Making Music: Aerosols, Droplets and the Risks of SARS-CoV-2 Transmission

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Motivation

- Clusters of COVID-19 associated with choirs around the world (e.g. Charlotte 2020; Miller, et al. 2020)

- Consequently, governments instituted severe restrictions on singing and woodwind/brass instrument playing

- Significant cultural, economical and health consequences (e.g. Broadway/West End closures; restrictions on religious and amateur choirs; lost tax revenue)

- Is the act of singing inherently worse than speaking, or is the risk more associated with typical contexts around singing (high sound volume, sustained vocalization, group activity)?

Study Design

- Cohort of 25 professional singers:
  - 6 musical theatre, 5 choral, 5 opera, 2 gospel, 2 rock, 2 jazz, 1 pop, 1 actor-singer and 1 soul
  - 6 soprano/mezzo-soprano, 7 alto, 5 tenor and 7 bass/baritone
  - 13 female and 12 male

- Measurements conducted in zero-background environment (orthopedic operating room)

- Participants performed a sequence of activities directed into a funnel connected to an Aerodynamic Particle Sizer (APS)

- APS measures aerosol 0.5-20 μm diameter, providing number concentration and size distribution
Protocol

- Participants followed a sequence of activities that lasted approx. 1 h, with each activity repeated 3-5 times.

1. Sing one note, 10 s, 70-80 dB
2. Speak "Happy Birthday" (20 s)
3. Sing "Happy Birthday" (20 s)
4. Breathe 10 s, Repeat first

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Graph showing particle number concentration over elapsed time in seconds, with various activities and their respective sound levels and durations.
Number Concentrations (Relative to Speaking 70-80 dB)

Reproducibility across measurement (median values within ~10%)
Number Concentrations (Relative to Speaking 70-80 dB)

- Steep (>10×) increase in number concentration with increasing volume
Number Concentrations (Relative to Speaking 70-80 dB)

Modest enhancements for singing relative to speaking (1.5-2.5×)
Breathing spans a very wide range: Four participants emitted more while breathing than while speaking at 90-100 dB.
Breathing differs from vocalization. For vocalization, similar size distributions with increasing volume.
Breathing size distribution may reduce risk (assuming dose scales with delivered mass)
Mass Concentrations (Relative to Speaking 70-80 dB)

Substantial (>20×) increase in mass with increasing volume
Mass Concentrations (Relative to Speaking 70-80 dB)

Modest enhancements for singing relative to speaking (1.5-3.5×)
Conclusions and Summary

- Aerosol generation highly sensitive to volume (factor of 10)
- Singing somewhat enhances aerosol generation relative to speaking at same volume (factor of 2)
- Breathing aerosol spans a wide range but produces smaller particles (less aerosol mass)
- Aerosol production is lognormally distributed across participants; some people will produce much more than others

Guidelines should consider:
- 1) volume of the vocalization
- 2) number of participants (source strength),
- 3) environment (ventilation)
- 4) duration of the activity/period of vocalization