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COVID-19 and rhinological surgery☆

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Abstract
The *Coronavirus-19* (COVID-19) pandemic has caused disruptions in the normal patient care workflow, necessitating adaptations within the healthcare profession. The objective of this article is to outline some of these adaptations and considerations necessitated by COVID-19 within the subspeciality of rhinology and endoscopic skull base surgery.

Introduction

The *Coronavirus-19* (COVID-19) pandemic has resulted in an unprecedented disruption within health care and necessitated several adaptations. Several studies suggest that COVID-19 infects through the inhalation of droplets or as a consequence of direct inoculation of the respiratory epithelium.[1,2] The nasal cavity and nasopharynx constitute regions with heightened viral loads, likely as a result of increased expression of angiotensin-converting enzyme 2 receptor, the receptor for COVID-19 invasion, among the epithelium.[3,4] As such, otolaryngologists, being in close and frequent contact with these anatomic sites, are at possible heightened risk for infection.[5,6] Unsurprisingly, there were several early reports from China and Italy of increased infection rates amongst otolaryngologists and members of their surgical teams during skull base surgery, even those wearing personal protective equipment (PPE).[6]

The symptomatology of severe acute respiratory syndrome coronavirus-19 (SARS-CoV-2) has naturally placed otolaryngologists at the forefront for alterations in clinical practice and management. The field of Otolaryngology, of all surgical subspecialities, has produced the highest number of SARS-CoV-2 related research, with rhinology being the most published subgroup.[3] Consequences from the pan-

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demic and their application to rhinology reflect the need for continuing research. For example, the cancellation of elective surgeries during the early wave of the pandemic, and potentially from future waves, creates a surgical backlog, of which rhinologic procedures are likely at the tail end.[7] Such delays can negatively impact patients and result in worsened quality of life and outcomes.[3,7] Furthermore, rhinologic procedures are often aerosol-generating procedures (AGPs), thereby further increasing the risk for infection among providers and warranting research on effective preventative strategies. In addition, clinical management needs to be considered as sensory disorders resulting from SARS-CoV-2 are also hallmarks of certain rhinologic conditions.[3] As such, there are several important rhinologic considerations in the context of the current pandemic.

Effect on Practice and Telemedicine

The initial apex of the pandemic significantly affected the routine patient-care workflow. Several surveys amongst rhinologists have characterized changes in practice patterns at the height of the pandemic, many of which have persisted into the present day.[8-10] A dramatic reduction of in-person care resulted in a sizable decrease of in-office procedures. Papagiannopoulos et al's survey of rhinologists noted that 60% of respondents performed 0 endoscopies daily during the initial phases of the pandemic.[8] This mirrored the finding that the vast majority of rhinologists performed fewer than 20% of the number of pre-pandemic nasal endoscopies.[9] As a consequence of decreased in-office patient visits, Setzen et al. found that over 96% of rhinologists had incorporated telemedicine services into their practices.[4] While the incorporation of telemedicine does not result in full pre-pandemic clinical volumes, it does help limit unnecessary interactions, thereby presenting an important component of future clinical practice given the risk for future waves and pandemics.[10]

The long-term viability of telemedicine in rhinologic clinics is dependent on both physician and patient satisfaction with the care provided and received, respectively. As many sinonasal conditions can be diagnosed via virtual visit, patient care may not necessarily by significantly compromised.[11] However, inherent limitations of virtual encounters do exist, such as the lack of physical examination, which can alter clinical thresholds for utilization of other resources, such as computed tomography (CT) scans.[12] A study across different subspecialties within Otolaryngology have found favorable patient satisfaction rates with telemedicine.[13-16] Morisada et al. reported similar patient satisfaction with telemedicine vs in-person office visits of patients undergoing rhinosinusitis management.[17] Hentati et al. corroborated these findings for patients presenting to a tertiary rhinology center, noting that 71.1% of patients felt their needs were met during the virtual encounter.[13] However, it is important to note that patient satisfaction with telemedicine visits does not necessarily equate to a preference for it. Hentati and et al. reported that the majority of their patients (62.2%) preferred an in-person experience, often citing the lack of physical examination as key determinant. Similarly, patients undergoing endoscopic skull base surgery also reported comparable satisfaction rates with telemedicine to in-office visits; however, patients preferring in-office visits also frequently pointed to nasal endoscopy as a principle reason.[18]

A systematic review of telemedicine in Otolaryngology found very high physician satisfaction rates with telemedicine.[19] These findings were mirrored amongst rhinologists. Specifically, a survey of American Rhinologic Society (ARS) members found that 82.0% of respondents were satisfied with their telemedicine practice to some degree.[10] Similar findings have been reported abroad, as rhinologists reported a 89.7% satisfaction rate with telemedicine.[20] Furthermore, continued satisfaction with telemedicine will likely be linked to reimbursement rates. Specifically, the pandemic led several states to reimburse telemedicine encounters at the same rate as in person visits, lending to its financial viability for physicians during the pandemic.[21] However, continued identical reimbursement rates is uncertain and will likely further impact long-term feasibility given the limitations of telemedicine. As such, telemedicine appears to be a temporary viable option in the setting of a pandemic for rhinology practice, mitigating SARS-CoV-2 spread and PPE use while providing satisfactory care.

Decreasing Viral Transmission Risk

There has been an increasing transition of procedures from the operating room to the office in rhinology.[22] Such procedures include cryotherapy ablation, balloon sinus dilation, and limited endoscopic sinus surgery (ESS) with or without micro debrider use amongst others.[4] Performance of these procedures and their capacity to produce airborne particulates necessitates the questions of what is appropriate PPE, the risk profile for each specific procedure, and how and if to test for SARS-CoV-2 prospectively in both the operating room and office setting.[4]

Aerosols are suspended gas particles that can potentially harbor pathogens.[23] They typically have diameters <5 to 10 μm and are capable of penetration of the lower airways, potentially resulting in viral transmissions such as SARS-CoV-2.[23] Van Doremalen et al. reported that aerosolized SARS-CoV-2 particles can remain viable in the air for at least 3 hours and on surfaces for up to 72 hours.[24] The viral burden in the nasal mucosa coupled with the aerosol generating capacity of several procedures poses a manifest risk for infection. Several authors have sought to characterize this risk during endonasal instrumentation.[25-28] Workman et al. found that the use of high-speed drills and bipolar electrocautery generated significant airborne particulates while hand instrumentation and microdebriders with inbuilt suction capacity did not.[25] In contrast, Sharma et al. and Leong et al. found that microdebrider use did result in the production of extranasal droplets.[26,29] Furthermore, both rigid and flexible nasal endoscopy pose significant risks to otolaryngologists due to the prolonged proximity to patients, production of airborne aerosol quantities, and the unpredictable risk of triggering sneezing events.[25]

These realities have influenced current guidelines. The Center for Disease Control and Prevention (CDC) has recommended six air changes per hour to remove airborne contaminants when performing AGPs. This has led to increased room turnover time and has impacted clinical productivity.[30] Naturally, clinicians have sought avenues to improve air filtration, resulting in the incorporation of high-efficiency particulate air (HEPA) filters in numerous otolaryngology clinics.[30,31] Gill et al. found that HEPA incorporation into their clinics resulted in up to a 700% increase in clinical productivity per hour, as a result of decreased room turnover time.[30] They note that HEPA incorporation resulted in return of aerosol concentrations to baseline significantly faster.[31] Specifically, HEPA-incorporated office spaces reached baseline aerosol levels in nearly half the time and necessitated, on average, only 2.26 air changes compared to 4.18 air changes.[31] It is important to note these findings are specific to the particular HEPA filter used in the study along with other office characteristics such as room size and temperature.[31] Nonetheless, these results do indicate that HEPA incorporation can facilitate decreased room turnover time and protect both patients and clinical team members from potentially aerosolized viral particles.

Workman et al. found that regular surgical masks were inadequate in protecting against generated airborne aerosol particles.[25] As such, previous guidelines had recommended minimum PPE should include gloves, gown, and N95 respirator with face shield for patients with unknown SARS-CoV-2 status.[32] Furthermore, risk mitigation strategies include preoperative patient testing.[28] Given the potential for false negative tests from nasopharyngeal swabs and other methods for SARS-CoV-2 testing, several institutions test twice for patients preoperatively and recommend adopting certain safety techniques universally for both SARS-CoV-2 positive and negative patients.[33,34] Several studies have evaluated staff SARS-CoV-2 infections in the postoperative setting. Taha et al. implemented a safety protocol which included several safety features such as universal p100 filter respirator use, eye protection (via face shield or goggles), reducing the number of care providers in evaluation settings, and pre-evaluation screening questionnaires for patients.[35] They ultimately reported zero staff infections after over 150 sinonasal, skull base, open airway, and endoscopy procedures.[35] Penner et al. had similar results with no reported provider SARS-CoV-2 infections after adopting appropriate precautions.[36] These results suggest that preoperative patient screening and utilization of appropriate PPE can successfully mitigate risk to healthcare providers. This is especially important as SARS-CoV-2 becomes potentially endemic in our society.

Beyond appropriate PPE precautions, the use of suction in endonasal surgery can also decrease droplet spread. Certain high aerosol generating instruments such as an electrocautery or microdebrider cannot be eliminated during endoscopic anterior skull base surgery.[33] As such, judicious use and integration of other protective techniques such as suction are beneficial. For example, Sharma et al. reported that addition of a suction device was successful in reducing aerosols, noting a particular benefit for the surgical smoke evacuation system.[26] Similarly, Leong et al. note that the addition of suction during microdebrider use significantly reduced droplet spread outside of the nasal cavity.[29] These findings have been echoed by the works of Workman et al. and Dharmarajan et al, who both found a significant benefit with suction technology.[25,37] As such, the utilization of these techniques during surgery can protect rhinologists from unnecessary aerosol exposure.

Alternative methods also include placement of a mask on the patient during surgery. In a cadaveric model simulating ESS, Jones et al. found that the use of a negative-pressure mask during surgery resulted in 98% reduction in particulates $<5\,\mu$m and elimination of larger droplets >5–$10\,\mu$m (Figure 1).[38] Helman et al. tested the use of 3-D printed masks during endoscopic skull base surgery.[39] Their method did reduce, but not eliminate, aerosolized particulate detection while preserving surgical maneuverability. They attributed the spillage to instrument removal from the surgical ports in the mask.[39] Viera-Antiles et al. also explored the utility of 3D-printed masks. Their negative pressure mask system resulted in a 72% reduction in droplet spread during endoscopic skull base surgery.[40] These techniques reflect promising avenues for maintaining surgical efficacy while protecting caregivers from unnecessary exposure.

Endoscopic Skull Base Surgery

Endoscopic endonasal surgery is a mainstay of treatment for anterior skull base and pituitary tumors. While the COVID-19 pandemic suspended elective procedures, certain patients with neurosurgical emergencies could not tolerate delayed intervention. In a review of their single center experience in New York City, an epicenter of the early part of the pandemic, Maragokos et al. shared alterations to their skull detailed that all pituitary tumor cases base practice. This group were postponed until the development of neurological sequalae such as visual impairment.[33] Specifically, changes in treatment algorithms were necessitated as several patients were managed medically, if possible.[33] For example, some patients with neoplastic disease were treated with chemotherapy and radiation therapy without a traditional debulking surgery beforehand, reflecting the need for flexibility during a pandemic.[33] Given the AGP nature of endoscopic skull base surgery, surgeons must continue to adopt several risk mitigation strategies, as detailed, to minimize risk for themselves and members of their operating team.

Physicians should also be cognizant of the impact of prolonged intensive care unit (ICU) and hospital stay. Prioritization of early discharge both reduces patient risk for

Figure 1 Endoscopy mask. Reprinted with permission.[38]

hospital acquired infections and decreases resource utilization (ie, ICU beds, nursing staff, etc.) such that it can be distributed elsewhere.[34] To facilitate streamlining, Mallari et al. shared the benefits of their care protocols in reducing resource utilization during the pandemic.[34] Their pandemic protocol included clearly communicating their goal for postoperative day (POD) one discharge to both the patient and family and to all members of the care team, ensuring prompt evaluations by staff and encouraging early mobilization by patients.[34] Furthermore, patients evaluated in the recovery room with normal postoperative courses (expected changes on CT, stable neurological exam, etc.) were not sent to the ICU.[34] Their protocol resulted in significant decrease in LOS while not increasing complication, reoperation, or 30-day readmission rates.[34]

COVID-19 can induce a hypercoagulable state, increasing the risk for micro and macrovascular thrombosis and ultimately death.[41,42] As such, surgeons should have heightened awareness when performing flaps in at-risk patients. Talmor et al. reported the first case of pedicled nasoseptal (NSF) flap failure due to necrosis in a patient with COVID-19, hypothesizing a thrombotic event induced flap failure.[43] Inouye et al. also presented two SARS-CoV-2 associated cases of impaired wound healing in patients undergoing head and neck free flap reconstruction.[44] Benmoussa et al. also noted free flap failure in a SARS-CoV-2 positive patient undergoing gingival mandibular carcinoma resection and reconstruction.[45] These reports are rare in the literature; however, they underlie the need for increased awareness for this potential complication.

Nasopharyngeal swabs are commonly utilized to diagnose patients with SARS-CoV-2, with over half a billion tests performed.[46,47] The procedure is a general intervention, however, incorrect technique can result in uncommon complications such as foreign body creation secondary to swab fracture, epistaxis, and injury to the skull base leading to cerebrospinal fluid leak.[46-51] Many of these case reports have been associated with prior defect due to encephalocele or meningocele, however, some patients without any evidence of defect have reported this complication.[47] These concerns, while rare, should be kept in mind during management of patients postoperatively from anterior skull base surgery. Specifically, Aaronson et al. argued that SARS-CoV-2 testing should not be performed during the first 2 weeks after surgery and that nasopharyngeal tests should be avoided until at least 6 weeks postoperatively once healing has been confirmed via nasal endoscopy.[52]

COVID-19 Olfactory Dysfunction

Post viral anosmia is a common cause for adult olfactory dysfunction, accounting for 40% of all cases.[53] With regards to COVID-19, Kaye et al. reported that approximately 73% of patients experienced anosmia prior to diagnosis, with nearly 27% having anosmia as their initial symptom.[54] Similar findings have resulted in anosmia being identified as a hallmark finding of SARS-CoV-2 infection with many patients continuing to have olfactory dysfunction after resolution of illness.[54-56] These findings are particularly relevant to rhinologists as olfactory dysfunction is also a common symptom of chronic rhinosinusitis (CRS).[3]

Rhinosinusitis is a prevalent condition, accounting for up to 10% of outpatient primary care and otolaryngology visits.[3] As such, otolaryngologists should be aware of the differential findings between COVID-19 and CRS induced olfactory loss. COVID-19 associated olfactory dysfunction often presents acutely and often with other manifestations of viral illness.[3,57] Radiographic differences have also been described. Naeini et al. analyzed CT scans to assess the mechanism for COVID-19 induced smell loss, finding no

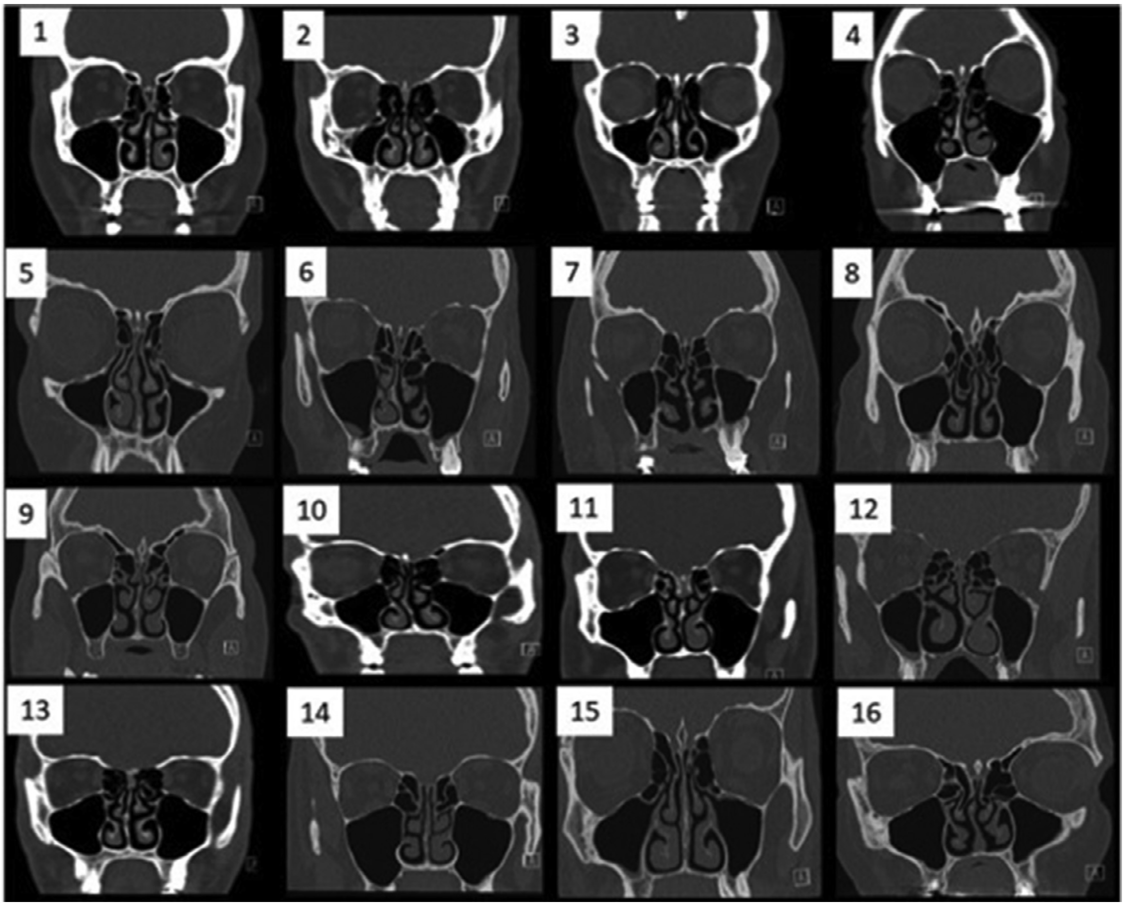

Figure 2 Computed tomography scans for each patient in clinical series. All patients had anosmia secondary to COVID-19. Each number reflects a different patient from the clinical series. Reprinted with permission.[59]

significant mucosal thickening or opacification.[58] Lechien et al. also noted anosmia in the context of clear olfactory clefts amongst several patients (Figure 2).[59] In contrast, Loftus et al. demonstrated the association between increased CT scan opacification and olfactory dysfunction in CRS with nasal polyposis (CRSwNP), highlighting the importance of mucosal thickening as precipitating olfactory loss in CRS patients (Figure 3).[60,61] These findings illustrate a likely sensorineural etiology for COVID-19 induced anosmia, a pathophysiological difference to the obstructive etiology of CRS.[62] Specifically, COVID-19 induced olfactory dysfunction may result from SARS-CoV-2 infection of the sustentacular cells. These cells support olfactory neurons, and their loss may result in sensorineural deficits without direct infection of the olfactory neurons.[62]

Anosmia induced by mucosal injury has a relatively rapid recovery of usually 3 days.[55,58] The recovery time for most COVID-19 anosmic patients is generally within 4 weeks, but 21%-39% of patients may have continued dysfunction.[3] The recovery rates for these have also varied from 31.7%-89% in self-reported studies, and is reported that 7% of patients remain anosmic at 12 months post infection.[53] Olfactory dysfunction can significantly impact patient quality of life.[63] Valsamidis et al. reported that patients with complete or partial smell loss had higher rates of stress and depression.[64] A review of COVID-19 patients with olfactory dysfunction concluded that 67.7% of these patients had a quality of life deficit.[65] Furthermore, the constellation of chemosensory dysfunction and emotional turmoil can reduce a person's interest and enjoyment of eating, potentially resulting in nutritional deficiencies.[57] These sequelae from COVID infection should be kept in mind, and anosmic patients should be counseled on the possible dangers associated with lack of smell.

Rhinosinusitis Management

Rhinosinusitis can influence the expression of proteins on cells of the nasal epithelium.[66] Alterations in expression of ACE2 or transmembrane serine protease 2 (TMPRSS2), receptors for SARS-CoV-2, can theoretically modulate risk for COVID-19 infection.[66] One study found that patients with CRSwNP had reduced expression of ACE2 and TMPRSS2, suggesting a lower risk of COVID-19 for CRS patients.[66] Alternatively, Lee et al. found that CRS patients, with and without polyposis, had no difference in ACE2 expression.[67] Eosinophilic inflammation has also been demonstrated to reduce ACE2 expression in rat models.[68] Interferon-gamma driven inflammation, however, has

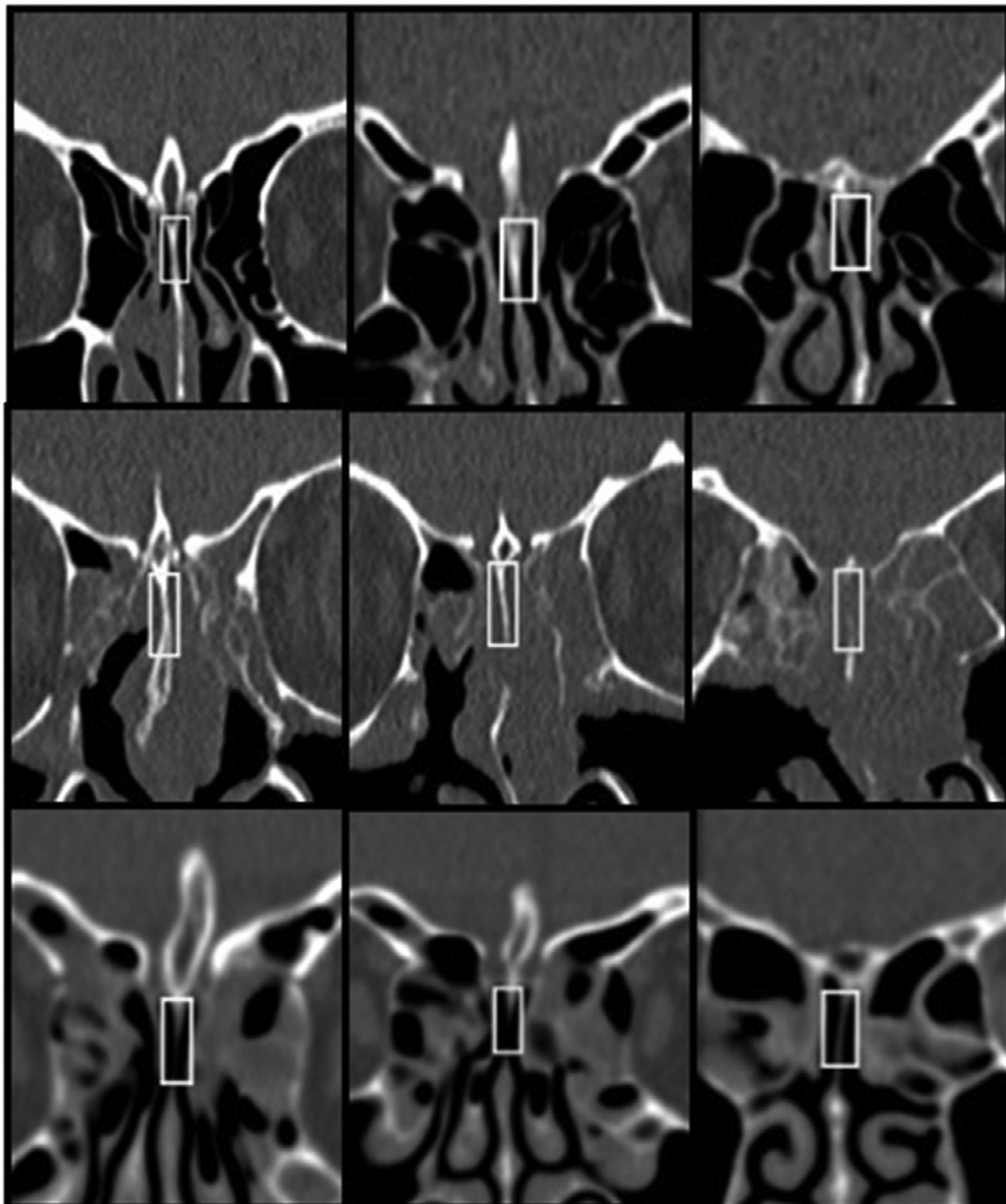

Figure 3 Computed tomography images of the olfactory cleft of patients in the control, chronic rhinosinusitis with nasal polyposis (CRSwNP), and chronic rhinosinusitis without nasal polyposis (CRSw/oNP) groups. The top panel is images from the control group, middle panel from the CRSwNP group, and bottom panel from the CRSw/oNP group. Reprinted with permission.[61]

been shown to upregulate ACE2 expression.[69] Given these heterogenous results, there is no consensus on the effect of rhinosinusitis on susceptibility or severity of COVID-19 infection.

Changes in treatment utilizing corticosteroid therapy for rhinitis have been discussed due to concerns for interaction with SARS-CoV-2. The International Consensus Statement on Allergy and Rhinology: Rhinosinusitis 2021 recommended maintenance of topical corticosteroids even in the setting of COVID infection as there is no evidence of increased infectivity for these patients.[3] Furthermore, the possibility for increased coughing and sneezing with corticosteroid discontinuation could increase risk for dissemination of the virus.[70] Given the efficacy of steroids in treating CRS, their continuation may help reduce the need for surgical intervention.[3] Outpatient utilization of topical saline or corticosteroid irrigations for pre-existing allergies and chronic rhinosinusitis also should not be dramatically reduced, as over 80% of rhinologists recommended continuation of current treatment plans.[8] The question of biologic therapy for these patients has also been explored. Förster-Ruhrmann et al. reported evidence suggesting that CRSwNP patients can continue treatment with dupilumab.[71] The European Academy of Allergy and Clinical Immunology recommended COVID-negative patients should continue their biologics while treatment should be suspended during SARS-CoV-2 infection.[72] Ultimately, based on best evidence and guidelines, current medical management for rhinologic conditions remain largely unchanged during the pandemic.

Academics

The heightened risk of SARS-CoV-2 transmission has directly impacted resident physician education. Diversion of personnel to care for patients with COVID-19 coupled with the cancellation of elective procedures directly translated to reduced clinical and surgical opportunities for residents. These realities have prompted some authors to advocate for increased use of community-driven online resources such as the Collaborative Multi-Institution Residency Education Program.[73] These types of platforms allow residents to continue learning about Otolaryngology in the context of the pandemic. Surgical training has also been directly impacted. Chou et al. performed a survey of otolaryngology residents and reported that 98.3% of residents had decreased case volume and 43.7% had decreased surgical involvement.[74] Similarly, Murthy et al's survey found 43% of respondents were not involved in any skull base procedures, even in COVID-19 negative patients, during the onset of the pandemic.[75] Respondents reported supplementing their knowledge through online modalities such as website surgical videos provided by the ARS.[75] The increased utilization of online resources has been steadily increasing, but clearly reflects a major development in resident education as a consequence of COVID.[73,75]

The pandemic has significantly impacted normal research and other scholarly activities. Understanding these effects is critical as reductions in scholarly activity can affect the delivery of novel therapeutic advances or techniques for patients. During the initial stages of the pandemic, 1052 clinical trials were suspended in the United States, with 86% of trials being suspended due to the pandemic.[76] These delays raise concerns about the effect of the pandemic on the interpretability of data from trials.[77] In a survey of ARS members, Grayson et al. reviewed these considerations. Researchers noticed changes in times to the Institutional Review Board (IRB) and Institutional Animal Care and Use Committee approval processes.[78] Their study also found significant alterations in conduction of laboratory based research. All respondents participating in animal based research had halted their normal activities while 96% of those pursuing *in vitro* studies had deviations from pre-COVID-19 norms.[78] Clinical trials were also significantly impacted as 51.1% of respondents were only able to enroll patients into COVID related projects while 36% could not register any new participants.[78] These alterations will likely directly impact publishing productivity, theoretically slowing the progress of important rhinologic research activity. Furthermore, the long-term effects of decreased hospital revenue and cost from COVID may result in the decreased funding for scholarly activity.[78] These unprecedented circumstances will likely have long lasting implications on rhinology research that may not become apparent for several years.

Conclusion

The COVID-19 pandemic has significantly altered clinical and scholarly activity worldwide in all fields of medicine. High viral loads in the nasal cavity and nasopharynx, frequency of AGPs, and COVID symptomatology position rhinologists in the forefront of being impacted. Increased adoption of telemedicine appears to be a viable avenue for maintaining clinical care while reducing unnecessary health risks for providers and patients. Furthermore, advances in risk mitigation strategies are likely to be progressively adopted given the continued presence of COVID and may prove extremely valuable in possible future pandemics.

Disclosures

The author reports no potential conflict of interest.

Conflicts of Interest

The authors declare that they have no conflict of interest.

References

1. Gengler I, Wang JC, Speth MM, et al: Sinonasal pathophysiology of SARS-CoV -2 and COVID -19: A systematic review of the current evidence. Laryngoscope Investigative Otolaryngology 5:354–359, 2020. doi:10.1002/lio2.384.
2. Davis ME, Yan CH: Coronavirus disease-19 and rhinology/facial plastics. Otolaryngol Clin North Am 53:1139–1151, 2020.
3. Orlandi RR, Kingdom TT, Smith TL, et al: International consensus statement on allergy and rhinology: Rhinosinusitis 2021. International Forum of Allergy & Rhinology 11:213–739, 2021. doi:10.1002/alr.22741.
4. Setzen M, Svider PF, Pollock K: COVID-19 and rhinology: A look at the future. Am J Otolaryngol 41 102491, 2020 2020/05/01/. doi:10.1016/j.amjoto.2020.102491.
5. Anagiotos A, Petrikkos G: Otolaryngology in the COVID-19 pandemic era: The impact on our clinical practice. European Archives of Oto-Rhino-Laryngology 278(3):629–636, 2021.
6. Patel ZM, Fernandez-Miranda J, Hwang PH, et al: Precautions for endoscopic transnasal skull base surgery during the COVID-19 pandemic. Neurosurgery 87:E66–E67, 2020.
7. Andrews P, Anschuetz L, Baptista PM, et al: Awake rhinology surgery in response to the COVID-19 pandemic in Europe. ORL 1–10, 2021. doi:10.1159/000517155.
8. Papagiannopoulos P, Ganti A, Kim YJ, et al: Impact of COVID-19 pandemic on ambulatory and operating room rhinology practice in the US. American Journal of Rhinology & Allergy 35:441–448, 2021. doi:10.1177/1945892420961962.
9. Setzen M, Svider PF, Setzen S, et al: The novel corona virus and rhinology: Impact on practice patterns and future directions. Am J Otolaryngol 41 102569, 2020 2020/11/01/. doi:10.1016/j.amjoto.2020.102569.

10. Svider PF, Setzen M, Ow R, et al: Incorporation of telemedicine by rhinologists: The COVID-19 pandemic and beyond. Am J Otolaryngol 41 102567, 2020 2020/11/01/. doi:10.1016/j.amjoto.2020.102567.
11. Gilani S, Bommakanti K, Friedman L: Electronic consults in otolaryngology: A pilot study to evaluate the use, content, and outcomes in an academic health system. Annals of Otology, Rhinology & Laryngology 129:170–174, 2020.
12. Samarrai R, Riccardi AC, Tessema B, et al: Continuation of telemedicine in otolaryngology post-COVID-19: Applications by subspecialty. Am J Otolaryngol 42 102928, 2021 2021/05/01/. doi:10.1016/j.amjoto.2021.102928.
13. Hentati F, Cabrera CI, D'Anza B, et al: Patient satisfaction with telemedicine in rhinology during the COVID-19 pandemic. Am J Otolaryngol 42 102921, 2021 2021/05/01/. doi:10.1016/j.amjoto.2021.102921.
14. Hoi KK, Brazina SA, Kolar-Anderson R, et al: A longitudinal comparison of telemedicine versus in-person otolaryngology clinic efficiency and patient satisfaction during COVID-19. Annals of Otology, Rhinology & Laryngology 000348942110553, 2021. doi:10.1177/00034894211055349.
15. Layfield E, Triantafillou V, Prasad A, et al: Telemedicine for head and neck ambulatory visits during COVID-19: Evaluating usability and patient satisfaction. Head Neck 42:1681–1689, 2020.
16. Rimmer RA, Christopher V, Falck A, et al: Telemedicine in otolaryngology outpatient setting—single center head and neck surgery experience. Laryngoscope 128:2072–2075, 2018.
17. Morisada MV, Hwang J, Gill AS, et al: Telemedicine, patient satisfaction, and chronic rhinosinusitis care in the era of COVID-19. American Journal of Rhinology & Allergy 35:494–499, 2021.
18. Du M, Papazian E, Adams D, et al: Patient satisfaction with telemedicine is noninferior to in-office visits: Lessons from a tertiary rhinology and endoscopic skull base surgery practice. International Forum of Allergy & Rhinology, 2021. doi:10.1002/alr.22903.
19. Ning AY, Cabrera CI, D'Anza B: Telemedicine in otolaryngology: A systematic review of image quality, diagnostic concordance, and patient and provider satisfaction. Ann Otol Rhinol Laryngol 130:195–204, 2021. doi:10.1177/0003489420939590.
20. Lechien JR, Radulesco T, Distinguin L, et al: Patient and otolaryngologist perceptions of telemedicine during COVID-19 pandemic. Eur Arch Otorhinolaryngol 278:4101–4105, 2021 2021/10/01. doi:10.1007/s00405-021-06624-9.
21. Medicare Cf, Services M. Medicare telemedicine health care provider fact sheet. 2020.
22. Lee JT, DelGaudio J, Orlandi RR: Practice patterns in office-based rhinology: Survey of the American Rhinologic Society. American journal of rhinology & allergy 33:26–35, 2019.
23. Tellier R, Li Y, Cowling BJ, et al: Recognition of aerosol transmission of infectious agents: A commentary. BMC Infectious Diseases 19:101, 2019 2019/01/31. doi:10.1186/s12879-019-3707-y.
24. van Doremalen N, Bushmaker T, Morris DH, et al: Aerosol and surface stability of SARS-CoV-2 as compared with SARS-CoV-1. N Engl J Med 382:1564–1567, 2020. doi:10.1056/NEJMc2004973.
25. Workman AD, Jafari A, Welling DB, et al: <? covid19?>Airborne aerosol generation during endonasal procedures in the era of COVID-19: Risks and recommendations. Otolaryngology–Head and Neck Surgery 163:465–470, 2020.
26. Sharma D, Ye MJ, Campiti VJ, et al: Mitigation of aerosols generated during rhinologic surgery: A pandemic-era cadaveric simulation. Otolaryngology–Head and Neck Surgery 164:433–442, 2021.
27. Tuli IP, Trehan S, Khandelwal K, et al: Diagnostic and therapeutic endonasal rhinologic procedures generating aerosol during COVID-19 pandemic: a systematized review. Brazilian Journal of Otorhinolaryngology 87:469–477, 2021.
28. Williams S, Leong S: One year into the COVID-19 pandemic: What do we know so far from studies assessing risk and mitigation of droplet aerosolisation during endonasal surgery? A systematic review. Clinical Otolaryngology 46(6):1368–1378, 2021.
29. Leong SC, Mogre D, Andrews P, et al: Reducing the risks of endoscopic sinonasal surgery in the Covid-19 era. Clinical Otolaryngology 46(4):809–815, 2021.
30. Gill AS, Oakley G, Error M, Kelly K, Orlandi R, Alt JA: Optimizing clinical productivity in the otolaryngology clinic during the COVID-19 pandemic. International Forum of Allergy & Rhinology 11(7):1121–1123, 2021. doi:10.1002/alr.22766.
31. Gill AS, Kaur K, Shipman P, et al: Nasal endoscopy, room filtration, and aerosol concentrations during live outpatient encounters: a prospective, case-control study. International Forum of Allergy & Rhinology 12:71–82, 2022. doi:10.1002/alr.22874.
32. Howard BE, Lal D: Rhinologic practice special considerations during COVID-19: visit planning, personal protective equipment, testing, and environmental controls. Otolaryngology–Head and Neck Surgery 163:676–681, 2020.
33. Maragkos GA, McNeill IT, Kessler R, et al: Reintroducing Endoscopic Skull Base Surgery During the COVID-19 Pandemic: A Single-Center Experience from the United States COVID-19 Epicenter. Journal of Scientific Innovation in Medicine 4(2):20, 2021. doi:10.29024/jsim.94.
34. Mallari RJ, Avery MB, Corlin A, et al: Streamlining brain tumor surgery care during the COVID-19 pandemic: A case-control study. PLoS One 16 e0254958, 2021.
35. Taha MA, Hall CA, Rathbone RF, et al: Rhinologic procedures in the era of COVID-19: Health care provider protection protocol. Am J Rhinol Allergy 34:451–455, 2020. doi:10.1177/1945892420927178.
36. Penner F, Grottoli S, Lanotte MMR, et al: Pituitary surgery during Covid-19: A first hand experience and evaluation. J Endocrinol Invest 44:635–636, 2021. doi:10.1007/s40618-020-01354-x.
37. Dharmarajan H, Freiser ME, Sim E, et al: Droplet and aerosol generation with endonasal surgery: Methods to mitigate risk during the COVID-19 pandemic. Otolaryngol Head Neck Surg 164:285–293, 2021. doi:10.1177/0194599820949802.
38. Jones HAS, Salib RJ, Harries PG: Reducing aerosolized particles and droplet spread in endoscopic sinus surgery during COVID-19. Laryngoscope 131:956–960, 2021. doi:10.1002/lary.29065.
39. Helman SN, Soriano RM, Tomov ML, et al: Ventilated upper airway endoscopic endonasal procedure mask: surgical safety in the COVID-19 era. Operative Neurosurgery 19:271–280, 2020. doi:10.1093/ons/opaa168.
40. Viera-Artiles J, Mato D, Valdiande JJ, et al: A novel aerosolisation mitigation device for endoscopic sinus and skull base surgery in the COVID-19 era. Eur Arch Otorhinolaryngol 278:1869–1877, 2021. doi:10.1007/s00405-020-06462-1.
41. Tang N, Li D, Wang X, et al: Abnormal coagulation parameters are associated with poor prognosis in patients with novel coronavirus pneumonia. J Thromb Haemost 18:844–847, 2020. doi:10.1111/jth.14768.
42. Hanff TC, Mohareb AM, Giri J, et al: Thrombosis in COVID-19. Am J Hematol 95:1578–1589, 2020.
43. Talmor G, Grube JG, Eloy JA, et al: Nasoseptal flap necrosis after endoscopic skull base surgery in the setting of COVID-19 pandemic. World Neurosurg 140:374–377, 2020 2020/08/01/. doi:10.1016/j.wneu.2020.05.237.
44. Inouye D, Zhou S, Clark B, et al: Two cases of impaired wound healing among patients with major head and neck free-flap reconstruction in the setting of COVID-19 infection. Cureus 13(2):e20088, 2021. doi:10.7759/cureus.20088.
45. Benmoussa N, de Kerangal Q, Leymarie N, et al: Failure of free flaps in head and neck oncology surgery in COVID-19 patients. Plast Reconstr Surg 146:251e–252e, 2020.
46. Ovenden C, Bulshara V, Patel S, et al: COVID-19 nasopharyngeal swab causing a traumatic cerebrospinal fluid leak. ANZ J Surg 91:1021–1022, 2021. doi:10.1111/ans.16910.
47. Agamawi YM, Namin A, Ducic Y: Cerebrospinal fluid leak from COVID-19 swab. OTO open 5 2473974 × 211059104, 2021.
48. Rajah J, Lee J: CSF rhinorrhoea post COVID-19 swab: A case report and review of literature. J Clin Neurosci 86:6–9, 2021 2021/04/01/. doi:10.1016/j.jocn.2021.01.003.
49. Paquin R, Ryan L, Vale FL, et al: CSF leak after COVID-19 nasopha-

ryngeal swab: A case report. Laryngoscope 131:1927–1929, 2021. doi:10.1002/lary.29462.

50. Hakimi AA, Goshtasbi K, Kuan EC: Complications associated with nasopharyngeal COVID-19 testing: An analysis of the MAUDE database and literature review. American Journal of Rhinology & Allergy 36(2):281–284, 2021 19458924211046725.
51. Fang CH TJ, Baredes S, Eloy JA: Cerebrospinal fluid leak after COVID-19 nasal swab test. MD Advisor 14:27–28, 2021.
52. Aaronson DM, Poetker DM, Long CM, et al: COVID-19 Testing in the era of modern neurosurgery: Mitigating risk in our vulnerable patient populations. World Neurosurg 152:80–83, 2021 2021/08/01/. doi:10.1016/j.wneu.2021.06.027.
53. Karamali K, Elliott M, Hopkins C: COVID-19 related olfactory dysfunction. Curr Opin Otolaryngol Head Neck Surg 30(1):19–25, 2022. doi:10.1097/MOO.0000000000000783.
54. Kaye R, Chang CD, Kazahaya K, et al: COVID-19 anosmia reporting tool: initial findings. Otolaryngology–Head and Neck Surgery 163:132–134, 2020.
55. Klopfenstein T, Kadiane-Oussou N, Toko L, et al: Features of anosmia in COVID-19. Médecine et Maladies infectieuses 50:436–439, 2020.
56. Saussez S, Lechien JR, Hopkins C: Anosmia: An evolution of our understanding of its importance in COVID-19 and what questions remain to be answered. Eur Arch Otorhinolaryngol 278:2187–2191, 2021.
57. Desai M, Oppenheimer J: The importance of considering olfactory dysfunction during the COVID-19 pandemic and in clinical practice. The Journal of Allergy and Clinical Immunology: In Practice 9:7–12, 2021 2021/01/01/. doi:10.1016/j.jaip.2020.10.036.
58. Naeini AS, Karimi-Galougahi M, Raad N, et al: Paranasal sinuses computed tomography findings in anosmia of COVID-19. Am J Otolaryngol 41 102636, 2020. doi:10.1016/j.amjoto.2020.102636.
59. Lechien JR, Michel J, Radulesco T, et al: Clinical and radiological evaluations of COVID-19 patients with anosmia: Preliminary report. Laryngoscope 130:2526–2531, 2020. doi:10.1002/lary.28993.
60. Raviv JR, Kern RC: Chronic rhinosinusitis and olfactory dysfunction. Taste and smell 63:108–124, 2006.
61. Loftus C, Schlosser RJ, Smith TL, et al: Olfactory cleft and sinus opacification differentially impact olfaction in chronic rhinosinusitis. Laryngoscope 130:2311–2318, 2020.
62. Khan M, Yoo S-J, Clijsters M, et al: Visualizing in deceased COVID-19 patients how SARS-CoV-2 attacks the respiratory and olfactory mucosae but spares the olfactory bulb. Cell 184:5932–5949, 2021 e15.
63. Ahmed OG, Rowan NR: Olfactory dysfunction and chronic rhinosinusitis. Immunology and Allergy Clinics 40:223–232, 2020.
64. Valsamidis K, Printza A, Constantinidis J, et al: The impact of olfactory dysfunction on the psychological status and quality of life of patients with nasal obstruction and septal deviation. International Archives of Otorhinolaryngology 24:237–246, 2020.
65. Saniasiaya J, Prepageran N: Impact of olfactory dysfunction on quality of life in coronavirus disease 2019 patients: A systematic review. The Journal of Laryngology & Otology 135:947–952, 2021. doi:10.1017/S0022215121002279.
66. Saheb Sharif-Askari F, Saheb Sharif-Askari N, Goel S, et al. Are patients with chronic rhinosinusitis with nasal polyps at a decreased risk of COVID-19 infection? Wiley Online Library; 2020:1182-1185.
67. Lee IT, Nakayama T, Wu CT, et al: Robust ACE2 protein expression localizes to the motile cilia of the respiratory tract epithelia and is not increased by ACE inhibitors or angiotensin receptor blockers. medRxiv, 2020. doi:10.1101/2020.05.08.20092866.
68. Dhawale VS, Amara VR, Karpe PA, et al: Activation of angiotensin-converting enzyme 2 (ACE2) attenuates allergic airway inflammation in rat asthma model. Toxicol Appl Pharmacol 306:17–26, 2016. doi:10.1016/j.taap.2016.06.026.
69. Ziegler CGK, Allon SJ, Nyquist SK, et al: SARS-CoV-2 Receptor ACE2 is an interferon-stimulated gene in human airway epithelial cells and is detected in specific cell subsets across tissues. Cell 181:1016–1035, 2020 e19. doi:10.1016/j.cell.2020.04.035.
70. Jian L, Yi W, Zhang N, et al: Perspective: COVID-19, implications of nasal diseases and consequences for their management. J Allergy Clin Immunol 146:67–69, 2020. doi:10.1016/j.jaci.2020.04.030.
71. Förster-Ruhrmann U, Szczepek AJ, Bachert C, et al: COVID-19 in a patient with severe chronic rhinosinusitis with nasal polyps during therapy with dupilumab. J Allergy Clin Immunol 146:218–220, 2020 e2. doi:10.1016/j.jaci.2020.05.005.
72. Vultaggio A, Agache I, Akdis CA, et al. Considerations on biologicals for patients with allergic disease in times of the COVID-19 pandemic: An EAACI statement. *Allergy*. 2020;75:2764-2774. doi:10.1111/all.14407
73. Newsome HA, Davies OMT, Doerfer KW: Coronavirus disease 2019—An impetus for resident education reform? JAMA Otolaryngology–Head & Neck Surgery 146:785–786, 2020. doi:10.1001/jamaoto.2020.1587.
74. Chou DW, Staltari G, Mullen M, et al: Otolaryngology resident wellness, training, and education in the early phase of the COVID-19 pandemic. Annals of Otology, Rhinology & Laryngology 130(8):904–914, 2021 0003489420987194.
75. Murthy AK, Fontan CT, Filippa Trikantzopoulou M, et al: Impact of the COVID-19 pandemic on otolaryngology resident rhinology education. International Forum of Allergy & Rhinology, 2022. doi:10.1002/alr.22956.
76. Asaad M, Habibullah NK, Butler CE: The impact of COVID-19 on clinical trials. Ann Surg 272:e222–e223, 2020. doi:10.1097/sla.0000000000004113.
77. Servick K: Clinical trials press on for conditions other than COVID-19. Will the pandemic's effects sneak into their data? Science, 2020. https://www.science.org/content/article/clinical-trials-press-conditions-other-covid-19-will-pandemic-s-effects-sneak-their. doi:10.1126/science.abc6606.
78. Grayson JW, McCormick JP, Thompson HM, et al: The SARS-CoV-2 pandemic impact on rhinology research: A survey of the American Rhinologic Society. Am J Otolaryngol 41 102617, 2020 2020/09/01/. doi:10.1016/j.amjoto.2020.102617.