

# Music in the time of COVID-19

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## ABSTRACT

“Music gives a soul to the universe, wings to the mind, flight to the imagination and life to everything” said Plato the great philosopher. In the current time of COVID-19 pandemic encompassing the world, music has lost its stage and has become confined to the virtual sphere. Though many of its connoisseurs are eagerly waiting for musical performances to resume, it poses a greater threat of creating an infection cluster through virus particles emitted from a possibly infected singer. Various experiments have estimated particle emission rates by performers during vocalization activities. Simulations have also measured time course of emitted particles in a closed environment leading to the infection spread. In this mini review we attempt to compile and interpret available information and assess that possible impact a musical performance can play in spreading the infection.

## Introduction

COVID-19 disease caused due to infection by a novel form of beta coronavirus designated as nCov-2019 or SARS-CoV-2 has brought the world to its knees in the last 7-8 months severely affecting activities in all spheres of life. High infectivity of the virus has forced governments world-wide to lay embargo on mass gatherings which has impacted the social, religious, cultural and sports lives of humanity. For the musically inclined people this has taken a devastating effect as all forms of live concerts, choir and singing performances have come under the ban, forcing music to be confined to the online world only. Music performances as nucleus of a COVID-19 infection storm came into highlight from a cluster of 100+ affected individuals who attended a number of live music events between February and April 2020 in Osaka, Japan. Rigorous contact tracing was able to pinpoint source of these infections to a single individual with symptoms who participated in many of the events [1,2].

Spread of infections was reported not only amongst audience of music concert, but also between members of a choir in Skagit county, Washington who seemed to have passed on the virus to each other over a couple of practice sessions [3]. However, it is not clear whether the activity of singing in confined area or just social interaction between members was the prime contributor in

spreading infection. It is now quite well-known that SARS-CoV-2 primarily infects human through the respiratory epithelial cells. Spike proteins on the virion surface binds to the Angiotensin-Converting Enzyme 2 (ACE2) receptor of cells to force its entry and start the pathogenesis process through replication by fooling the host genome. Virus particles are typically transmitted from infected persons as droplets in air or fomites on various surfaces that commonly come in human contact. Thus, to assess the potential of music performance or singing in particular as a key mechanism for spread of COVID-19, it will be important to understand formation of the droplets during vocal activities.

Impact of COVID-19 on singing was reviewed in detail by Naunheim and co-workers [4] mostly in qualitative terms. As pointed out in this review, phonation during talking and singing generates larger quantities of droplets and aerosol. In the background of a large number of asymptomatic COVID-19 positive patients worldwide, such vocal activities may have the potential to nucleate large clusters of infection. In this mini-review, we aim to gather available quantitative information on droplet generation during vocal activities and assess their potential in spreading COVID-19.

## Generation of Infective Particles from Respiratory Tract

### Droplet and Aerosol Generation

Droplets emerging through nose and mouth during breath, speech or other vocal activities can be traced to three anatomic components as their source - bronchiolar fluid film in the lungs, trachea and larynx and the oral cavity (Figure 1). Mechanisms of droplet generation from each of these body parts and their further spread, extensively reviewed by Wei & Li [5] are summarized in (Table 1). Extensive studies on respiratory droplets generated through pre-set inhale-exhale patterns revealed largest droplet size < 2 μm [6]. Though such droplets have possibility of aerosol formation, their sub-micron size restrict them to contain very few SARS-CoV-2 virions that are of ~ 0.1 μm diameter itself [7]. On the other hand, large millimetre-sized droplets generated from oral cavity have limited potential of airborne spread since their large size causes deposition within short distances due to gravitational domination.

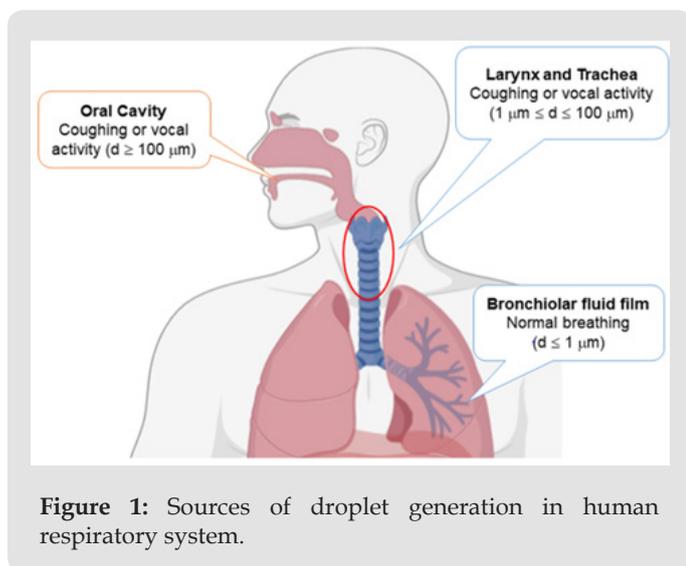


Figure 1: Sources of droplet generation in human respiratory system.

Table 1: Source and characteristics of respiratory droplets.

Source and Size of Droplets	Biomechanics	Physiological Mechanism	Fate of Droplets
Bronchiolar fluid film in lungs ( $d \leq 1 \mu m$ )	Burst of fluid film	Normal breathing	Rapid evaporation, limited airborne spread
Trachea and larynx ( $1 \mu m \leq d \leq 100 \mu m$ )	Instability caused by shear on air-mucous layer	Coughing and vocal activities	Airborne spread as droplets or aerosols
Oral cavity ( $d \geq 100 \mu m$ )	Droplet formation from saliva or the mucous layer	Coughing, talking and other vocal activities	Deposition within a short distance due to gravity

Intermediate size droplets typically formed at rear of oral cavity are the most likely culprits for airborne spread since they can pack a larger quantity of virions and at the same time are less susceptible

to gravitational pull. Experiments done with voluntary coughing of subjects from different age groups have shown droplets sizes in the range of 5-10 μm with a concentration of ~ 1000 droplets/cm<sup>3</sup> and mean flow rates 0.1 – 0.9 L/s [8] leading to emission rates of 10<sup>5</sup>-10<sup>6</sup> droplets/s. With an initial release velocity of around 8.5 m/s [9], a cough can generate a shower of 10 -100 million of virions within a few meters of radius.

### Droplet Formation Through Vocal Activities

Though coughing and sneezing can generate high load of virus-carrying particles, such conditions are mostly applicable for patients with symptoms, who under the present circumstances will either be in isolation or equipped with face mask or other protective gears. Meanwhile vocal activities including speech and singing by infected but asymptomatic individuals are likely to pose greater threat of airborne spread in public spaces.

In a recent but pre-COVID-19 era research, Asadi et al. [10]. studied emission of droplets by making a set of volunteers to pronounce /a/ (the vowel sound in 'saw') or to read an English text at varying amplitudes. This study was an important landmark as its results indicated – (i) the particle emission rate is linearly correlated with amplitude of vocalization, but (ii) particle size distribution is independent of amplitude. In the specific context of singing, another study [11] measured particle emissions for a cohort of 12 singers that included both professional opera singers and amateurs who performed a 2-minute item of various categories including talking, soft singing, loud singing, and singing with exaggerated diction or at high pitch.

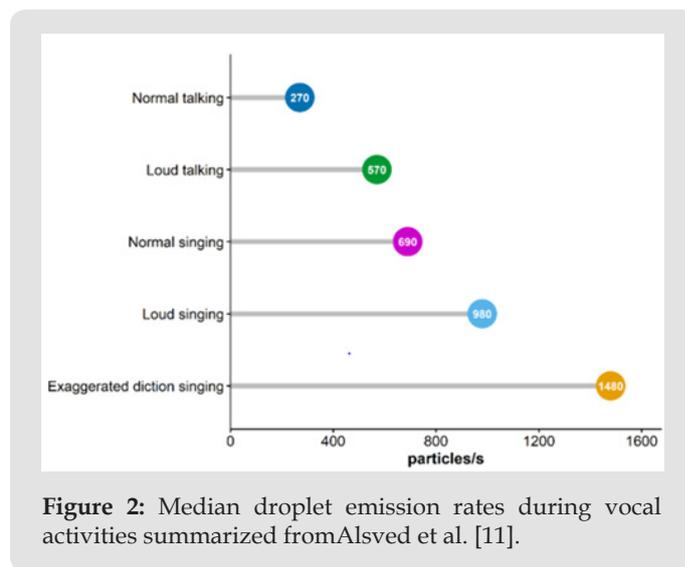


Figure 2: Median droplet emission rates during vocal activities summarized fromAlsvéd et al. [11].

The results showed a gradual increase in emitted particle rate from talking to soft singing to loud singing with singing at high pitch emitting the greatest number of particles. Though both experiments described above used an aerodynamic particle sizer for recording emissions, the emission rates (6-53 particles/s for vocalization) recorded by Asadi et al. [10] was order of magnitude

lower than the rates (median rate 570 particles/s for loud talking) recorded by Alsvéd et al. [11] most likely due to presence of additional filters in the experimental setup of former. Nevertheless, both experiments were important to demonstrate that singing, an in particular loud singing that generate more air pressure in the vocal chord can generate significantly larger number of particles than normal talking between individuals (Figure 2). Peak emission rate recorded by Alsvéd et al. [11] for loud singing with exaggerated diction was nearly 3000 particles/s. Assuming a 10  $\mu\text{m}$  particle size as discussed before, this would mean an outflow of nearly  $3 \times 10^5$  virions/s, which is probably 0.001 times the particles emitted in coughing, but still significant in spreading infection.

### Role of Air Flow System

Emission rates mentioned above are derived from purely experimental setups that are far from public space environments having air flow or HVAC system that may enhance travel distance of emitted particles. Simulation studies [9] have shown that while at zero ambient air speed, saliva droplets emitted by a person may hit the ground within a 2-metre distance (something which is advised by most governments and public health agencies as the social distancing norm), presence of a modest background air flow at 4 km/h can extend the "safe distance" to 6 metres. Further, presence of air flow also appears to reduce the droplet size by evaporation at a faster rate, thereby heightening aerosol formation of the particles. Another simulation study by Riediker et al. [12] assessed the effect of air change of HVAC systems on temporal course of virions emitted by breathing or coughing in a closed room of 50m<sup>3</sup> size.

Though, this data does not include emissions from vocal activities, but taking emission due to coughing of a typical person as standard shows that with around 10 air changes/h (typical rates in a public auditorium or a meeting room), the viral load attains a plateau in less than 30 minutes with a steady-state concentration of virions  $\sim 10/\text{m}^3$  volume. This number is rather low as a person in the audience who typically breathes 0.5 m<sup>3</sup>/h air volume would probably be exposed to < 10 copies of virus during a 2-hour performance. However, the number would increase significantly for an infected singer performing at high pitch in a smaller room. This could possibly increase the breathing viral loads of person in audience to 100 copies or more that are sufficient to cause infection.

### Discussion

With no end of the pandemic in sight, many reports are emerging on spread of disease by asymptomatic individuals [13,14]. Absence of detectable symptoms like hypothermia, coughing, sneezing or dyspnea makes it difficult to isolate and contain such individuals. Moreover, with normal activities resuming at most part of the world, it is likely that music and other performances will also revive soon. Number of audiences may be curtailed in such events, but an asymptomatic COVID-19 positive performer herself

can be a greater risk factor. Limited available data on music and COVID-19 presented in this mini-review vindicates the heightened potential of generating significant number of droplets during loud speeches or high-pitch singing. As music involves exercising vocal cords, such performance produces intermediate size droplets that are less affected by gravity and are more likely to turn as aerosols. Both studies with vocal activities reported in this review [15] have recorded particles sizes mostly in 5-10  $\mu\text{m}$  range, which did not depend on the loudness or pitch of the vocal activity.

From the perspective of a singer, COVID-19 infection can have long-term deleterious effects on the respiratory system affecting their professional lives. For earlier forms of coronaviruses (SARS and MERS), several studies have observed long-term respiratory changes even after recovery [15]. For SARS-CoV-2, follow-up of a large pool of patients from Italy for a period of 60 days post onset of initial symptoms showed that  $\sim 88\%$  still reported one of the symptoms at the end of follow-up period, including 43.4% patients presenting dyspnea. Also, several studies reported abnormalities in chest CT image even for asymptomatic patients. A recent meta-analysis synthesizing 7 such studies estimated around 63% patients (95% CI: 44% - 78%) presenting chest CT findings including ground-glass opacity though asymptomatic initially [16]. Perhaps it will take a few more years to conclusively understand long-term adverse effects of COVID-19 on respiratory system, but for now it may be prudent to assume that SARS-CoV-2 may affect a musician for some months even after recovery.

Overall, findings presented and summarized in this mini-review points to an emergent realization that practice of music, in particular in confined areas can create an infection cluster – not only due to social interaction between the audience but due to particles emitted from an infected asymptomatic singer. Being of intermediate size range, these particles have greater potential towards aerosol formation aided by possible air-flow systems. Under such situations, the 2-meter social distancing norms may not be of relevance. Experiments [11] show that use of masks can bring down the particle emission rate by two-third, but it is surely not practical for a vocalist to deliver serene performance wearing a mask. Though music performance in the time of COVID-19 may soothe many souls but can also create new infection clusters among practitioners and audience. Till the pandemic subsides, it would be a safer option to contain musical performances in the realm of online world.

### Conflict of Interest

Authors declare no conflicts of interest.

### Acknowledgement

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