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Safer Singing During the SARS-CoV-2 Pandemic: What We Know and What We Don't

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INTRODUCTION

While the novel coronavirus outbreak has profoundly altered health care systems across the globe, it has also affected similar change and devastation on the social, educational, and cultural communities upon which many rely, including communities of choral singers, solo performers, conductors, voice teachers, and the professionals that collaborate with them. Even as citizens of the most heavily impacted countries took to their balconies to serenade first responders and health care workers, singers of most genres who typically perform in ensembles have been told to not carry on their beloved practice. This message, promoted by the lay media and by early reports of "super-spreading" of the virus at choral events in the United States and abroad,[1,2] has been reinforced by expert and nonexpert opinion regarding the transmissibility of SARS-CoV-2 through droplets and aerosols, the generation of respiratory particles when singing, and concern about the interpersonal interactions that routinely accompany vocal performance, both in groups and in one-on-one teaching situations.

Unfortunately, there is a paucity of data about both how SARS-CoV-2 is transmitted by singing and how to bring communities of singers back together safely. The data available about disease spread through vocalization, most of which preceded the current pandemic, address primarily transmission of disease through droplets and aerosols and are specific neither to this virus nor to singing.[3−6] Specifically, there is a lack of data addressing how to congregate and sing safely in choral environments such as churches, concert halls and practice spaces, as well as stages, theatres and other venues. In addition, protective measures such as safest distancing between singers, wearing masks or other personal protective equipment (PPE), using larger rehearsal or performance spaces, reducing the number of singers inside a certain enclosed space, reducing the duration of rehearsals or performances, and using real time air and surface cleaning methods such as increased ventilation, UV-C light and HEPA filtration specific to a singing environment among other topics have not been studied well enough to provide evidence on which to base advice to the singing community.

Opinion on these matters is plentiful and often divergent. A recent webinar with a panel of experts in the world of voice care and singing left the audience with the message, "There is no safe way for singers to rehearse together until there is a COVID-19 vaccine and a 95% effective treatment in place."[7,8] Although, this may ultimately prove to be accurate, evidence-based practice (defined as an approach to health that integrates scientific research, patient preferences and values, and clinical expertise to make the best recommendations possible) does not allow for such a definitive conclusion to be made at this time.[9] It must be understood, that these recommendations and decisions are made not only on what scientific information is available but on intuition and unsystematic experience that is often biased and inaccurate.

We do not understand all the risks posed by COVID 19 to ourselves, friends, family and colleagues, who wish to resume educational, performance, communal and congregational singing safely. Evidence-based practice demands that we critically evaluate our current state of knowledge to come up with the best possible information to disseminate. In this article, we review the information that exists relating to singing and COVID-19. This paper is intended to provide guidance based on what we know: the best available data, analyzed and scrutinized by a panel of experts in the medical, behavioral and basic science world of voice care, of whom many are professional singers, choir directors or teachers of singing. While it may not be able to afford any definitive answers, this work will offer suggestions of best practices for those singing groups that are willing to mitigate risk knowing that the risk cannot be brought to zero. Finally, this report will hopefully stimulate the larger voice research community to study the emerging consensus on

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safe resumption of singing and pursue scientific understanding of COVID-19.

COVID-19 IS LIKELY SPREAD BY RESPIRATORY PARTICLES

Given the relatively recent emergence of the SARS-CoV-2 virus, the precise mechanisms of its transmission have not been studied extensively. Early research showed presence of the virus in the respiratory tract.[10] The World Health Organization (WHO) initially postulated that droplets and fomites were the primary modes of transmission, but that airborne transmission via aerosol was possible.[11] The rapid spread of this disease around the world led many researchers to suspect that aerosols (particles smaller than droplets) might play a more important role than initially suspected. It was shown that SARS-CoV-2 virus can survive on surfaces and in aerosol form in laboratory simulations,[12] a finding consistent with previous knowledge about other coronaviruses and influenza viruses.[13–15] Clinically, hospitals in Wuhan, China demonstrated high concentrations of viral RNA in aerosol form in medical staff areas,[16] but it is important to note that several other studies failed to corroborate that observation.[17,18] Additionally, it appears that SARS-CoV-2 can be spread even by nonsymptomatic patients, and this spread is presumed to be from respiratory transmission.[19–21] Many patients do not present with classic symptoms, including fever.[22] Such nonsymptomatic transmission is crucially important to consider in planning return to occupational and recreational activities as nonsymptomatic patients will not know they are ill and will not isolate, unwittingly putting others at risk when they go out into society.

Considering the biology of the virus and epidemiology of the pandemic, respiratory particles are beyond doubt responsible for at least some transmission of disease, and aerosol transmission is plausible.[23] However, the experimental results from preliminary SARS-CoV-2 research often are created in a laboratory. One commonly cited study[12] demonstrating virus persistence in aerosols used nebulizers and a Goldberg drum to generate aerosols with viral particles. It has been emphasized by the WHO that these techniques do not reflect a clinical setting.[24] Furthermore, the presence of virus in aerosol form does not necessarily lead to infection. This is likely to depend also on the infective potential of the virus,[25] the viral load, ventilation, possibly individual susceptibility and other factors, all of which require further study. It should be emphasized that there is no consensus on the mechanisms of spread and their impact on clinically relevant disease transmission.

PHONATION PRODUCES DROPLETS AND AEROSOLS

Respiratory particles, including droplets and aerosols, exist in human exhaled breath.[5,14,23,26,27] Other functions of the respiratory tract that also are thought to produce these particles at a higher level than breathing include phonation,[4] sneezing,[28] and coughing.[6] Asadi et al[5] demonstrated that certain individuals are "speech superemitters" who exude significantly more aerosol particles than others, and this has been corroborated by previous literature.[29] The same group also demonstrated that louder phonation resulted in greater aerosol generation.[5]

These points raise questions about how the types of phonation in which humans engage (talking, cheering, singing, etc) affect the generation of aerosols. This is particularly relevant to the voice community attempting to safely engage in traditionally in-person activities such as instruction, rehearsals, and performances. Because airflow is a key element of all singing styles, one might expect the same risk of disease transmission among various singing styles and genres (ie, gospel, classical, barbershop, etc). Yet Konnai et al[30] have shown that whispered and breathy phonation produce significantly greater airflow than normal phonation at all levels of loudness. Sound is transmitted by pressure waves, and theoretically viruses are buffeted on airflow. Singing with a more 'resonant' voice and less airflow, an accomplishment associated with trained singers of many genres who learn to manage breathing efficiency to sing long phrases, could in theory be less likely to transmit disease.[31,32] Furthermore, airflow and subglottic pressure are known to vary between styles of singing.[33,34] Microphone use may have the opposite effect, as it is known to lower voice intensity.[34,35] However, it is still ultimately unknown how aerosol production varies according to voice type, vocal register, or vocal style (belt, growl, classical, choral, etc), and this topic deserves more study.

Regardless of the variation in types of singing, eliminating this aerosol burden entirely is unlikely. Johnson et al[6] have noted that aerosols are generated in the alveoli of the lungs, but also in the larynx and the oral cavity. Fabian et al. suggest the re-opening of collapsed small airways after an exhalation plays a large role in aerosol particle production. Whether the greater use of the vital capacity in singing has any impact on the creation of aerosols as compared to singing techniques that utilize shallower breaths and a shorter vocal tract is unknown at this time.[36]

ENVIRONMENT AFFECTS RISK

Since the early days of the pandemic, governmental bodies across the world have recommended "social distancing" or "physical distancing" techniques as the optimal way to reduce the spread of SARS-CoV-2.[37] Given the epidemiology of the pandemic, it is clear that transmission happens from person to person after close contact. Although very little definitive data exist for SARS-CoV-2, a systematic review considering other similar viruses demonstrated that physical distancing of 1 meter or more led to a significant 82% decrease in viral transmission, with protection increasing as the distance lengthened (risk decreased by half with each 1m interval studied).[38,39] Anecdotally, clusters of transmission appear to happen more in environments with

close quarters including schools, households, meat packing plants, gyms, choral practice rooms, and music clubs.[1,40,41]

Ventilation may play an important role in transmission. This has been established by a systematic review of the literature performed by Li et al, which showed strong evidence that there is an association between ventilation and air movement patterns in buildings, and the spread of infectious disease (SARS, measles, influenza, among others).[42] However, the authors note that their data were not sufficient to recommend any minimum standards for ventilation of public and private spaces. There is some evidence to suggest that natural ventilation is an effective, low-cost strategy to reduce infection risk.[43] A study comparing ventilating using open doors and windows versus mechanically ventilated rooms suggested that the former strategy is superior;[44] and natural ventilation has been suggested as a strategy in the past by the WHO.[45] Therefore, environments with increased distance between potentially infected subjects and with good ventilation are preferable to environments with close contact and poor ventilation; this should apply not only to hospital environments but also to public and private areas in which rehearsals or performances are held.

Advanced techniques for air filtration or sterilization should be considered when ventilation is not adequate. Ultraviolet (UV) radiation has also been employed during the COVID-19 pandemic, based on evidence from both influenza virus[46] and other coronaviruses.[47] UV induces damage in DNA and RNA of bacteria and viruses, leading to their inability to replicate.[48,49] Likewise, filtration systems can remove viral particles from the air, including influenza and measles,[50,51] and were used during the SARS outbreak. Finally, ionization of the air may help with bacteria[52] and influenza virus.[53] While it is likely that these measures are useful as part of a concerted effort towards reduction of viral spread, there is insufficient evidence to confirm that any one of these is sufficient. Additionally, in contrast to selection of outdoor environments or rooms with window/door ventilation, such filtration and sterilization techniques require significant expertise for proper functioning.

When considering the environment, one must also consider the natural climate. Given COVID-19′s emergence during winter months in the Northern hemisphere, much attention has been given to the effect of temperature and humidity on the virus. Preliminary data have suggested that high temperatures and relative humidity can decrease both the infectivity and mortality associated with the virus.[54–56]

PPE HELPS PREVENT VIRUS SPREAD

N95 masks, and to a lesser extent surgical masks, also have been shown to protect from coronavirus transmission, although most of these data come from other coronaviruses.[38,57] Relative to the COVID-19 pandemic itself, models have demonstrated that even only moderately protective face mask could lead to lower infection rates.[58] Cloth masks should fit well, be made of several layers and ideally has water-resistant fabric.[39,59] Rather than filtering out small particles like N95 masks, cloth masks may reduce transmission by containing expired jets of respiratory particles when worn by infected patients. Globally, many countries have urged citizens to wear home-made masks for this reason.[60] While there has been limited discussion of PPE use in singers, it is reasonable to assume that PPE use will help singers more safely interact with one another, though this will not be sufficient to establish safety.

Eye protection has been more controversial. Although there are known ocular manifestations of COVID-19,[61] the SARS-CoV-2 virus has not been cultured from ocular secretions, and it is unclear whether ocular exposure is a source of transmission; regardless, eye protection has been recommended widely in healthcare environments with moderate risk of viral transmission.[62,63] A recent systematic review of other viral outbreaks has shown benefit in reducing viral transmission when ocular protection is used.[38]

AGE, RACE, INCOME LEVEL, AND HEALTH COMORBIDITIES AFFECT RISK

We have also recognized demographic differences in terms of severity and fatalities. Since the early days of the outbreak, advanced age has been identified as a risk factor for both hospitalization and mortality.[64,65] The specific underlying conditions of obesity and diabetes/metabolic syndrome have been correlated with worse outcomes.[66] There are also disproportionate rates of death from COVID-19 in the African-American and Latinx communities that are likely more a manifestation of longstanding disparities than genetic predisposition.[67,68] As such, the demographic of singing groups should be considered. Children's groups, for instance, are likely at less risk for suffering from severe COVID-19 disease than an elderly or African American ensemble, although transmission risk may be equivalent. Heightened vigilance in communities that may be more vulnerable appears paramount.

DISCUSSION

It cannot be overemphasized enough that the data we have about COVID-19 and the SARS-CoV-2 virus are still preliminary. While the existing research cited in this manuscript is helpful, much of it is based on observational, cross-sectional, or retrospective data. Some of it is likely underpowered to answer pressing questions about COVID-19 and some is anecdotal and experientially based. Decision-makers are appealing to the scientific community to inform the planning of activities and budgeting in the near- and long-term, but it is crucial that scientific claims are examined with great caution. Scientific studies provide evidence for or against theories and hypotheses, but often do not establish proof. Furthermore, science also takes time. Governments and organizations around the world have dedicated a tremendous amount of resources to further research towards vaccination,[69] but other avenues of research (into contact tracing, PPE, and specific to singing and performance) should also be pursued. It should be our goal to facilitate

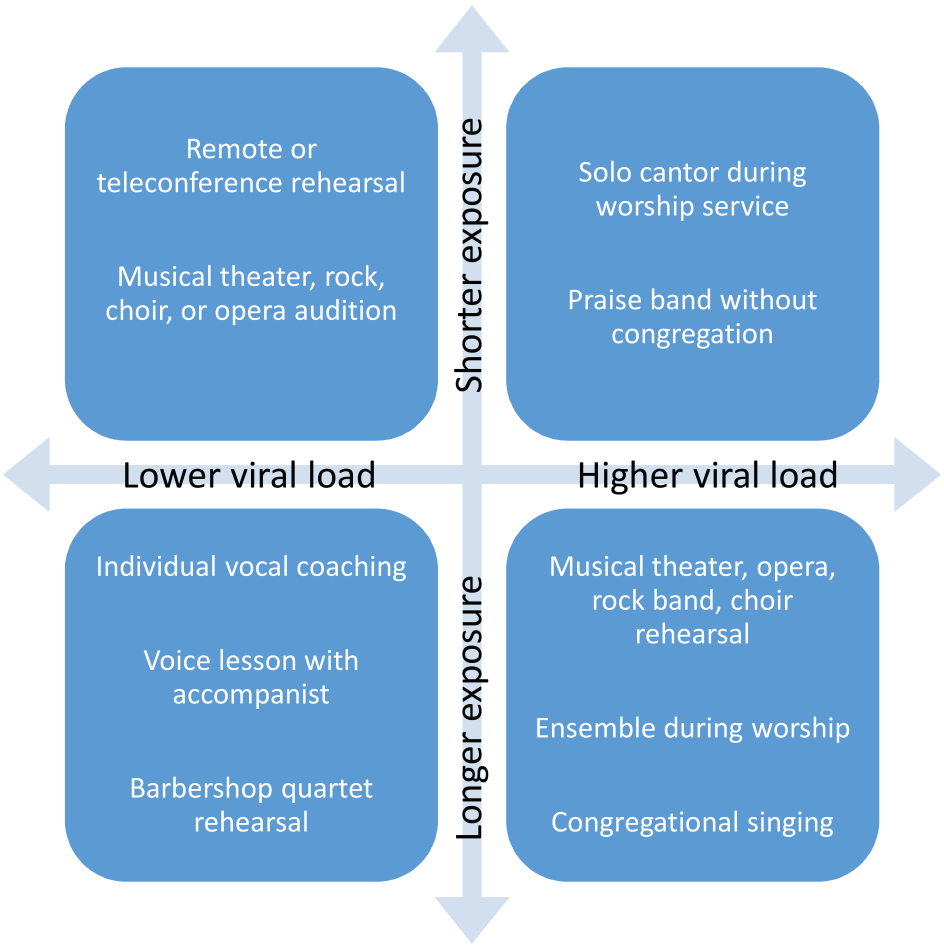

FIGURE 1. Examples of Potential Risk Associated With Types of Vocal Performance.

efforts for ever-increasing adoption of evidence-based practice in our field.

Nevertheless, it is incumbent on the voice and performing arts communities to consider how to incorporate available evidence and scientific consensus, albeit evolving, into practice. Choosing a correct path is difficult and requires balancing objective and dispassionate review of information against emotionally charged or inherently biased reactions or instincts. Ultimately, we do not believe that all vocal performance should stop until herd immunity is achieved through vaccination or naturally or until a cure for COVID-19 is discovered.

Different types of vocal performances will require different levels of complexity to optimize safety (Figure 1). Choral, educational and theatre organizations have the most to consider regarding safe-singing practices. Theatrical performance that requires the audience to see the faces and expressions of the performers (opera, musical theatre, plays, etc, as has evolved in and remains the primary style in the Western world) will face challenges beyond the scope of this paper.

PPE will almost certainly play a central role in establishing safer environments for singing, regardless of the setting. Just as governments have encouraged face mask usage across American communities to reduce transmission through coughing, sneezing, coughing, and close contact, singing organizations should encourage PPE use to minimize the risk of spreading infection in all except remote (ie, teleconferencing) rehearsals and performances. It should be acknowledged that beyond the issues with speaking and singing leading to SARS-CoV-2 transmission as presented in this paper, the inability of the performer to wear a mask to deliver an effective and emotive performance will be a difficult, if not insurmountable, obstacle to returning to live theatre as it is known in the Western world without substantial concessions.

Additionally, social distancing recommendations and limitations on large gatherings restrict the ability to gather an audience in a traditional theater or concert venue.

Places of worship not only have choirs to consider but also congregations who gather and expect to participate. The aerosolized viral load risk increases by a) singing or congregating for longer periods of time, b) increasing the number of infected singers (choir or congregation member) in a closed space, and c) the limited ability or inability to clear the air in the space. Performance spaces, and, possibly

more concerning, rehearsal spaces may not be ventilated well or even have windows to open. Private and educational voice teaching studios also may have the same limitations and must mitigate risk. Ideally, but not practically, one could determine if the size of the room, air filtration ability and air turnover time are sufficient to mitigate risk to even one teacher and his or her singing student together in a space.[70] No evidence has emerged to date regarding the risk mitigation of transmitting SARS-CoV-2 by placing plexiglass shields in singing voice studios between teachers and students. It is likely barriers such as these can mitigate a sneeze or cough from showering a person on the other side of the plexiglass with droplets. However, if the plexiglass is not completely separating two people into two separate air spaces, a teacher and student are occupying the same air space and the above risks apply. Future studies are needed to determine if plexiglass shields between a teacher and student, singing with or without masks, reduce disease transmission in otherwise closed spaces.

While fans blowing air away from choirs in rooms with open doors may help, the risk mitigation in doing that will be individual to the duration of the rehearsal or performance and the space and the size of the group performing because singing with more than one person in a room carries increased risk of disease transmission. Safe-distance singing in the near future probably will require fewer singers than would typically fill the choir stalls or rehearsal space who are all wearing masks and singing for shorter periods of time. Rehearsing and performing outdoors, with social distancing and cloth masks worn appropriately might be the least risky of all environments for larger groups that must rehearse and perform en masse together, although there is no evidence to support this speculation.

Technology to improve our ability to make music collaboratively online falls into two broad categories: laggy and real-time. Laggy solutions include common video conferencing software at higher quality audio settings,[71] or the use of a separate high quality audio only platform in conjunction with a video platform.[72] Real-time solutions are more technology driven, but made possible through both higher tech network-based platforms[73] and lower tech wireless audio setups.[74] These approaches could eliminate the risk of virus transmission to a teacher or student, chamber ensemble, or possibly even choral group through the elimination of in-person or proximal activity. This may serve a purpose but also is less enjoyable than the preferred and traditional method of singing in spaces with better acoustics and the ability to see and hear cues and body language from fellow performers.

Choirs in faith-based and community-based ensembles with members who have health conditions as previously identified, as well as members of color or advanced age, should appreciate the statistically higher rate of COVID-19 fatalities when calculating their risk to benefit ratio. COVID-19 testing before each choir rehearsal, in addition to body temperature and other screening might be useful. However, specific conclusions regarding screening tests for SARS-CoV-2 in the singing community cannot be made. We do not anticipate that our vocal communities will have widespread access to testing in the near future that would allow for immediate testing prior to congregation, however symptom screening questions and temperature checks could be implemented.

In this spirit, we suggest the following points to decrease the risk of SARS-CoV-2 transmission, fully acknowledging that there is no certainty or scientific evidence regarding the risks specifically for the voice community, nor the efficacy of these interventions, all of which require research.

1. Rehearse outside when possible. Inside, open windows and doors and use ventilation strategies such as fans to blow air away from the singer(s).
2. Use PPE, at least cloth face masks. Singing is possible with a mask. Masks can cause breathing challenges for some, and this may affect especially singers with underlying pulmonary dysfunction.
3. Rehearse alone, remotely, or in smaller groups. When with others, physical distancing of six feet or more appears paramount.
4. Rehearse in shifts or smaller sections, if possible, ideally in separate locations. Consider having a few representatives from each voice part and, if necessary, change the repertoire to accommodate.
5. Shorten rehearsal times. There is no absolutely "safe" duration of for rehearsal, and so organizations should do everything they can to limit rehearsals to the shortest possible time period.
6. Limit extraneous activities (eg, breaks, socializing, food etc).
7. Wipe down items that have been set up or touched by others before and after use (chairs, scores/paper music, instruments, music stands, etc).
8. Screen for symptoms, including fever, upper respiratory infection symptoms such as coughing and nasal congestion, loss of smell and taste. Take temperatures of singers prior to entering the rehearsal space. Remember that some infected patients will not have any symptoms.
9. Avoid direct contact (eg, hand-shaking, joining hands).
10. Practice meticulous hygiene. Wash or disinfect hands before, during and after rehearsals. Singers should not touch their face as part of a warm up exercise or singing instruction method (or anytime unnecessarily).
11. Sick singers should stay home as should singers who have been around a COVID-19 positive patient. Exposed singers should self-quarantine for two weeks.

These points must be taken as only recommendations. They are based on scant and often weak scientific evidence and on "common sense" that, while based on a wealth of experience, could still prove to be wrong. They may mitigate risk of transmitting SARS-CoV-2 but do not eliminate risk. It

will be up to the singers themselves, teachers of singing, church and private choral leaders, performer guilds and unions and other entities to weigh the risks and decide when and how to resume their charge in their individual performance spaces. Ultimately, each person must evaluate his or her own risk and risk tolerance to make a personal decision as to whether or not to continue in his or her performance activities.

CONCLUSIONS

Scientific research has not examined safe singing practices in relation to the risk of SARS-CoV2 transmission. The evidence that exists is based on prior viral outbreaks and situations that may or may not translate to various singing environments. It is likely the risk can be mitigated with certain practices, but risks cannot yet be eliminated. Each individual community of singers and performers must do what it can to mitigate as much risk as possible and then decide if that risk mitigation of SARS-CoV-2 transmission is sufficient to resume each singing activity considered, taking into account all of the factors discussed above.

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