 (100%)	Infected 90 (25%)	Uninfected 271 (75%)
Argentina	1 (0.3)	0 (0.0)	1 (0.4)
Australia	2 (0.6)	0 (0.0)	2 (0.8)
Bahrain	2 (0.6)	0 (0.0)	2 (0.8)
Bolivia	9 (2.5)	4 (4.5)	5 (1.9)
Brazil	1 (0.3)	0 (0.0)	1 (0.4)
Cambodia	1 (0.3)	0 (0.0)	1 (0.4)
Canada	1 (0.3)	1 (1.1)	0 (0.0)
Colombia	4 (1.1)	0 (0.0)	4 (1.5)
Costa Rica	1 (0.3)	0 (0.0)	1 (0.4)
Dominican Republic	2 (0.6)	1 (1.1)	1 (0.4)
Ecuador	2 (0.6)	2 (2.2)	0 (0.0)
Ethiopia	2 (0.6)	0 (0.0)	2 (0.8)
Greece	2 (0.6)	0 (0.0)	2 (0.8)
Guatemala	1 (0.3)	0 (0.0)	1 (0.4)
India	117 (32.8)	42 (47.2)	75 (28.0)
Italy	1 (0.3)	0 (0.0)	1 (0.4)
Jordan	2 (0.6)	2 (2.2)	0 (0.0)
Kenya	1 (0.3)	0 (0.0)	1 (0.4)
Kuwait	5 (1.4)	2 (2.2)	3 (1.1)
Lebanon	2 (0.6)	0 (0.0)	2 (0.8)
Mexico	2 (0.6)	0 (0.0)	2 (0.8)
Namibia	1 (0.3)	1 (1.1)	0 (0.0)
Oman	1 (0.3)	0 (0.0)	1 (0.4)
Peru	1 (0.3)	1 (1.1)	0 (0.0)
Qatar	10 (2.8)	1 (1.1)	9 (3.4)
Saudi Arabia	8 (2.2)	1 (1.1)	7 (2.6)
Spain	5 (1.4)	2 (2.2)	3 (1.1)
Turkey	1 (0.3)	0 (0.0)	1 (0.4)
United Arab Emirates	11 (3.1)	2 (2.2)	9 (3.4)
United Kingdom	3 (0.8)	3 (3.4)	0 (0.0)
United States	148 (41.5)	17 (19.1)	131 (48.9)
Yemen	7 (2.0)	7 (7.9)	0 (0.0)
Missing	4	1	3

[a] All percentages are based on the number of respondents to each question. Because of rounding, percentages may not total 100.

Supplemental Table 4

Infection timing and risk factors reported by COVID-19–infected health care workers according to COVID-19 tracheostomy provider status

Risk factor	No. (%) of respondents[a] Total,[b] 90 (100%)	Nontracheostomy, 37 (42%)	Tracheostomy, 53 (58%)	*P*
Infected due to work				.47
No	38 (44)	18 (49)	20 (41)	
Yes	48 (56)	19 (51)	29 (59)	
Missing	3	0	3	
Infected within 14 days of tracheostomy on COVID-19–positive patients[c]				NA
No	39 (44)	0 (0)	39 (76)	
Yes	3 (3)	0 (0)	3 (6)	
Unsure	9 (10)	0 (0)	9 (18)	
Not applicable	37 (42)	37 (100)	0 (0)	
Missing	2	0	2	
Lack of PPE				.83
No	66 (74)	27 (73)	39 (75)	
Yes	23 (26)	10 (27)	13 (25)	
Missing	1	0	1	
Lack of personal precaution				.19
No	62 (70)	23 (62)	39 (75)	
Yes	27 (30)	14 (38)	13 (25)	
Missing	1	0	1	
Lack of precaution by coworkers				.50
No	69 (78)	30 (81)	39 (75)	
Yes	20 (22)	7 (19)	13 (25)	
Missing	1	0	1	
Lack of precaution by patients				.77
No	64 (72)	26 (70)	38 (73)	
Yes	25 (28)	11 (30)	14 (27)	
Missing	1	0	1	
Lack of precaution outside work				.36
No	67 (75)	26 (70)	41 (79)	
Yes	22 (25)	11 (30)	11 (21)	
Missing	1	0	1	
Unknown COVID-19 status of individual				.11
No	59 (66)	21 (57)	38 (73)	
Yes	30 (34)	16 (43)	14 (27)	
Missing	1	0	1	
Personal vaccination status				.12
Unvaccinated	12 (14)	8 (22)	4 (8)	
Partially or fully vaccinated	73 (86)	29 (78)	44 (92)	
Missing	5	0	5	

Abbreviations: NA, not applicable; PPE, personal protective equipment.

[a] All percentages are based on the number of respondents to each question. Because of rounding, percentages may not total 100.
[b] Ninety of the 361 total survey respondents reported a history of COVID-19 infection.
[c] Comparative analyses not performed given that factor does not apply to nontracheostomy providers.

Supplemental Table 5

COVID-19 infection by tracheostomy provider and vaccination status

Provider type	Vaccination status	No. (%) of providers[a] Total, 361 (100%)	Infected, 90 (25%)	Uninfected, 271 (75%)	*P*[b]
Nontracheostomy	Partially or fully	155 (89)	29 (78)	126 (92)	.02
	Unvaccinated	19 (11)	8 (22)	11 (8)	
Tracheostomy	Partially or fully	148 (92)	44 (92)	104 (92)	.94
	Unvaccinated	13 (8)	4 (8)	9 (8)	
	Missing	26	5	21	

[a] All percentages are based on the number of respondents to each question. Because of rounding, percentages may not total 100.
[b] Calculated from χ^2 tests.

Supplemental Table 6
Demographics and health care factors by country income

Variable	No. (%) of participants[a]		
	Total,[b] 356 (100%)	Low or middle income, 157 (44%)	High income, 199 (66%)
Reported COVID-19 infection			
Uninfected	267 (75)	97 (62)	170 (85)
Infected	89 (25)	60 (38)	29 (15)
Country[c]			
India	117 (33)	117 (75)	0 (0)
United States	148 (42)	0 (0)	148 (74)
Other	91 (26)	40 (25)	51 (26)
Sex			
Male	198 (56)	94 (60)	104 (52)
Female	157 (44)	62 (40)	95 (48)
Missing	1	1	0
Race			
White	150 (46)	17 (13)	133 (70)
Non-White	174 (54)	117 (87)	57 (30)
Missing	32	23	9
Age			
<45 y	280 (79)	141 (90)	139 (70)
≥45 y	76 (21)	16 (10)	60 (30)
Date of survey response			
Before February 1, 2021	96 (27)	9 (5.7)	87 (44)
February 1, 2021 or later	260 (73)	148 (94)	112 (56)
COVID-19 country caseload[d]			
≤Median	178 (50)	149 (95)	29 (15)
>Median	178 (50)	8 (5)	170 (85)
Type of health care professional[e]			
Physicians	116 (33)	25 (16)	91 (46)
APP or ICU provider (NOS)	42 (12)	7 (5)	35 (18)
Nurse, RCP, therapist, or technician	173 (49)	112 (73)	61 (31)
Other	20 (6)	9 (6)	11 (6)
Missing	5	4	1
Years in practice			
<10	250 (70)	135 (86)	115 (58)
≥10	105 (30)	22 (14)	83 (42)
Missing	1	0	1
COVID-19 tracheostomy provider			
Nontracheostomy provider	179 (50)	73 (47)	106 (53)
Tracheostomy provider	176 (50)	83 (53)	93 (47)
Missing	1	1	0
COVID-19 care frequency			
Less than weekly	151 (42)	65 (41)	86 (43)
At least weekly	205 (58)	92 (59)	113 (57)
HCP vaccination status			
Vaccinated	301 (91)	135 (87)	166 (94)
Unvaccinated	31 (9)	20 (13)	11 (6)
Missing	24	2	22

Continued

Supplemental Table 6
Continued

Variable	No. (%) of participants[a]		
	Total,[b] 356 (100%)	Low or middle income, 157 (44%)	High income, 199 (66%)
Concern for contracting COVID-19			
Not at all/mild	118 (33)	35 (22)	83 (42)
Moderate	109 (31)	48 (31)	61 (31)
Very/extreme	128 (36)	73 (47)	55 (28)
Missing	1	1	0
PPE availability			
<75% of needs met	52 (15)	36 (23)	16 (8)
≥75% of needs met	302 (85)	119 (77)	183 (92)
Missing	2	2	0
Facility type			
Nonteaching	194 (54)	119 (76)	75 (38)
Teaching	162 (46)	38 (24)	124 (62)
Facility COVID-19 designation			
Non–COVID-designated	280 (79)	131 (83)	149 (75)
COVID-designated	76 (21)	26 (17)	50 (25)

Abbreviations: APP, advanced practice provider; HCP, health care professional; ICU, intensive care unit; NOS, not otherwise specified; PPE, personal protective equipment; RCP, respiratory care practitioner.

[a] All percentages are based on the number of respondents to each question. Because of rounding, percentages may not total 100.
[b] Country was identified by 356 of 361 total participants.
[c] A complete list of respondents by countries of employment is provided in Supplemental Table 3.
[d] Median cumulative confirmed cases per million people based on country and date of survey response: 46 326 (range, 27-157 103).
[e] Other types of health care professionals who responded to the survey included trainees, administrative health care professionals, and those not otherwise specified.

Supplemental Table 7
Tracheostomy provider subset demographics

Characteristic	No. (%) of tracheostomy providers[a] Total,[b] 145 (100%)	Infected, 42 (29%)	Uninfected, 103 (71%)	P
Country of employment				. 006
India	45 (31)	19 (46)	26 (25)	
United States	60 (42)	9 (22)	51 (50)	
Other countries[c]	38 (27)	13 (32)	25 (25)	
Missing	2	1	1	
Country income level				<.001
Low or middle	68 (48)	29 (71)	39 (38)	
High	75 (52)	12 (29)	63 (62)	
Missing	2	1	1	
Sex				.93
Female	63 (43)	18 (43)	45 (44)	
Male	82 (57)	24 (57)	58 (56)	
Race				.42
Non-White	63 (47)	15 (42)	48 (49)	
White	70 (53)	21 (58)	49 (51)	
Missing	12	6	6	
Age				.002
<45 y	105 (72)	38 (90)	67 (65)	
≥45 y	40 (28)	4 (10)	36 (35)	
Date of survey response				.02
Before February 1, 2021	42 (29)	6 (14)	36 (35)	
February 1, 2021 or after	103 (71)	36 (86)	67 (65)	
COVID-19 caseload on survey date[d]				<.001
≤Median	47 (33)	23 (56)	24 (24)	
>Median	96 (67)	18 (44)	78 (76)	
Missing	2	1	1	
Type of health care worker				.01
Physician	54 (38)	9 (21)	45 (45)	
APP or ICU provider (NOS)	17 (12)	3 (7)	14 (14)	
Nurse, RCP, therapist, or technician	70 (49)	29 (69)	41 (41)	
Other[e]	2 (1)	1 (2)	1 (1)	
Missing	2	0	2	
Years in practice				.12
<10	97 (67)	32 (78)	65 (63)	
≥10	47 (33)	9 (22)	38 (37)	
Missing	1	1	0	
COVID-19 care frequency				.86
At least once weekly	36 (25)	10 (24)	26 (25)	
Less than once weekly	109 (75)	32 (76)	77 (75)	
Vaccination status				>.99
Partially or fully	117 (91)	35 (92)	82 (91)	
Unvaccinated	11 (9)	3 (8)	8 (9)	
Missing	17	4	13	
Concern for contracting COVID-19 infection				.64
Not at all/mild	48 (33)	12 (29)	36 (35)	
Moderate	43 (30)	12 (29)	31 (20)	
Very/extreme	54 (37)	18 (42)	36 (35)	
PPE availability on survey date				.06
<75% of needs met	22 (15)	10 (24)	12 (12)	
≥75% of needs met	123 (85)	32 (76)	91 (88)	
Facility type				.005
Nonteaching	81 (56)	31 (74)	50 (49)	
Teaching	64 (44)	11 (26)	53 (51)	
Facility COVID-19 designation				.84
COVID-19–designated	105 (72)	30 (71)	75 (73)	
Non–COVID-19–designated	40 (28)	12 (29)	28 (27)	

Abbreviations: APP, advanced practice provider; HCP, health care professional; ICU, intensive care unit; NOS, not otherwise specified; PPE, personal protective equipment; RCP, respiratory care practitioner.

[a] All percentages are based on the number of respondents to each question. Because of rounding, percentages may not total 100.
[b] A total of 145 tracheostomy providers of the 179 total health care providers involved in tracheostomies were able to provide procedural details.
[c] A complete list respondents by countries of employment is listed in Supplemental Table 3.
[d] Median cumulative confirmed cases per million people based on country and date of survey response: 46 326 (range 27-157 103).
[e] Other types of health care professionals who responded to the survey included trainees, administrative health care professionals, and those not otherwise specified.

Supplemental Table 8

Periprocedural complications reported by COVID-19 tracheostomy providers and history of provider COVID-19 infection

Complication	No. (%) of providers		
	Total[a] 145 (100%)	Infected 42 (29%)	Uninfected 103 (71%)
False route			
No	137 (94)	38 (90)	99 (96)
Yes	8 (6)	4 (10)	4 (4)
Significant desaturation			
No	125 (86)	40 (95)	85 (83)
Yes	20 (14)	2 (5)	18 (17)
Minor bleeding			
No	73 (50)	15 (36)	58 (56)
Yes	72 (50)	27 (64)	45 (44)
Major bleeding			
No	141 (97)	40 (95)	101 (98)
Yes	4 (3)	2 (5)	2 (2)
Loss of airway			
No	137 (94)	37 (88)	100 (97)
Yes	8 (6)	5 (12)	3 (3)
Cardiac arrest			
No	138 (95)	40 (95)	98 (95)
Yes	7 (5)	2 (5)	5 (5)
Other			
No	138 (95)	39 (93)	99 (96)
Yes	7 (5)	3 (7)	4 (4)

[a] One hundred forty-five tracheostomy providers of the 179 total health care professionals involved in tracheostomies on COVID-19–positive patients were able to provide procedural details.