COVID-19 Transmission to Health Care Personnel During Tracheostomy Under a Multidisciplinary Safety Protocol

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Background Tracheostomies are highly aerosolizing procedures yet are often indicated in patients with COVID-19 who require prolonged intubation. Robust investigations of the safety of tracheostomy protocols and provider adherence and evaluations are limited.
Objectives To determine the rate of COVID-19 infection of health care personnel involved in COVID-19 tracheostomies under a multidisciplinary safety protocol and to investigate health care personnel's attitudes and suggested areas for improvement concerning the protocol.
Methods All health care personnel involved in tracheostomies in COVID-19–positive patients from April 9 through July 11, 2020, were sent a 22-item electronic survey.
Results Among 107 health care personnel (80.5%) who responded to the survey, 5 reported a positive COVID-19 test result (n=2) or symptoms of COVID-19 (n=3) within 21 days of the tracheostomy. Respondents reported 100% adherence to use of adequate personal protective equipment. Most (91%) were familiar with the tracheostomy protocol and felt safe (92%) while performing tracheostomy. Suggested improvements included creating dedicated tracheostomy teams and increasing provider choices surrounding personal protective equipment.
Conclusions Multidisciplinary engagement in the development and implementation of a COVID-19 tracheostomy protocol is associated with acceptable safety for all members of the care team. (*American Journal of Critical Care.* 2022;31:452-460.)

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Since the first report of a novel coronavirus in Wuhan, China,[1] the persistence of the ensuing COVID-19 pandemic has created massive global challenges for public health, research, and health care.[2] Although many cases of COVID-19 are mild, patients with severe illness often require intensive care because of acute hypoxemic respiratory failure,[3] necessitating prolonged mechanical ventilation in up to approximately 12% of patients.[4] The increase in respiratory failure has resulted in an increased need for tracheostomies in patients with COVID-19.[5]

Because tracheostomies are highly aerosolizing procedures,[6,7] many authorities have raised concerns regarding the potential for transmission of COVID-19 to health care personnel during the procedure and have established recommendations to enhance patient and provider safety.[8-12] The data on rate of infection of health care personnel in association with tracheostomies have largely demonstrated limited viral transmission; however, most reports are anecdotal[13-16] or from cohorts of small teams of proceduralists, without consideration of the broader health care team.[17-24]

Researchers have advocated for health care personnel–centered studies to investigate the risk for COVID-19 transmission during tracheostomy,[25] yet few studies have included the entire complement of physicians, nurses, surgical technologists, and respiratory care practitioners involved in the procedure. In the current study, we describe the COVID-19 tracheostomy protocol implemented at our institution and investigate the rate of transmission of COVID-19 to health care personnel involved in tracheostomy procedures as well as the beliefs and attitudes of health care personnel concerning their own safety.

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Methods

We conducted the present study at Michigan Medicine, which provided tertiary and referral services during the initial pandemic surge. According to the protocol at our institution, tracheostomies were performed either at the bedside in a negative-pressure room or in the operating room, depending on the proceduralist's judgment. The institutional protocol for performing tracheostomy during the COVID-19 pandemic was developed through multidepartmental stakeholder engagement that specified standards and practices for performing tracheostomy (Supplement 1, available online only at ajcconline.org). This review of provider safety under the protocol was determined by our institutional review board to be a quality assurance/quality improvement initiative (HUM00187214) and was not regulated as human subjects research.

> Tracheostomy, a highly aerosolizing procedure, is often needed in patients with severe COVID-19.

Survey Participants

All health care personnel involved in tracheostomy procedures on COVID-19–positive patients from April 9, 2020, through July 11, 2020, were invited to participate in a postprocedure survey (Supplement 2, available online only). Proceduralists, anesthesiologists, and surgical technologists were identified by retrospective medical record review of procedure notes. To identify other members of the tracheostomy team, we also included any respiratory care practitioner or nurse who was charting vitals or respiratory parameters at the time of tracheostomy.

Because many individuals performed more than one tracheostomy and each tracheostomy involved multiple providers in the room, adherence to the use of personal protective equipment (PPE) and use of properly filtered rooms are reported as percentages of the total number of provider–tracheostomy encounters. Patient demographics, procedure type, COVID-19 status, and duration from intubation to tracheostomy were also obtained via the electronic medical record and stored in a password-protected REDCap (Research Electronic Data Capture) database (version 10.0).[26]

Survey Design and Administration

A multidisciplinary team comprising frontline health care personnel involved in COVID-19 tracheostomy care, individuals well-versed in COVID-19 tracheostomy literature and survey design, and representatives from occupational health services iteratively developed a 22-question survey using Qualtrics software, version 2020 (Qualtrics, LLC). The survey was assessed for clarity and vetted against a quality checklist to eliminate design flaws, such as leading questions, dual questions, or inadequate response options.

The survey was distributed via email, and follow-up reminders were sent to nonrespondents at 1, 2, and 3 weeks. The survey included questions regarding the health care personnel's use of PPE, development of symptoms, or receipt of a positive result on a COVID-19 test within 21 days of the procedure. Individuals were not mandated to complete the survey and were given the option to participate or not as part of the community reviewing the institutional protocol. COVID-19 can present with a variety of symptoms; therefore, we used the symptoms employees are screened for every day at our institution (eg, fever, cough, shortness of breath). The survey also included questions regarding familiarity with the protocol, perceived provider safety, breaches of protocol, and suggested areas for improvement. Participants were given the option of choosing to answer or not to answer questions pertaining to COVID-19. Survey responses were maintained on a password-protected folder behind the institutional firewall that could be accessed by the study team only. The study team had no other access to individual records.

All health care personnel involved in tracheostomy procedures on COVID-19–positive patients from April 9 through July 11, 2020, were surveyed.

The occupational health services department reviewed the list of all health care personnel present when a tracheostomy was performed in a COVID-19–positive patient to identify instances in which individuals were tested for COVID-19 in the 3-week interval after participation in a tracheostomy. The results were reported to the study team in aggregate only to maintain individual privacy. We compared responses to the survey regarding COVID-19 status and symptoms with the data from occupational health services to assess survey reliability.

Analyses

All survey data were collected from December 12, 2020, through January 15, 2021. Descriptive statistics of counts, proportions, means, and SDs were used to analyze closed-ended survey items using Excel, version 2020 (Microsoft Corporation). Times to tracheostomy and number of procedures were reported as medians and interquartile ranges. Given the brevity of responses, open-ended survey items were reviewed and analyzed using inductive content analysis. Inductive content analysis is recommended when there is limited literature on the phenomenon under study.[27] Author T.C.S. generated the initial codes and categories. Author P.K.P. reviewed the responses and categories and provided additional input. Open-ended questions left blank or that received an "N/A" response were excluded from analysis. Differences in the ratio of respondents to nonrespondents between health care provider groups were compared by using χ^2 testing.

Results

A total of 64 tracheostomies were performed on COVID-19–positive patients from April 9, 2020, through July 11, 2020. Among the cohort of 64 patients who had tested positive for COVID-19 by quantitative polymerase chain reaction (qPCR) at their initial presentation, the mean time from initial diagnosis to tracheostomy was 24 days (SD, 10 days) and the mean time from last positive test to tracheostomy was 19 days (SD, 11 days). Thirteen patients (20%) had a negative result on a follow-up test from tracheal aspirate or nasopharyngeal swab before tracheostomy. Of 146 health care personnel initially identified as being eligible for survey distribution, 7 were travelers or were not available for further contact, and 6 responded that they did not participate in a tracheostomy procedure, for a total of 133 unique individuals. Of the 133 individuals, 50 were physicians, 49 were nurses, 31 were respiratory care practitioners, and 3 were surgical technologists. Proceduralists

included physicians from multiple disciplines, including otolaryngology, thoracic surgery, acute care surgery, neurocritical care, and interventional pulmonology. Surveys were completed by 80.5% of participants (Table 1). Characteristics and outcomes of the health care personnel who responded to our survey are presented in Table 2. No significant difference in occupation was found between respondents and nonrespondents when occupation was self-reported (ie, proceduralist, anesthesiologist, fellow/resident, nursing, respiratory care professional, surgical technologist); however, we did note differences in disciplines when physicians were considered as a single group ($\chi^2 = 8.4$, $P = .04$).

Table 1
Survey response by health care provider group

Health care provider group[a]	No. of survey responders	No. of survey nonresponders
Physicians	46	4
Proceduralist	22	1
Anesthesiologist	6	1
Resident or fellow	18	2
Nonphysicians	61	22
Nurse	34	15
Respiratory care practitioner	25	6
Surgical technologist	2	1

[a] χ^2 by individual group was 8.8 ($P = .12$); χ^2 by physician vs nonphysician was 8.4 ($P = .04$).

Adherence to Protocol

Most providers (91%) had previous experience with tracheostomies before the procedure on a COVID-19–positive patient. A total of 325 provider–tracheostomy encounters were reported. Respondents reported using standard PPE (an N95 mask with eye protection, a powered air-purifying respirator [PAPR], or a negative-pressure tent [AerosolVE]) in 100% of the tracheostomies performed. About 33% of cases were completed with an N95 mask and eye protection; 67% were performed using a PAPR. Four respondents reported having used a negative-pressure tent in addition to an N95 mask with eye protection. Three provider–tracheostomy encounters were reported in a neutral pressure room; one respondent reported being "unsure" of what type of room was used. A total of 99% of provider–tracheostomy encounters were reported as being performed in either a negative-pressure room or a room with a high-efficiency particulate air (HEPA) filter.

Health Care Personnel Symptoms and Infections

Five respondents (5%) reported new symptoms (n = 3) or a positive COVID-19 test result (n = 2) within 21 days of performing a tracheostomy. In contrast, no cases were identified by cross-matching with institutional occupational health services data. Three of the 5 respondents reported other high-risk exposures occurring during the same time frame.

Two respondents reported a positive COVID-19 test result within 21 days of performing a tracheostomy procedure (Table 2), one being the primary proceduralist and the other a resident physician. One respondent reported participation in 3 tracheostomies, and the other reported performing 4 tracheostomies

Table 2
Characteristics and outcomes of health care personnel who responded to the survey

Role	No. (%) of 107 respondents		No. of tracheostomies performed, median (range)	Performed tracheostomy using proper PPE, No. (%) of respondents	No. of respondents with	
	Total	With prior tracheostomy experience			Positive COVID-19 test result within 21 days of procedure	Symptoms of COVID-19 within 21 days of procedure
Proceduralist	22 (21)	22 (100)	2 (1-28)	22 (100)	1	1
Anesthesiologist	6 (6)	6 (100)	3 (1-14)	6 (100)	0	0
Resident or fellow	18 (17)	17 (94)	2 (1-10)	18 (100)	1	0
Nurse	34 (32)	30 (88)	2 (1-11)	34 (100)	0	1
Respiratory care practitioner	25 (23)	21 (84)	2 (1-14)	25 (100)	0	1
Surgical technologist	2 (2)	2 (100)	2 (2)	2 (100)	0	0

Abbreviation: PPE, personal protective equipment.

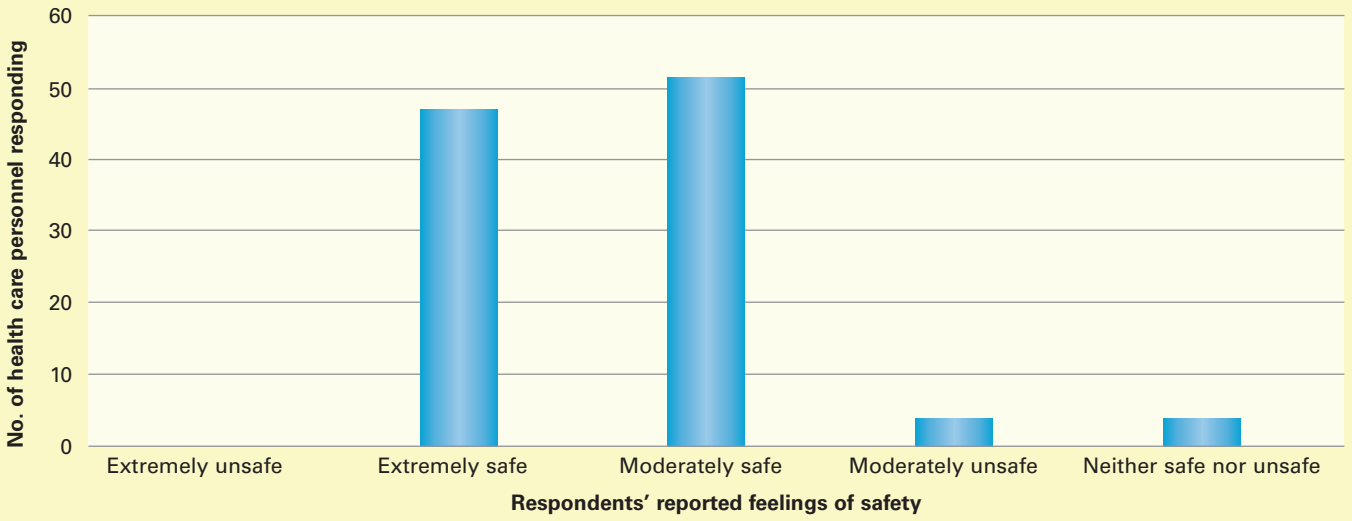

Figure Perceived feelings of safety among health care personnel under the multidisciplinary tracheostomy protocol. (One participant did not respond to this question.)

during this period. During each tracheostomy, these providers used standard PPE and performed the procedure in a negative-pressure setting, either at the bedside or in the operating room. Neither provider reported having any other high-risk exposures outside the tracheostomy; however, one noted in the comments section that they most likely contracted the virus at another health care facility or via community spread. These 2 respondents never worked together in performing a tracheostomy during the study period.

Three other respondents reported new symptoms within 21 days of participating in tracheostomy procedures, including one nurse, one respiratory care practitioner, and one proceduralist. One respondent reported a new cough, one had a baseline increase in their inhaler usage, and one reported "other" symptoms without specifying the symptoms. One of these respondents had performed more than 4 tracheostomies and the other 2 respondents reported having performed one tracheostomy. During each tracheostomy, these providers used standard PPE and performed the procedure in either a negative-pressure room or a room with a HEPA filter. Two of these individuals did not receive a COVID-19 test and one respondent received a negative result on a COVID-19 test within 21 days of the tracheostomy. Two respondents reported having other high-risk exposures outside the tracheostomy and definite causality could not be determined for any of the respondents.

For the 5 health care personnel reporting positive test results or symptoms, patient data regarding ongoing infectivity were assessed by examining follow-up COVID-19 testing. Four of these 5 survey respondents performed at least one COVID-19 tracheostomy in a patient for whom a negative result on a COVID-19 test was not available at the time the tracheostomy was performed.

Personnel Attitudes and Suggestions for Improvement

Overall, most respondents were aware (63%) or somewhat aware (28%) of the institutional tracheostomy protocol. The Figure outlines the respondents' feelings of safety; 92% of respondents reported feeling extremely safe or moderately safe at the time of the procedure. Seven respondents reported perceived breaches of protocol. These breaches included having open or unsecure airways (n = 2), staff who were unfamiliar with PPE donning and doffing or the tracheostomy procedure itself (n = 2), and ancillary staff entering and exiting an operating room, which was perceived as potentially contaminating the sterile field (n = 3). One of these reports was by a health care worker who also reported new-onset symptoms within 21 days of the tracheostomy procedure.

Table 3 outlines the 4 key categories and representative excerpts abstracted from 2 of the open-ended questions on the survey. Some (40%) of the open-ended questions were left blank or received a response of "N/A [not applicable]." Respondents reported adequate PPE and deliberate, closed-loop communication as key elements that enhanced their feelings of safety. Two opportunities for improvement included increasing PAPR availability for all providers and forming dedicated tracheostomy teams to perform all COVID-19 tracheostomies throughout the hospital.

Discussion

Some of the most provocative data from this study relate to the 5 survey respondents who reported

Table 3
Qualitative content analysis of attitudes and areas for improvement of health care personnel who responded

Category	% of respondents[a]	Sample excerpt
Provider safety		
Proper PPE	67	"Appropriate PPE by all staff members is critical to safety of the procedure."
Communication	18	"Working with a team that can communicate and work AS A TEAM."
Improvements		
PAPRs for all health care personnel	25	"PAPR for all in room, feels more durable than N95 + face shield."
Dedicated teams performing tracheostomy	25	"Consider tracheostomy team approach which is done in other institutions, ie, expert providers with additional knowledge about optimal approach for COVID."

Abbreviations: PAPRs, powered air-purifying respirators; PPE, personal protective equipment.

[a] Responses were included in more than one category if both categories were represented in a single response; percentages were calculated based only on those who had responded.

either positive test results (n = 2) or symptoms (n = 3) within 21 days of the procedure, but for whom no causal link with tracheostomy could be established. Four of the 5 individuals with symptoms or infection reported that they had been involved in at least one tracheostomy in a patient with COVID-19 without documented conversion to COVID-19–negative status. Yet, this 80% rate of "no negative test" exactly matches the base rate in the entire sample, in which only 20% of patients undergoing tracheostomy had negative results on follow-up COVID-19 testing (our institutional protocol did not require a negative COVID-19 test result in patients undergoing tracheostomy). For reference, the overall rate of community spread for the county in which this study took place (Washtenaw County) was 4673.5 cases per million (0.47%) throughout the study period.[28]

The Multidisciplinary Approach

Achieving the buy-in of our entire multidisciplinary team was an important aspect of ensuring adherence to the protocol. Many have reported success engaging multidisciplinary teams when caring for tracheostomy patients both before[29,30] and throughout the COVID-19 pandemic.[31-33] Our collaborative approach emphasized diverse stakeholder engagement across the health care enterprise. This collaboration was particularly important in enabling providers to feel safe during the acute phase of the pandemic, during which time a complex relationship existed between ensuring the safety of health care personnel and ensuring patient-centered outcomes.[34] Just as interdisciplinary rounds have been shown to improve patient outcomes,[35] cultivating this interprofessional approach was essential to ensuring both staff safety and optimal patient care.

Our protocol had several important elements. Tracheostomies were to be performed preferentially in the intensive care unit to minimize transport of patients, and procedures took place in either negative-pressure rooms or, as a secondary choice, in externally vented rooms with a HEPA filter. In such cases, we favored an open versus a percutaneous procedure, given the lack of high-quality data on aerosolization and historical reports from the severe acute respiratory syndrome (SARS) pandemic.[36,37] Additionally, our protocol recommended the use of a PAPR or N95 mask with eye protection for all tracheostomy-related cases and procedures for COVID-19–positive patients and patients with an unknown COVID-19 status. Our survey results indicated that respondents were largely aware of and adherent to these protocol recommendations.

It is important to note that the survey response rate varied between provider groups, with responses from nursing, respiratory care practitioners, and surgical technology personnel being less likely than responses from physicians. It is not clear whether this difference reflects particular group engagement, responsiveness to email, or other factors, but it highlights the critical importance of tailoring assessments of safety interventions to reach all members of the health care team. Similarly, self-reporting identified a small number of cases and symptoms that were not detected by routine occupational health processes, highlighting the importance of communication and the challenges of process-building for surveillance.

> Health care providers were largely familiar with and adherent to institutional protocols, and most providers felt safe while performing tracheostomies on patients with COVID-19.

COVID-19 Testing and Timing of Procedure

Testing accuracy throughout a patient's disease course is still not well understood,[38] and guidelines on pretracheostomy testing vary widely.[25] The results of follow-up COVID-19 testing before tracheostomy may be misleading because counts of dead or inert virus can be amplified for weeks or months after infectivity has subsided.[39,40] Given these constraints, as well as the limited availability of testing materials at the beginning of the pandemic,[41] our providers did not rely solely on COVID-19 testing to influence their decision-making. Given that widescale testing has become more readily available, a negative COVID-19 test result before a tracheostomy procedure may provide additional assurance of waning of viral load with corresponding reduction in transmission risk. At the same time, the role of antibody testing in obviating the need for PCR testing in this setting is unclear, given that vestiges of former infection may persist, yielding positive test results in patients who are no longer infectious.

Knowing when to perform tracheostomy can be challenging.[42-44] Tracheostomy practice remains diverse in terms of timing, with some institutions still preferring longer periods of use of a closed ventilator circuit versus earlier transition to an open system. Some patients may benefit from early tracheostomy (<4-7 days) and others from delay (>14 days), and optimal approaches to ventilation, weaning, and decannulation continue to be refined.[45-49] In the landmark Trac-Man trial, early tracheostomy (within 4 days) was not found to improve 30-day mortality or secondary outcomes in intubated patients.[50] This finding has informed evidence-based recommendations to perform tracheostomy at or after 10 days. Viral load and infectivity are now believed to be markedly reduced after 10 days of ventilatory support, which typically corresponds to a significantly longer time since initial infection.[42] Although our protocol initially endorsed deferral of tracheostomy in patients with COVID-19 until after 21 days, practices at our institution evolved in response to emerging evidence, resulting in guidance that earlier timing of tracheostomy might improve patient outcomes without increased risk to health care personnel.[23]

Areas for Improvement

Our survey participants provided suggestions for improving the tracheostomy protocol. For example, although the extant literature[51] and our study data provide no evidence of the superiority of PAPRs over N95 masks in reducing the risk for transmission, dedicated PAPR availability may improve *perceived* safety. Given the high rates of anxiety, moral distress, and health care provider burnout documented amid the pandemic,[52,53] such requests warrant due consideration.

Two other quality improvement opportunities involved communication and developing dedicated tracheostomy teams. Some respondents advocated for team huddles, especially with physician leadership, before entering the room. Other respondents proposed dedicated tracheostomy teams—which have been recommended[36] and implemented at other institutions[19,54]—to ensure each provider is comfortable with the protocol and to minimize the number of providers in each room. The value of dedicated equipment and teams must be weighed against workforce demands amid acute surges.

Last, the need for wide dissemination of protocols was evident in survey responses. Although most participants (92%) described being either familiar or somewhat familiar with our tracheostomy protocol, 9 participants were unfamiliar with it. Additionally, 7 breaches of protocol were reported in our study. These findings underscore the need to circulate and familiarize staff with key protocol measures, ensuring education for every individual who may be involved in a tracheostomy for a patient with COVID-19.

Our work has several implications for nurses involved in the care of patients with a tracheostomy tube, both during the initial procedure and during subsequent patient care. Nurses should follow the same protective measures as proceduralists and should recognize the potential for aerosol generation during routine postoperative procedures, such as suctioning of the tracheostomy tube, cleaning of the tracheostomy site, and any maneuvering of patients or circuits. Nurses also play a critical role in partnering with physicians and allied health professionals to ensure safe and coordinated care, including care provided by respiratory therapists, speech language pathologists, and other members of the multidisciplinary team.[45]

Limitations

This study is not without limitations. Our method of identifying health care personnel involved in tracheostomies was imperfect, as evidenced by the 6 individuals surveyed who reported not being involved in a tracheostomy during this period. Similarly, some individuals involved in tracheostomies were not surveyed, including those who were travelers or who may not have been documented in charting. The survey was also subject to response bias, though our populations of respondents and nonrespondents

were similar, but not identical, with respect to health care role.

Our assessment of infection control practice and adherence to protocols (including proper donning and doffing of PPE) is limited by the self-reported nature of our survey; however, our findings do reflect true clinician practice. Among respondents who reported positive symptoms or testing, we were unable to confirm whether transmission occurred during tracheostomy procedures. It is possible that respondents with nonspecific symptoms did not contract COVID-19 altogether or that the 2 participants with confirmed infection contracted the virus in another health care setting or in the community. Community exposure was a significant predictor of infection of health care personnel during this period.[55] Three of these 5 individuals described other high-risk exposures within the same time frame.

We also did not study COVID-19 infection in personnel providing postprocedural care. Last, participants in this study were from a single institution, limiting our study's generalizability. Considerations may differ in different geographies, particularly in relation to available supplies that may differ widely in resource-rich versus low- and middle-income countries.

With the shifting landscape of the pandemic and the evolution of COVID-19 treatment, this work continues to be relevant. Rapid viral mutations and pockets of persistent infection in undervaccinated regions keep institutional commitments to risk reduction for health care providers as a vital concern. Despite the inability to determine causality, we were able to demonstrate that, even before vaccination was available, participation in tracheostomy under an institutional protocol was safe for multidisciplinary personnel and was not associated with high rates of transmission. The findings of this study inform the tracheostomy safety literature and our ongoing responses to future emergent challenges.

Conclusions

Our survey results indicate that health care personnel were largely familiar with and adherent to institutional protocols and that most providers felt safe while performing tracheostomies on COVID-19 patients. However, a small portion of our survey respondents reported possible infection during the 21-day window following tracheostomy, introducing the possibility of rare instances of viral transmission among physicians, nurses, surgical technologists, or respiratory care professionals. Procedural risks and safety should therefore be considered for all health care personnel participating in tracheostomy. Potentially preventable breaches in protocol were also identified, as was inconsistent reporting to central health services. Interprofessional teams developing and adapting protocols should consider elements of equipment, perioperative testing, continued education, and preprocedure safety huddles to ensure closed-loop communication, with the goal of reducing transmission risk to zero.

FINANCIAL DISCLOSURES
None reported.

REFERENCES

1. Huang C, Wang Y, Li X, et al. Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China. *Lancet.* 2020;395(10223):497-506.
2. Fauci AS, Lane HC, Redfield RR. Covid-19 - navigating the uncharted. *N Engl J Med.* 2020;382(13):1268-1269.
3. Grasselli G, Zangrillo A, Zanella A, et al. Baseline characteristics and outcomes of 1591 patients infected with SARS-CoV-2 admitted to ICUs of the Lombardy Region, Italy. *JAMA.* 2020;323(16):1574-1581.
4. Wang D, Hu B, Hu C, et al. Clinical characteristics of 138 hospitalized patients with 2019 novel coronavirus–infected pneumonia in Wuhan, China. *JAMA.* 2020;323(11):1061-1069.
5. Avilés-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.* 2021;147(1):41-48.
6. Pandian V, Morris LL, Brodsky MB, et al. Critical care guidance for tracheostomy care during the COVID-19 pandemic: a global, multidisciplinary approach. *Am J Crit Care.* 2020; 29(6):e116-e127. doi:10.4037/ajcc2020561
7. Balakrishnan K, Schechtman S, Hogikyan ND, Teoh AYB, McGrath B, Brenner MJ. COVID-19 pandemic: what every otolaryngologist-head and neck surgeon needs to know for safe airway management. *Otolaryngol Head Neck Surg.* 2020;162(6):804-808.
8. 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.* 2020;146(6):579-584.
9. 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
10. Heyd CP, Desiato VM, Nguyen SA, et al. Tracheostomy protocols during COVID-19 pandemic. *Head Neck.* 2020;42(6):1297-1302.
11. Kowalski LP, Sanabria A, Ridge JA, et al. COVID-19 pandemic: effects and evidence-based recommendations for otolaryngology and head and neck surgery practice. *Head Neck.* 2020;42(6):1259-1267.
12. Shiba T, Ghazizadeh S, Chhetri D, St. John M, Long J. Tracheostomy considerations during the COVID-19 pandemic. *OTO Open.* 2020;4(2):2473974X20922528. doi:10.1177/2473974X20922528
13. Turri-Zanoni M, Battaglia P, Czaczkes C, Pelosi P, Castelnuovo P, Cabrini L. Elective tracheostomy during mechanical ventilation in patients affected by COVID-19: preliminary case series from Lombardy, Italy. *Otolaryngol Head Neck Surg.* 2020; 163(1):135-137.
14. Kwak PE, Connors JR, Benedict PA, et al. Early outcomes from early tracheostomy for patients with COVID-19. *JAMA Otolaryngol Head Neck Surg.* Published online December 17, 2020. doi:10.1001/jamaoto.2020.4837
15. D'Ascanio L, Pandolfini M, Capalbo M, Tempesta M. Minimizing healthcare worker contamination risk during tracheostomy. *J Am Coll Surg.* Published online May 14, 2020. doi:10.1016/j.jamcollsurg.2020.04.028
16. Volo T, Stritoni P, Battel I, et al. Elective tracheostomy during COVID-19 outbreak: to whom, when, how? Early experience from Venice, Italy. *Eur Arch Otorhinolaryngol.* Published online July 12, 2020. doi:10.1007/s00405-020-06190-6

17. Chao TN, Harbison SP, Braslow BM, et al. Outcomes after tracheostomy in COVID-19 patients. *Ann Surg.* 2020;272(3):e181. doi:0.1097/SLA.0000000000004166
18. Breik O, Nankivell P, Sharma N, et al. Safety and 30-day outcomes of tracheostomy for COVID-19: a prospective observational cohort study. *Br J Anaesth.* 2020;125(6):872-879.
19. Angel L, Kon ZN, Chang SH, et al. Novel percutaneous tracheostomy for critically ill patients with COVID-19. *Ann Thorac Surg.* 2020;110(3):1006-1011.
20. Sood RN, Dudiki N, Alape D, Maxfiel MW. Healthcare personnel safety during percutaneous tracheostomy in patients with COVID-19: proof-of-concept study. *J Intensive Care Med.* 2020:0885066620980384. doi:10.1177/0885066620980384
21. Aodeng S, Wang W, Chen Y, et al. Safety and efficacy of tracheotomy for critically ill patients with coronavirus disease 2019 (COVID-19) in Wuhan: a case series of 14 patients. *Eur J Cardiothorac Surg.* 2020;58(4):745-751.
22. Picetti E, Fornaciari A, Taccone FS, et al. Safety of bedside surgical tracheostomy during COVID-19 pandemic: a retrospective observational study. *PLoS One.* 2020;15(9):e0240014. doi:10.1371/journal.pone.0240014
23. Thal AG, Schiff BA, Ahmed Y, et al. Tracheotomy in a high-volume center during the COVID-19 pandemic: evaluating the surgeon's risk. *Otolaryngol Head Neck Surg.* Published online September 1, 2020. doi:10.1177/0194599820955174
24. Riestra-Ayora J, Yanes-Diaz J, Penuelas O, Molina-Quiros C, Sanz-Fernández R, Martin-Sanz E. Safety and prognosis in percutaneous vs surgical tracheostomy in 27 patients with COVID-19. *Otolaryngol Head Neck Surg.* 2020;163(3):462-464.
25. 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(6):1136-1147. doi:10.1177/0194599820961985.
26. 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 Inform.* 2009;42(2):377-381.
27. Elo S, Kyngäs H. The qualitative content analysis process. *J Adv Nurs.* 2008;62(1):107-115.
28. COVID-19 Cases in Washtenaw County. Accessed February 2, 2021. https://www.washtenaw.org/3108/Cases
29. Prager JD, Baker CD. The multidisciplinary tracheostomy team: a parachute for tracheostomy-dependent children. *JAMA Otolaryngol Head Neck Surg.* 2019;145(11):1042-1043.
30. McKeon M, Kohn J, Munhall D, et al. Association of a multidisciplinary care approach with the quality of care after pediatric tracheostomy. *JAMA Otolaryngol Head Neck Surg.* 2019;145(11):1035-1042.
31. Brenner MJ, Pandian V, Milliren CE, et al. Global Tracheostomy Collaborative: data-driven improvements in patient safety through multidisciplinary teamwork, standardisation, education, and patient partnership. *Br J Anaesth.* 2020;125(1):e104-e118. doi:10.1016/j.bja.2020.04.054
32. McGrath BA, Wallace S, Lynch J, et al. Improving tracheostomy care in the United Kingdom: results of a guided quality improvement programme in 20 diverse hospitals. *Br J Anaesth.* 2020;125(1):e119-e129. doi:10.1016/j.bja.2020.04.064
33. Smith JD, Chen MM, Balakrishnan K, et al. The difficult airway and aerosol-generating procedures in COVID-19: timeless principles for uncertain times. *Otolaryngol Head Neck Surg.* 2020;163(5):934-937.
34. Brenner MJ, De Cardenas J, Standiford TJ, McGrath BA. Assessing candidacy for tracheostomy in ventilated patients with coronavirus disease 2019: aligning patient-centered care, stakeholder engagement, and health-care worker safety. *Chest.* 2021;159(1):454-455.
35. Kim MM, Barnato AE, Angus DC, Fleisher LF, Kahn JM. The effect of multidisciplinary care teams on intensive care unit mortality. *Arch Intern Med.* 2010;170(4):369-376.
36. Tay JK, Khoo ML, Loh WS. Surgical considerations for tracheostomy during the COVID-19 pandemic: lessons learned from the severe acute respiratory syndrome outbreak. *JAMA Otolaryngol Head Neck Surg.* 2020;146(6):517-518.
37. Long SM, Chern A, Feit NZ, et al. Percutaneous and with COVID-19: comparison and outcomes of an institutional series in New York City. *Ann Surg.* 2021;273(3):403-409. doi:10.1097/SLA.0000000000004428
38. Sethuraman N, Jeremiah SS, Ryo A. Interpreting diagnostic tests for SARS-CoV-2. *JAMA.* 2020;323(22):2249-2251.
39. McGrath BA, Brenner MJ, Warrillow SJ, et al. Tracheostomy in the COVID-19 era: global and multidisciplinary guidance. *Lancet Respir Med.* 2020;8(7):717-725.
40. 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(10):887-888. doi:10.1001/jamaoto.2020.2630
41. Beetz C, Skrahina V, Förster TM, et al. Rapid large-scale COVID-19 testing during shortages. *Diagnostics.* 2020;10(7):464. doi:10.3390/diagnostics10070464
42. Piccirillo JF. Otolaryngology–head and neck surgery and COVID-19. *JAMA.* 2020;324(12):1145-1146.
43. Brook AD, Sherman G, Malen J, Kollef MH. Early versus late tracheostomy in patients who require prolonged mechanical ventilation. *Am J Crit Care.* 2000;9(5):352-359.
44. Ahmed Y, Cao A, Thal A, et al. Tracheotomy outcomes in 64 ventilated COVID-19 patients at a high-volume center in Bronx, NY. *Laryngoscope.* 2021;131(6):e1797-e1804. doi:10.1002/lary.29391
45. Pandian V, Boisen S, Mathews S, Brenner MJ. Speech and safety in tracheostomy patients receiving mechanical ventilation: a systematic review. *Am J Crit Care.* 2019;28(6):441-450
46. Greenberg JA, Balk RA, Shah RC. Score for predicting ventilator weaning duration in patients with tracheostomies. *Am J Crit Care.* 2018;27(6):477-485.
47. Sole ML, Talbert S, Penoyer DA, Bennett M, Sokol S, Wilson J. Comparison of respiratory infections before and after percutaneous tracheostomy. *Am J Crit Care.* 2014;23(6):e80-e87. doi:10.4037/ajcc2014232
48. Chan LYY, Jones AYM, Chung RCK, Hung KN. Peak flow rate during induced cough: a predictor of successful decannulation of a tracheotomy tube in neurosurgical patients. *Am J Crit Care.* 2010;19(3):278-284.
49. Guentner K, Hoffman LA, Happ MB, et al. Preferences for mechanical ventilation among survivors of prolonged mechanical ventilation and tracheostomy. *Am J Crit Care.* 2006;15(1):65-77.
50. Young D, Harrison DA, Cuthbertson BH, Rowan K, TracMan Collaborators. Effect of early vs late tracheostomy placement on survival in patients receiving mechanical ventilation: the TracMan randomized trial. *JAMA.* 2013;309(20):2121-2129.
51. Licina A, Silvers A, Stuart RL. Use of powered air-purifying respirator (PAPR) by healthcare workers for preventing highly infectious viral diseases—a systematic review of evidence. *Syst Rev.* 2020;9(1):173. doi:10.1186/s13643-020-01431-5
52. Azoulay E, De Waele J, Ferrer R, et al. Symptoms of burnout in intensive care unit specialists facing the COVID-19 outbreak. *Ann Intensive Care.* 2020;10(1):110. doi:10.1186/s13613-020-00722-3
53. Chew NW, Lee GK, Tan BY, et al. A multinational, multicentre study on the psychological outcomes and associated physical symptoms amongst healthcare workers during COVID-19 outbreak. *Brain Behav Immun.* 2020;88:559-565.
54. Krishnamoorthy S, Polanco A, Coleman N, et al. The safety and efficacy of tracheostomy in patients diagnosed with COVID-19: an analysis of 143 patients at a major NYC medical center. *Ann Surg.* Published online November 11, 2020. doi:10.1097/sla.0000000000004612
55. Akinbami LJ, Vuong N, Petersen LR, et al. SARS-CoV-2 seroprevalence among healthcare, first response, and public safety personnel, Detroit Metropolitan Area, Michigan, USA, May–June 2020. *Emerg Infect Dis.* 2020;26(12):2863-2871.