Statement of Work: Aerosol Generation from Playing Band Instruments and Risk of Infectious Disease Transmission

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Background

The significance of viral transmission via small airborne droplets (also commonly referred to as 'aerosols') has been intensely discussed in the context of the SARS-CoV-2/COVID-19 (severe acute respiratory syndrome coronavirus-2/coronavirus disease 2019) pandemic (Morawska and Cao 2020; Lewis 2020). This is one of three commonly accepted modes of viral transmission, the other two being via larger respiratory droplets (which fall close to where they are expired), and direct contact with contaminated surfaces (fomites).

While evidence for airborne transmission of COVID-19 is incomplete, several hospital-based studies have performed air-sampling for SARS-COV-2 (Ong et al. 2020; Guo et al. 2020; Chia et al. 2020; Ding et al. 2020; Jiang et al. 2020; Liu et al. 2020; Santarpia et al. 2020). Four of these studies found several positive samples for SARS-CoV-2 genome (RNA) in air using polymerase chain reaction (PCR) testing, two found very small numbers of positive samples, and only one found no positive air samples. This evidence at least demonstrates a *potential* risk for airborne transmission of SARS-CoV-2.

Because of this potential risk from infection via droplets and aerosols as illustrated in the above studies and others that are rapidly forthcoming, many activities that occurred prior to the pandemic will have to be modified, especially those that have the potential to generate particles. These activities include things like singing and playing band instruments. Singing has been implicated in several outbreaks (Hong Kong Karaoke 2020; Skagit Valley Choir 2020). There have been no reports yet implicating the playing of instruments. However, the potential is likely. In one study, the number of particles emitted while playing plastic blowing horns used by sports fans was 658 x 10^3 #/L compared to 3.7 x 10^3 #/L for shouting. The majority of these particles were between 0.5 and 5 μm in diameter (Lai et al., 2011).

The singing episodes plus the published data on plastic horn playing suggest that further investigation is warranted into the possibility of infectious aerosol generated from playing band instruments. Concern has been expressed specifically regarding wind and brass instruments because the sound is produced by a controlled flow of exhaled air. For wood winds, the flow is

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impeded by reeds on the mouthpieces. But for brass such as trumpets and flute instruments the flow is not impeded (Music Making Risk 2020). A study is needed to better understand aerosol production in instrument playing so that professional musicians and students of music can resume playing in rehearsal and public spaces in a manner that is safe for the nearby musicians as well as any listeners. A description of the proposed methods to be used in this study is the focus of this Statement of Work.

Methods

The goal of this project would be to provide measurements and risk modelling estimates in a timely manner to better understand particle emissions from play band instruments. To accomplish this goal, we propose the following four activies:

1. Chamber studies to measure particle generation rate from a three instrument players, flute, clarinet, and trumpet
2. Flow imaging studies to qualitatively document the emission and particulate plume through photography and lasers
3. Field rehearsal studies measuring concentrations in a rehearsal room at the University of Colorado Boulder
4. Modelling of risk of transmission using the Wells-Riley Model

Chamber Studies

A musician will enter our aerosol testing chamber using appropriate social distancing, masks, gloves and other lab protocols as needed for maintaining a clean, infection-free environment. A flute, clarinet, and trumpet player will be initially recruited for the study. Once in the chamber the player will initiate a set series of notes at both a soft and loud volume. A stainless-steel cylinder will direct the emitted flow from the end of the instrument to the sampling ports located in the wall of the chamber. These ports are connected to our aerosol instrumentation.

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We will measure particles between 10 and 420 nm with a scanning mobility particle sizer and between 300 nm and 20 mm with an aerodynamic particle sizer. An ultrasonic spirometer will be used to measure the mean flow volume of breath into the instrument by the musicians. Each measurement will be repeated at least 10 times. In between each experiment and prior to any testing the air in the chamber will be purged with particle-free air, and also cleaned using a HEPA air cleaner to reduce the background particle concentrations as low as possible.

In addition to the above measurements, which will provide baseline aerosol emissions information, we will also investigate interventions to reduce potential exposure and risk. These include plastic shields at the end of the instruments or the use of a music stand to block the aerosols.

Flow Imaging

Once the chamber studies collecting baseline aerosol data have been completed, qualitative imaging will be used to estimate the emission of >1-micron aerosols from playing the flute, clarinet and trumpet. These studies will take place in our aerosol testing chamber. Initially schlieren imaging will be used to see the warm exhalations from the musician through the instrument and get an overall understanding of relative airflows from the instrument bell, fingerholes, fipples and the musician's nose and mouth. Next, laser light sheets will be placed perpendicular to the principal flows; micron and larger droplets scatter the laser light, and these images will be recorded with a high-speed video camera. These recordings will then be used to align the laser sheets in the plane of the principal flows so that the particles travel along the sheet. These resulting data have the potential to be analyzed for velocity fields, but in any case, should qualitatively indicate the direction and magnitude of the particle laden jet motion. In the event that insufficient aerosols for imaging are emitted, stage fog in the area of the musician will be used instead.

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Field Rehearsal Studies

Another goal of this study is to assess the potential impact of aerosol generation in a rehearsal room with multiple players, in a more realistic scenario. The ability to proceed with this part of the study depends on whether the research team as well as university officials think we can proceed safely. This would be ideal so that we can better understand the impact of dilution ventilation in real practice spaces and also to test the loading of aerosol in a larger space along with the impact of interventions. Methods similar to those used in the aerosol chamber study will be applied.

Modelling and Data Analysis

Data analysis will be conducted after every experiment to assess the success of the measurements as the study progresses. Particle size distributions will be generated, and standard aerosol data methods will be used. Emission rates will be estimated using the material-balance method. The Wells-Riley model will also be explored to estimate the probability of infection (P) assuming the instrument player is infected (equation 1):

$$P = 1 - \exp\left(-\frac{Iqpt}{Q}\right) \qquad \text{(equation 1)}$$

Where I = # of infectors, p = pulmonary ventilation rate of a person, q is the quanta generation rate, t is the exposure time interval, and Q is the room ventilation rate with clean air. The quanta are usually estimated epidemiologically from outbreak cases; in this application we would use the particle generation rate and assume roughly 1 virus per particle, and that 0.1% of all viruses are infectious. This modelling would provide opportunities to explore how room ventilation rates would impact infection risk, as well as reducing the generation rate through interventions.

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Summary

The risk of COVID infection from droplets and aerosols generated by playing band instruments could be significant. This study is needed to better understand potential risk and how to mitigate the risk so that musicians can return to playing and music students will be able to continue playing in school bands, practicing and performing.

References

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Budget

	Principal Investigator:	Shelly Miller			Title:	Aerosol generation from playing band instruments and risk of infectious disease transmission	
	Co-Principal Investigator(s):	Marina Vance					
		Jean Hertzberg					
					Duration:	06/01/2020 - 12/31/2020	
					Year 1	Year 2	Total
Category	**A. Salaries and Wages**						
	PI: Shelly Miller						
Regular Faculty	100% time, 0.25 months, Summer				3,632	0	3,632
	Co-PI: Marina Vance						
Regular Faculty	100% time, 0.25 months, Summer				2,926	0	2,926
	Co-PI: Jean Hertzberg						
Regular Faculty	100% time, 0.25 months, Summer				3,330	0	3,330
	Graduate Research Assistant						
Graduate Research Assistant	50% time, 4.5 months, AY				12,515	0	12,515
Graduate Research Assistant	100% time, 2.5 months, Summer				13,500	0	13,500
	Total Salaries and Wages				35,903	0	35,903
	B. Fringe Benefits			***Rate***			
Regular Faculty	PI: Shelly Miller			*28.40%*	1,031	0	1,031
Regular Faculty	Co-PI: Marina Vance			*28.40%*	831	0	831
Regular Faculty	Co-PI: Jean Hertzberg			*28.40%*	946	0	946
Graduate Research Assistant	Graduate Research Assistant			*12.00%*	3,122	0	3,122
	Total Fringe Benefits				5,930	0	5,930
	Total Salaries and Wages and Fringe Benefits				41,833	0	41,833
	C. Capital Equipment						
	Total Capital Equipment				0	0	0
	D. Travel						
	Total Travel				0	0	0
	E. Participant Support						
	Total Participant Support				0	0	0
	F. Other Direct Costs						
	Materials and Supplies						
Materials and Supplies	Lab Supplies				10,000	0	10,000
	Other Direct Costs						
Tuition	Tuition Remission (F&A Exempt)		*No. GRAs*	*No. Semesters*	7,917	0	7,917
	Total Other Direct Costs				17,917	0	17,917
	G. Total Direct Costs				**59,750**	**0**	**59,750**
	Total Direct Costs less Sub F&A (for NIH)				59,750	0	59,750
	MTDC Base	*Number of Subs:*		*0*	*51,833*	*0*	*51,833*
	***update MTDC formula as applicable for each year if subaward costs are less than $25,000 in Year 1*						
				IDC Exclusions	*7,917*	*0*	*7,917*
	H. Facilities and Administration (F&A) Costs						
	On Campus: MTDC Base						
	Predetermined for 7/1/14-6/30/15:			53.00%			
	Predetermined for the period 7/1/15-6/30/16:			53.50%			
	Predetermined for the period 7/1/16-6/30/18:			54.00%			
	Provisional thereafter per HHS agreement dated 7/8/19.				27,990	0	27,990
	I. Total Costs				87,740	0	87,740
	Total Amount Requested:				**$87,740**		