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COVID-19 and laryngological surgery

Parastou Azadeh Ranjbar, BS\textsuperscript{a}, Ahmad Issa Al Omari, MD\textsuperscript{b}, Derek Mann, BS\textsuperscript{a}, Bailey Balouch, BS\textsuperscript{a}, Robert T. Sataloff, MD, DMA, FACS\textsuperscript{c}

From the \textsuperscript{a}Drexel University College of Medicine, Philadelphia, Pennsylvania \textsuperscript{b}Department of Otolaryngology-Head and Neck Surgery, Drexel University College of Medicine, Jordan University of Science and Technology, Philadelphia, Pennsylvania \textsuperscript{c}Department of Otolaryngology-Head and Neck Surgery, Drexel University College of Medicine, Lankenau Institute for Medical Research, Philadelphia, Pennsylvania

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In 2019, the emergence of the novel SARS-CoV-2 virus in Wuhan, China transformed society and caused major changes in medical care. Efforts to implement protocols to keep providers and their staffs safe during care of all patients ensued. Within the field of laryngology, the risk of aerosol generation and viral spread was among the highest in medicine. It is important to understand the impact of COVID-19 on presurgical and surgical laryngoscopic care as well as the evolution of knowledge that led to our current practices and protocols.

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Overview

In December 2019, a novel infectious respiratory disease known as Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) appeared in Wuhan, China. The multi-system disease caused by SARS-CoV-2 was termed COVID-19, and by March 11th, 2020, the World Health Organization (WHO) declared the outbreak a global pandemic as COVID-19 spread exponentially across the world.\textsuperscript{1}

The emergence of COVID-19 caused major changes in medical care. In the early stages of the pandemic, “nonessential” sectors of society were brought to an abrupt halt, with medicine being no exception. Due to the paucity of evidence-based studies on COVID-19 infection due to its novelty, surgeons and intensivists have struggled to deal with decisions on how to care for critically ill COVID-19 patients. Moreover, there has been an effort to implement protocols to keep providers and their staffs safe during the routine care of all patients.\textsuperscript{2} Within the field of laryngology, the risk of aerosol generation and viral spread was among the highest. Although this article focuses on laryngologic surgery, appropriate surgery can occur only following thorough outpatient examination and surgical decision making. So, presurgical issues are included in our discussion. During the lockdown period, the risk of laryngeal examination and manipulation during surgery outweighed the benefits in the majority of non-cancer cases. Many in-person evaluations were replaced by virtual visits, and cohesive interdisciplinary care of voice patients was interrupted. Diagnostic and surgical delays occurred at unprecedented rates and have had lasting consequences
for patients due to complications of untreated or poorly managed laryngeal disease.

As knowledge about the virus improved and case rates dropped, a cautious return to practice was advised by the American Academy of Otolaryngology—Head and Neck Surgery (AAO-HNS) on May 8, 2020. As we entered the stages of re-opening with maximal precautions in place, new challenges and changes to practice included navigating surgical practice with appropriate personal protective equipment (PPE) use, airflow ventilation, and visitation limitations. Laryngologists, like many care providers, transitioned to the routine use of nasopharyngeal or oropharyngeal swabs for COVID-19 screening prior to operative, aerosol-generating procedures. By the time the first vaccines had emerged, the precautions in place had become our new norm. Although some early restrictions have eased, the impact of COVID-19 persists in our daily practice. In addition to complications due to delays in care, voice surgeons are witnessing the impacts on the larynx and voice from COVID-19 itself. The need for surgeries appears higher than before. The long-lasting effects of the virus on the respiratory tract are a continued concern, and research is to clarify effects, duration of effects and optimal treatment.

**Early Pandemic: Effects of COVID-19 on Laryngology Care**

Since the emergence of COVID-19, otolaryngologists and others have faced numerous, unprecedented challenges that have impacted patients and providers in unforeseen ways. The AAO-HNS made an announcement in March 2020 explaining the necessity of limiting care only to time-sensitive and emergent problems and advocated for routine use of appropriate PPE when treating patients of all age groups—a policy that applied to otolaryngologists in both areas facing high infection rates and those in areas with limited virus penetration. The delays of in-person care and cancellation of elective surgical procedures during the initial lockdown period, though necessary, have had adverse consequences. There also were substantial delays in office patient care, particularly for patients from out-of-town who had previously been seen regularly by quaternary care laryngologists. Such cases included not only missed or delayed diagnoses of cancer of the larynx, but also diagnosis of benign lesions and associated scar that affected quality of life and professional voice use adversely.

Even with the postponement of all elective procedures, hospitals struggled to manage the influx of patients with not only limited resources, particularly ICU beds and PPE, but also with determining appropriate safety protocols for patients and providers. The lack of effective action from the federal government to maintain and distribute domestic inventories, as well as severe disruptions to the PPE global supply chain, amplified the problem. Often, the severe shortage of N95 masks required many to reuse despite the single-use designation of those masks. To address the challenge for the operating room and outpatient settings, decontamination methods, including UV germicidal irradiation, moist heat, microwave generated steam, and hydrogen peroxide vapor were studied and found to result in effective filtration during reuse as long as the integrity of respirator fit and seal is maintained. Their implementation allowed resumption of surgery that would have been delayed further because of shortages if single use had been required.

**COVID-19 Modes of Transmission**

While there was evidence of person-to-person transmission of COVID-19 as early as January 2020, the absolute and relative risk profiles of different modes of transmission remained unknown for months. While there was consensus that droplet transmission was the primary source of spread based on prior knowledge of SARS and MERS-CoV, it was not as clear whether fomites were a significant secondary source of transmission. The initial WHO published guidelines in February 2020 suggested that COVID-19 can be transmitted via fomites. The concern over fomite transmission persisted until a study from Rutgers New Jersey Medical School Newark took a closer look at real-world settings while evaluating fomites as a mode of transmission. The conclusions of that study, as well as from subsequent studies, indicated that fomites presented a relatively negligible risk of virus transmission, thus emphasizing the importance of prioritizing droplet precautions.

While surface transmission is not impossible, the evidence revealed that the predominant mode of COVID-19 transmission was airborne transmission through respiratory droplets and microscopic aerosols generated from coughing, talking or breathing. To understand the exact nature of aerosol transmission, Zheng et al. quantified particles, stratified by diameter, produced during various live-patient laryngology procedures using an optical particle counter measured 60 cm from the oral cavity. Compared to baseline, direct laryngoscopy was associated with a significant 6.71% increase in cumulative particles. Most measured particles (>99%) in the study were 0.3-1.0 μm in diameter, which increased significantly from baseline, while particles within 1.0-25 μm in diameter were significantly decreased. According to WHO and the Centers for Disease Control and Prevention (CDC), droplets are defined as particles greater than 5 μm in diameter, whereas aerosols or droplet nuclei are less than 5 μm in diameter. This definition, in concordance with the study, emphasizes the necessity of appropriate PPE to avoid COVID-19 aerosol transmission, especially since aerosols can remain airborne for up to minutes or hours in a non-ventilated enclosure.

**Aerosol Generating Procedures within Laryngology**

The field of otolaryngology, particularly the subspecialty of laryngology, is highly prone to airborne transmission from COVID-19 positive patients to healthcare workers. This is due to frequent close contact with
respiratory secretions and aerosolized particles that occur during head and neck examinations. Furthermore, studies have shown that the highest viral titers are present in the nose and respiratory tract. Laryngologists who work in close proximity to infected upper aerodigestive tissues for long periods of time were at an even greater risk for exposure to some of the highest viral loads, raising concerns for more severe infection. Flexible and rigid laryngoscopy, used commonly in routine laryngology examinations, often induce sneeze, cough and gag, placing laryngologists at risk of direct nosocomial infection. In fact, many of the first physician who died of COVID-19 in China were otolaryngologists. Therefore, initial precautions had to be stringent and adapted rapidly over time.

Early Pandemic APG Recommendations in Laryngology

Based on the evidence of transmission through droplets and aerosols, the earliest guidelines released by the laryngology community called for the use of flexible laryngoscopy for “only critical cases when findings may have an immediate impact on patient management.” Additionally, the early precautions that were advised included the following, among others:

- Strict screening of patients for fever, respiratory symptoms and travel history prior to the examination.
- Consider COVID-19 testing as a prerequisite.
- Anesthetic gels were recommended over atomized or nebulized anesthetics, given the concern the latter would contribute to the aerosolization of viral particles.
- Disinfection of laryngoscopes through automated reprocessing, gas sterilization with ethylene oxide, and chemical disinfection with glutaraldehyde, chlorine dioxide or ortho-phthalaldehyde. Use of 70% isopropyl alcohol was not recommended.

The indications for flexible examination that met critical status at that time included hemoptysis, odynophagia causing volume and/or nutritional depletion, or airway compromise secondary to infectious or malignant processes. Otherwise, physicians were advised to assess patients through virtual means pending further acquisition of knowledge regarding how to safely conduct this and other aerosol-generating laryngology procedures in the office and in the operating room.

The Emergence of Virtual Care

With in-person visits becoming unhealthy during the initial stages of the pandemic, telemedicine visits became routine. However, a current challenge of telemedicine in laryngology involves incorporating Speech-Language Pathologists (SLP). In many states, licensure requirements preclude voice therapy by telepractice unless the provider is licensed in the state where the patient is at the time of treatment. In some states, licensing restrictions were eased for the duration of individual states’ states of emergency due to COVID-19. This applied to laryngologists, as well as SLPs. These changes allowed healthcare professionals from out-of-state to treat in-state residents via telemedicine if certain requirements were met. These requirements often involved being licensed and in good standing in their home state, as well as disclosing appropriate identifying information to the other state’s licensing board. These changes offered increased healthcare access during a period when few felt safe traveling outside of their homes. In the practice of the senior author (Robert T. Sataloff, RT5), many patients travel from out-of-state locations for evaluation and treatment. The shift to telehealth visits for voice therapy has been particularly useful for improving compliance with voice therapy sessions for these out-of-state patients. However, the temporary loosening of state licensing restrictions for telehealth will lead to new issues when these temporary changes are reversed. These will particularly affect SLPs, as the ability to have productive telehealth sessions will be limited severely once again; and this is likely to be especially troublesome for out-of-state patients who have benefited from and became accustomed to the superior access to therapy provided by telemedicine.

The Re-Opening Phase and Laryngology Surgery

As knowledge regarding precautions and protective measures evolved, and the restrictions of the lockdown eased, new considerations emerged in the practice of laryngology. Guidelines to return to safe practice of laryngoscopy were released to aid otolaryngologists in the gradual return to practice in the Spring and Summer of 2020. A vital component of the re-opening phase was the development and mass production and distribution of rapid and accurate COVID-19 testing, which made returning to the operating room (OR) much safer for laryngologists, their patients and the healthcare team.

Resumption of Elective Laryngology Surgeries and Prioritization

As we entered the reopening stage, elective surgery case volume was decreased in the field of otolaryngology, and laryngology surgeries were no exception. This was due in part to patient hesitancy to undergo surgical intervention in the midst of the pandemic, especially during the early half of 2020. Reduced volume also was explained partially by the limited in-person clinic scheduling per hour, meaning that potential surgical cases might have been missed. Reduction in overall numbers of patients presenting with undiagnosed cancer during the pandemic have been reported, and the extent of voluntarily missed medical evaluations remains unknown. Diagnosis and management of benign vocal fold mass and/or vocal fold scar were delayed, which held the potential to affect quality of life
adversely, particularly for professional voice users. Delay in care of these pathologies interfered with their ability to perform optimally (singing or speaking, especially for prolonged periods) even virtually. This interfered with not only income, but also enjoyment of life. In addition, efforts to compensate for the vocal fold disorders and to continue to phonate predisposed patients to worsening masses, re-active masses and scar. There was a concern that as the COVID-19 burden decreased into 2021, the field would experience a drastic rise in belated and more advanced voice and airway pathologies. For many professional voice users whose livelihood depends on voice quality, the impact of COVID-19-related delays in care was and continues to be a leading issue that will directly impact laryngologists and their patients. As we neared the end of 2020, surgical cases were on the rise, and the roll out of procedures as recommended by AAO-HNS Future of Otolaryngology Task Force was crucial for ensuring that the most emergent and urgent cases were prioritized. Although the elective case load did not reach that of previous years, the need to triage the most time-sensitive pathologies commenced. Much like during the lockdown phase, the most emergent laryngeal surgical indications included impending airway obstruction requiring direct or indirect laryngoscopy, flexible laryngoscopy, bronchoscopy, and tracheotomy. The next level of urgent cases recommended for rollout included patients with progressive dysphonia, progressive dysphagia and glottic incompetence causing aspiration requiring resumption of strobosvelaryngoscopy (flexible or rigid), with or without intervention, endoscopic swallowing evaluation and esophagoscopy. The discretion of the treating physician and institutional and local policies were also major factors as gradual return to the OR commenced. Currently, the only indication for laryngeal surgery in a COVID-19-positive patient is impending airway obstruction.

Airflow Technology and Infection Prevention

The resumption of post-lockdown surgical OR cases was accompanied by drastic changes in the workflow for healthcare personnel and surgical patient experiences. In addition to appropriate PPE precautions, a major consideration was air ventilation in healthcare spaces. It was evident early that the proper enforcement of droplet and airborne precautions was crucial for preventing nosocomial spread of COVID-19. The average incubation period of COVID-19 is approximately 7 days but can be as long as 14 days; as such, pre-symptomatic transmission of COVID-19 poses a substantial challenge to controlling its spread, as pre-symptomatic patients have been shown to transmit infection. In the context of room airflow precautions, negative pressure spaces are ideal. However, this is not always feasible. Positive pressure ventilation is also acceptable if a negative pressure room is not available. Proper room pressurization (either positive or negative) is helpful to prevent the spread of airborne contaminants. Another important consideration in the optimization of airflow dynamics is the number of air exchanges for room ventilation. One aerosol clearance is associated with a 63% decrease in viral load, and 5 air exchanges removes >99% of initial viral load. In most clinical environments, it takes 25 minutes to complete 5 air exchanges. A standard operating room can complete 20 air exchanges per hour and filters air with removal of 80-97% of particles >5 μm. Furthermore, laminar airflow systems equipped with high-efficiency particulate air filters can remove >99.97% of particles >0.3 μm. Newsom et al have shown that in an “aerosol-generating procedure” cough model, vertical laminar airflow has a significant effect on decreasing the distance traveled by smaller droplets with limited effect on larger droplets in comparison to non-laminar flow in the OR. Such airflow systems are but rare in physician outpatient offices. During the pandemic, this has led laryngologists to take some patients to the operating room who normally would have been candidates for in-office surgery. Procedures in the OR and in the office are performed with an N95 mask (sometimes with a second mask) and with eye protection (Fig. 1). The scrub nurse is placed mid-way down the side of the table rather than near the head to limit exposure to droplets and aerosols that might be generated during surgery (Fig. 2).

General Hospital Precautions

The impact of COVID-19 was geographically diverse and relied on local city and state infection rates. In the practice of the senior author (RTS), the gradual resumption of surgeries in the late spring/early summer 2020 was accompanied by drastic changes in OR and recovery room precautions. Although intra-operative surgical techniques relied on the same principles, day-to-day workflow was drastically different. These changes included the implementation of pre-operative COVID-19 testing, mandatory use of PPE, visitor and observer restrictions, and requiring families of surgical patients to wait in their cars, necessitating that postoperative communication between the surgeon and families be by phone rather than personally face-to-face.

Additionally, during pre-operative evaluations, time was spent preparing patients and families for the reality of the visitation restrictions. On the day of surgery, limited visitation privileges resulted in decreased foot traffic in waiting and other hospital common spaces, providing added protection for hospital patients and healthcare workers. Upon arrival at the hospital or transfer from a hospital unit to the pre-op holding area, patients were required to wear level II surgical masks and asked to cover the nose and mouth until the time of intubation, as well as immediately following extubation. In the OR, the number of nonessential staff and student observers was minimized, as was the exchange of staff in each room.
Anesthesia Considerations in Laryngology Surgery

In the era of COVID-19 during the re-opening stage and now, laryngology operations require complete coordination and transparent communication among the anesthesia team, the operating room team, and the surgeon. Previously, some laryngeal procedures were performed safely under local anesthesia (some in the office). The use of general anesthesia with paralysis increased during recovery from the COVID-19 pandemic. Although voice cannot be monitored while the patient is under general anesthesia, the risk of droplet and aerosol generation and particulate
spread during breathing and phonation may outweigh the benefits for some OR procedures usually performed under local anesthesia, such as thyroplasty. However, in the study by Zheng et al., the change in particle generation was studied during ten direct laryngoscopy surgeries performed with either general endotracheal anesthesia (GETA) or low-frequency jet ventilation (details on aerosol generation with jet ventilation are discussed in greater detail below). Compared to baseline, GETA with or without CO2 laser use was associated with a 6.71% significant increase in cumulative particles, predominantly microparticles measuring 0.3-1.0 \( \mu \text{m} \) (\( P < 0.001 \)), highlighting the risk of aerosol generation even with GETA. Given these findings, it is crucial that during induction and intubation, all nonessential personnel are advised to leave the room until the airway is secured. Minimizing the numbers in the OR during intubation, in theory, provides time for air exchange systems to clear aerosolized particles. In preparation for safe intubation, anesthesiologists are advised to confirm tight connections on standard breathing circuits. Indirect intubation through video laryngoscopy (GlideScope; Verathon Inc., Bothell, WA) is a valuable tool for visualization of the airway, maximizing the distance between anesthesia providers and airway secretions. Indirect laryngoscopy for intubation also increases the chance of successful intubation at the first attempt, compared to the standard direct laryngoscopy blade. A shift in practice toward the use of long-acting muscle relaxants to minimize cough, inflation of the cuff prior to ventilation, and confirmation of correct tube placement using end-tidal CO2 are all measures used by our Anesthesia colleagues to minimize aerosol generation. During extubation, ventilation should be paused prior to deflating the endotracheal cuff.

Additionally, prior to the pandemic, high frequency jet ventilation (HFJV) for anesthesia during suspension microlaryngoscopy was a common alternative to endotracheal intubation. In the pandemic era, to reduce the number of aerosolized particles, the senior author (RTS) and colleagues in the field have minimized the use of tubeless techniques like HFJV, in favor of endotracheal intubation, which is a closed-circuit ventilation system. This practice has been based on anecdotal evidence from the SARS-CoV-1 epidemic suggesting that the use of a jet nebulizer for bronchodilator administration led to a hospital-wide outbreak of 138 reported cases. Further research into the role of HFJV compared to GETA in particle aerosolization is needed. Zheng et al reported that through the analysis of 3 direct laryngoscopy procedures using low-frequency jet ventilation, there was no significant difference in cumulative or microparticle production compared to baseline, and only a significant rise in droplets measuring 10-25 \( \mu \text{m} \) (\( P = 0.02 \)). However, the small sample size limits interpretation of these results. At present, use of GETA appears to be safest especially when appropriate PPE and OR ventilation are utilized.

Furthermore, in the practice of the senior author (RTS), laryngotracheal topical anesthesia with 4% topical xylocaine, administered through the direct laryngoscope onto the vocal folds at the end of each case is routine for microlaryngoscopies to minimize irritation of the larynx from surgical manipulation. In the era of COVID-19, the use of topical anesthetics that suppress cough has had the probable added benefit of reducing aerosolization of particles in the recovery area. Others in the field have reported using muscle relaxants during procedures for a similar purpose when performing high-risk airway procedures such as tracheotomy.

Instrumentation Considerations in Microlaryngoscopy

Several studies analyzing the risk of aerosol generation during voice surgery have provided direct evidence that CO2 laser use was associated with significantly higher levels of microparticle generation compared to baseline, microdebrider, and cold instrument use. In one study, CO2 laser during laryngology surgery was associated with a 14.70% rise in microparticles approximately 2.5 \( \mu \text{m} \) in diameter compared to baseline (\( P < 0.0001 \)). In a study by Sanmark et al., using CO2 laser was associated with the highest concentration of particles less than 1 \( \mu \text{m} \), as well as particles 1-5 \( \mu \text{m} \) in size. In addition, in contrast to cold instrumentation, the use of CO2 laser was associated with a 1.80-fold and 2.02-fold average rise in particles <1 \( \mu \text{m} \) and 1-5 \( \mu \text{m} \) in size, respectively (\( P < 0.0001 \)). Similarly, the use of microdebrider was associated with a 1.53-fold drop in the concentration of microparticles less than 1 \( \mu \text{m} \), and a 1.39-fold drop in particles sizes 1-5 \( \mu \text{m} \) compared to CO2 laser. These studies, and others, show the benefits of using cold steel or microdebrider instruments over CO2 laser, if possible, such as in cases of laryngeal papillomatosis debridement. While it appears that extensive use of CO2 laser creates substantial opportunities for aerosol transmission, it is also often a necessary tool in laryngology procedures. Thus, in cases during which its use cannot be avoided, it is imperative to maintain maximal PPE precautions. The effects of use of vascular lasers have not been studied, yet.

New Innovations

The resumption of surgical and clinical practice prompted many laryngologists to create novel innovations with the immediate goal of minimizing aerosol transmission during the pre- and post-operative evaluation of voice patients. Hoffman et al introduced a negative pressure face shield (NPFS) to minimize the risk of aerosol spread during flexible laryngoscopy, a high-risk, aerosol-generating procedure that is routinely required in the evaluation of the laryngology surgical patient. Innovations such as the NPFS attempted to mitigate the risk of the spread of microparticles while conserving precious PPE, given the international shortages at the time. The NPFS consisted of a box-like, clear acrylic face shield with 2 anterior access ports and a side wall suction port (Fig. 3). This reusable shield was secured to a disposable sterile wrap (Halyard...
H100 sterilization wrap, O&M Halyward, Inc, Alpharetta, Georgia) with tape, and draped around the head of the patient like a hood (Figures 4 and 5). The unused anterior access port was taped shut, and negative pressure was created within the device using a standard wall suction (Vacutron Suction Regulators by Chemetron, Inc), using a maximum regulated suction pressure of 320 ± 20 mm Hg. Patient satisfaction was assessed on a 5-point Likert scale, and patients reportedly tolerated the procedure well. No pain was reported, and 90% of patients did not report claustrophobia. No significant changes in oxygen saturation were found. The stability of the camera stand used to secure the NPFS in front of the patient’s face was difficult to assess, especially for patients who, at baseline, have trouble tolerating the flexible examination even without the NPFS.39

Another unique adaptation for limiting transmission of airborne particles during flexible laryngoscopy was the modified endoscopy face mask devised by Narwani et al.40 The mask involved creating a 3 mm slit in the central aspect of the silicone mask to allow passage of the scope transnasally (Figures 6 and 7).40 In addition to allowing the examination of the larynx in patients requiring ventilation (such as intubated COVID-19 patients or patients under general anesthesia), Narwani et al’s design utilizing widely available masks provided an advantage over the NPFS, although direct comparison of efficacy in particle dispersion has not been performed. Further research into the degree of aerosolization using the NPFS and the modified endoscopy face masks in comparison to standard flexible laryngoscopy and other proposed techniques would be helpful. Furthermore, these methods for aerosol containment would not be useful for rigid transoral laryngoscopy, as access to the oral cavity is limited with these devices, and adequate tongue retraction would be difficult or impossible to achieve without defeating the protective effects of either device.

**Post-Vaccination Era and its Effects on Laryngology**

The advent of COVID-19 vaccination development began very soon after the onset of the pandemic but took some time to be approved, manufactured, and mass-distributed throughout the U.S. and elsewhere. Since scientists already had been studying coronaviruses for many years prior to the pandemic, researchers were able to create vaccines for COVID-19 quickly due to the previously existing and ongoing research about coronaviruses. The Pfizer-BioNTech (New York, NY and Mainz, Germany, respectively) and Moderna (Cambridge, MA) 2-dose COVID-19 vaccine series were approved by the FDA via Emergency Use Authorization in mid-December of 2019,

**Fig. 3** NPFS. The acrylic negative pressure face shield oriented upright demonstrating inferior attachment flange (dotted arrows), flat upper surface, anterior access ports and suction port on the side. *Figure and caption republished with permission from Hoffman HT, Miller RM, Walsh JE, Stegall HR, Diekema DJ. Negative pressure face shield for flexible laryngoscopy in the COVID -19 era. Laryngoscope Investig Otolaryngol. 2020;5:718-726.
**Fig. 4** NPFS Setup. The negative pressure face shield with sterilization wrap is rotated in place and secured around the neck. *Figure and caption republished with permission from Hoffman HT, Miller RM, Walsh JE, Stegall HR, Diekema DJ. Negative pressure face shield for flexible laryngoscopy in the COVID-19 era. Laryngoscope Investig Otolaryngol. 2020;5:718-726.*

**Fig. 5** NPFS and Flexible Laryngoscopy. The procedure is done with the flexible scope passed through the upper of 2 ports. *Figure and caption republished with permission from Hoffman HT, Miller RM, Walsh JE, Stegall HR, Diekema DJ. Negative pressure face shield for flexible laryngoscopy in the COVID-19 era. Laryngoscope Investig Otolaryngol. 2020;5:718-726.*
Fig. 6  Equipment required for the modified endoscopy face mask. From left to right: adult endoscopy face mask with 5-mm endoscopy port, hook ring, heat and moisture exchanger with bacterial and viral filter, face mask harness, and No. 10 or 15 scalpel (not pictured). **Figure and caption republished with permission from Narwani V, Kohli N, Lerner MZ. Application of a Modified Endoscopy Face Mask for Flexible Laryngoscopy During the COVID-19 Pandemic. Otolaryngol Head Neck Surg. 2020;163(1):107-109.

Fig. 7  (A) In-office setup for flexible fiberoptic laryngoscopy, with a modified endoscopy face mask secured by a harness. (B) Flexible fiberoptic laryngoscopy at the level of the vocal folds, with a modified endoscopy face mask and a heat and moisture exchanger with bacterial and viral filter. *Figure and caption republished with permission from Narwani V, Kohli N, Lerner MZ. Application of a Modified Endoscopy Face Mask for Flexible Laryngoscopy During the COVID-19 Pandemic. Otolaryngol Head Neck Surg. 2020;163(1):107-109.
while the single-dose Johnson & Johnson (New Brunswick, NJ) vaccine was approved on February 27, 2020. Both 2-dose vaccination series are mRNA vaccines, while the J&J vaccine uses an inactivated common cold virus.\textsuperscript{41}

The first deliveries of COVID-19 vaccines began on December 14, 2020, and vaccine distribution was organized at the state level. The initial Phases 1a-1c of vaccine distribution emphasized vaccinating more vulnerable demographics first, including the elderly $\geq 65$ years of age, healthcare and essential workers, and individuals with high-risk medical conditions. By May 2021, immunization was available to nearly all individuals in the United States 12 years and older. By mid-fall of 2021, the approval of booster shots also had helped the public stay safe as the pandemic continues onward.\textsuperscript{41}

Since the advent of the vaccines, laryngologists have been able to serve their patients better. While the COVID-19 vaccines have been proven effective at preventing infection, serious illness and death, they are not 100\% effective at preventing COVID-19 infection and subsequent transmission. However, evidence shows that vaccination can prevent serious illness, and perhaps prevent hospitalization and death risks. From the perspective of the laryngologist, the added protection and subsequent decreased risk of COVID-19 infection in the vaccinated populace helps re-prioritize elective and nonurgent procedures and visits to reduce the delay of care secondary to the pandemic. Regardless of vaccination status, COVID-19 testing should still be considered shortly prior to any visit or procedure to avoid outbreaks due to either unvaccinated cases or breakthrough cases in vaccinated individuals. A significant obstacle that slows a return towards a pre-pandemic baseline is hesitancy towards the COVID-19 vaccine, which is a multifaceted and complex issue that requires more research, education initiatives, and judgment-free intervention to help slowly guide the populace towards better understanding the benefits of vaccination.\textsuperscript{42}

**Long-Term Effects of COVID on the Voice**

In addition to risks of surgery that might be required because of COVID-19 laryngeal problems, patients with COVID-19 are at increased risk for laryngeal injury and dysfunction due to prolonged intubation, respiratory failure, and other unique aspects of the illness. While it is generally well accepted that critically ill patients who require prolonged intubation and mechanical ventilation would benefit from early tracheotomy to reduce the incidence of laryngotracheal stenosis and decrease sedation needs, early protocols during the pandemic advocated or delayed tracheotomy to minimize aerosolization when the viral load was still elevated.\textsuperscript{43} Consequently, many patients remained intubated for up to 3-4 weeks, which is substantially longer than the pre-pandemic standards of 7-10 days, prompting experts to warn of an impending surge of patients with new voice, airway, and/or swallowing concerns after COVID-19.\textsuperscript{44} The senior author (RTS) and colleagues around the country already have seen patients with laryngeal stenosis and with mechanical vocal fold hypomobility/immobility among that patient population that undoubtedly will lead to an increase in laryngeal surgery needed for those patients.

The effects of the SARS-CoV-2 on the voice and larynx are also of concern. Rapaport and colleagues (including the senior author, RTS) reported a case series of 16 patients with new-onset dysphonia following COVID-19 infection.\textsuperscript{45} All patients were found to have idiopathic vocal fold (VF) paresis or paralysis despite having no prior history of intubation. Neuropathy was confirmed by laryngeal electromyography (LEMG) in some of those patients. Post-viral (COVID-19) vagal neuropathy was the most likely explanation for these findings and fit well with the clinical course. Several patients experienced improved VF motion following voice therapy with or without temporary VF injection medialization, and no patients have required surgical management during short-term follow-up, yet; but some patients have persistent paresis and are likely to require medialization. Further research is needed to guide decision-making and provide a meaningful prognosis to affected patients.

Neevel et al also reported a case series of patients presenting with laryngeal issues post-COVID-19 recovery.\textsuperscript{46} Twenty-four patients over a 13-month range were evaluated, of which only 18 patients required endotracheal intubation for a median duration of 14 days and 10 patients underwent tracheotomy. When evaluated at a median of 107 days after initially testing positive for SARS-CoV-2, the common presenting concerns were dysphonia, dyspnea, and dysphagia, from greatest frequency to least. Of the patients who required endotracheal intubation, vocal fold motion impairment, glottic injury, subglottic/tracheal stenosis, and posterior glottic stenosis were identified, also from greatest frequency to least. Patients who did not require intubation most frequently required treatment for muscle tension dysphonia. The muscle tension dysphonia was most likely compensatory for laryngeal injury/paresis. This case series showed that patients can develop a variety of substantial voice, airway, and/or swallowing issues after acute COVID-19 infection, and the complications are not limited to patients requiring tracheotomy or endotracheal intubation. There is an anticipated increase in need for laryngeal surgery such as vocal fold medialization for paresis, repair of intubation injuries (including vocal fold scar, arytenoid joint fixation, laryngeal stenosis repair, and others) for some patients with prolonged intubation.\textsuperscript{35,47}

**Conclusions**

The COVID-19 pandemic has introduced new challenges to the field of laryngology. Advances in knowledge about the SARS-CoV-2 virus as well as precautions to prevent transmission have allowed surgical care to resume. In the operating room, procedures such as direct laryn-
goscopy generate aerosols that can facilitate viral transmission. Laryngologists face the same challenge in the pre- and post-operative care of laryngology outpatients. Further research is needed to develop evidence-based guidelines for reducing the risk of COVID-19 transmission and evaluating risk of transmission with specific laryngeal surgeries and other encounters.

Disclosure

The authors report no potential conflicts.

CRediT authorship contribution statement

Parastou Azadeh Ranjbar: Writing – original draft, Writing – review & editing. Ahmad Issa Al Omari: Conceptualization, Supervision. Derek Mann: Writing – original draft. Bailey Balouch: Writing – review & editing. Robert T. Sataloff: Supervision, Writing – review & editing, Conceptualization.

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