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RESEARCH ARTICLE

Small Viral Particle Aerosol Transmission of SARS-CoV-2, Influenza A and Measles: Dual Pandemics, Outbreaks and Public Health Protection with the Use of Face Shields and Face Coverings

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Abstract

As the Covid-19 pandemic (SARS-CoV-2) continues to spread globally, the influenza virus circulates in communities capable of causing significant morbidity and mortality. Further, measles outbreaks are common events as well and may trail right behind the coronavirus that causes Covid-19 and the influenza virus. Recent aerosol studies have now demonstrated that respiratory pathogens less than 5 micrometers are able to be transmitted from human-to-human capable of causing great morbidity and mortality than ever experienced with a single pandemic. Healthcare systems and communities must be prepared to respond to all three infectious respiratory viruses that could inflict much greater illness and death than ever experienced with a single disease. This paper discusses the viruses, their disease burden to the community, and the recommendation on the routine use of face shields with face coverings (masks) to protect individuals from acquiring the viruses or spreading them into the community.

Keywords

SARS-CoV-2, Covid-19, Influenza virus, Measles virus, Aerosol transmission, Small particle (< 5 micrometers), Respiratory droplets and aerosols, Face shields, Face coverings (masks)

Introduction

With a possible second wave of SARS-CoV-2 that causes Covid-19 or sustained transmission this Fall and Winter, dual pandemics with seasonal influenza may occur simultaneously. Further, outbreaks of measles cases are common during the Winter months from global travel. Such a scenario is unimaginable as the influenza and measles viruses can cause great morbidity and mortality independent of each other. Many questions remain unanswered about how severe the presence of the influenza (and measles) virus will impact the SARS-CoV-2 pandemic. But one thing is certain, vaccination of both the influenza and measles viruses will decrease the burden of SARS-CoV-2 infection.

Healthcare systems and communities in the United States must be prepared to respond to all three infectious respiratory viruses that could inflict much greater illness and death than ever experienced with a single epidemic. This paper reviews the three viruses and their burden of disease to the community via respiratory droplets and small particle aerosol transmission (Table 1). Because of the infectiousness of each viral disease, the author recommends the use of face shields with face coverings to mitigate viral respiratory disease transmission. This paper will not discuss testing for the coronavirus, or the use of other non-pharmaceutical intervention measures as many papers have already been published in detail about these two issues.

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Table 1: Virus Characteristics.

Characteristics	Covid-19	Influenza A	Measles
Transmission Route	Respiratory Fomites Oral-Fecal	Respiratory Fomites Oral-Fecal	Respiratory
Level of Infectivity	Very contagious	Less contagious	Severly contagious
ncubation Period	2-14 days (median 5.1 days)	1-4 days (median 2 days)	10 days to onset of fever; 14 days to onset of rash
Risk Factors	Advanced age, chronic heart, lung, liver disease; immunocompromised; pregnancy; ethnicity; poverty	Risk factors similar to Covid-19	Malnutrition, vitamin A deficiency,
Clinical Signs & Symptoms	Fever, cough, chills, myalgia, fatigue, shortness of breath, loss of taste, smell, diarrhea	Fever, cough, chills, myalgia sore throat, nasal congestion	Generalized maculopapular skin rash, fever, cough, rhinitis, conjunctivitis, Koplik spots on mucosa of cheeks otitis media
Onset of Clinical Symptoms	Symptoms peak during 2nd to 3rd week of disease	Symptoms peak during 3rd to 7th day of illness	Prodromal phase 2-4 days of fever. Rash develops 2-4 days after fever. Koplik spots appear 1-2 days before onset of rash
Reproductive Number	2 to 4	1.5 to 2	9 to 18
Case Fatality Rate	0.25% to 3.0%	0.10%	< 0.01% to > 5% > 5%, may increase to 20-30% in refugees
Diagnostics	PCR testing, serologic testing	PCR testing	Detection of IgM antibodies, PCR testing
Antiviral Drugs	Nucleoside analog (Remdesivir)	Neuraminidase inhibitors, endonuclese inhibitors, M2 channel blockers	None
Vaccine	Yes	Yes	None

Infectious Small Particle Aerosol Transmission

It has always been questionable that viral transmission causing respiratory infections is from respiratory droplets less than 5 micrometers in size. However, it has recently been demonstrated that the coronavirus can be spread not only by respiratory droplets (> 5 micrometers) that fall to the ground by the forces of gravity within 3-6 feet of the individual, but also by aerosol (< 5 micrometers) and fomite transmission [1,2]. Moreover, the coronavirus can remain viable and infectious in aerosols for hours and on different surface tops for days [3].

Infectious aerosols are pathogens suspended in air and because of their small size and the ability to remain suspended in air for hours they are capable of colonizing and infecting the lower respiratory tract of the lungs. For SARS-CoV-2 to become infectious and cause acute respiratory distress syndrome (ARDS), it must invade the lower lung fields as it has been associated with a cytokine storm syndrome [4-6].

Normal breathing, sneezing and coughing consist of mucous containing salivary droplets contained in a multiphase turbulent gas cloud (puff) that traps and transports clusters of pathogenic respiratory droplets that can travel up to 27 feet in the air [7-9]. Respiratory droplets that remain within the cloud will evaporate producing residues or droplet nuclei (aerosol particles < 5 micrometers) suspended in air for many hours that are able to mix with airflow patterns of ventilation or climate control systems. As the turbulent gas cloud can remain in the air for hours, and air sampling has detected both coronavirus and influenza RNA particles, the use of face coverings and face shields are recommended for source control (decreasing the spread of infectious pathogens) and protecting the user (preventing the spread to others nearby) [1,10,11].

Exhalation breath and cough studies using polymerase chain reaction (PCR) testing to evaluate viral RNA genetic material consistently demonstrated viral particles less than 5 micrometers in size that included the influenza virus, human rhinovirus and respiratory syncytial virus. Bacteria were also detected with PCR testing of breathes during exhalation and included *E. coli*, *H. influenzae*, *P. aeruginosa*, *S. aureus*, and methicillin-resistant S. aureus [12-16].

Although the bacteria that causes tuberculosis was not detected in exhaled breath samples, it was detected in two face masks samples. In a study consisting of 78 patients, *M. tuberculosis* was detected in 86% of face mask samples compared to sputum samples [17]. Respiratory viruses and bacteria detected during exhalation and coughing may explain why asymptomatic individuals are infectious and capable of airborne viral transmission and why the author of this paper recommends the universal use of face shields with face coverings (masks) when out in the community [18].

Respiratory viruses have also been detected in hospital room air samples [19,20]. Using PCR testing, small viral particles less than 4.7 micrometers in size such as varicella-zoster virus, influenza virus and measles virus were detected, including the bacteria that causes tuberculosis, *M. tuberculosis* [21,22]. Such infectious aerosols are highly contagious and the possibility of airborne transmission in closed rooms with people during various community functions is possible. Very little data is available for the 2003 SARS-CoV-1 pandemic regarding air sampling studies [23,24]. However, air sampling in Toronto by PCR testing for viral RNA genetic material discovered SARS-CoV-2 that is the etiology for Covid-19. Such air sampling studies has also been detected in hospitals in China and the United States [1,3,25].

Asymptomatic Patient

There is very little information regarding the infectiousness of asymptomatic patients. In a retrospective study of 303 patients, Lee, et al. using PCR testing compared viral load of both asymptomatic and symptomatic SARS-CoV-2 infected patients in a community treatment center [26]. Evaluating cycle thresholds, they concluded that the viral load of asymptomatic patients (80.9%) was similar to symptomatic patients. With high viral load, viral shedding may be prolonged which suggest that the asymptomatic patient could be a super spreader for the coronavirus.

In a study by Zou and colleagues [2], they also reported that viral load in asymptomatic patients infected with the coronavirus was as high as infected symptomatic patients. It was also shown that viral shedding was detectable in sputum samples in SARS-CoV-2 infected patients that were symptom-free [27]. Based on these studies, asymptomatic individuals that circulate in the community have the potential to act as stealth coronavirus super-spreaders. To mitigate potential viral transmission from this cohort of infectious individuals will require isolation of these individuals and quarantine of all others who came into contact with them.

Disease Transmission

Mitigating the transmission of any infectious disease that may progress to a pandemic requires an understanding of the potential disease transmission of the pathogen [28-30]. The basic reproductive number (R_0) is an important epidemiological parameter that will allow clinicians and public health authorities to understand the epidemiological characteristics of a pandemic [31,32]. The reproductive number (R_0) is the average number of secondary cases produced by an infectious case in a susceptible population without intervention [33]. Calculating the R_0 is a very important epidemiologic metric as it allows a comparison between infectious diseases regarding the ability to be spread in a population.

An R_0 greater than 1 represents a disease that will be difficult to slow down and will spread rapidly in the community. A R_0 of less than 1 will not progress to a pandemic and will decay. The median R_0 of influenza has been reported to be between 1.5 to 2 and is not very contagious compared to measles, which has an estimated R_0 of 9 to 18 and is thus, extremely contagious. The R_0 of SARS-CoV-1 was approximately 1.7 to 1.9, while it is estimated that the R_0 of Covid-19 is between 2 and 4, with a median of 2.79 [29,30,34]. Guan et al. estimates that a R_0 between 2 and 3 correlates to a high pandemic potential where each infected individual can spread the virus to two or three other individuals [35].

Disease Burden and Treatment

Several vaccines are awaiting approval from the Food and Drug Administration in the management of the SARS-CoV-2 pandemic. However, the experimental intravenous antiviral drug, remdesivir received Emergency Use Authorization to treat patients hospitalized with severe coronavirus infection from the Food and Drug Administration (FDA, 2020 May 1). As of this writing, there have been three randomized clinical trials (RCTs) that compared a 10-day course of remdesivir. Reported results differed by each study [36-38]. Spinner and colleagues [38] also randomized a cohort to a 5-day course of remdesivir. Patients in the 5-day clinical course of remdesivir had a significant improvement in clinical outcome compared to patients receiving standard supportive care.

Several influenza viruses have caused pandemics in the 20th century (1957 H2N2 Asian flu; 1968 H3N2 Hong Kong flu; and 2009 H1N1 swine flu). But all pandemics are measured against the H1N1 Spanish influenza pandemic of 1918-1919. Over 500 million individuals were infected, and 50-100 million people killed around the globe due to sustained community spread [39-41]. It is estimated that 675,000 deaths occurred in the United States. Mortality was highest in young adults, aged 24-40 years possibly due to cytokine storm syndrome [4].

Avian influenza is a global threat to humans as its virulence and ability to mutate as a likely virulent pathogen has the potential for great morbidity and mortality. Humans are immunologically naïve to these strains (H5N1 and H7N9) that have the potential to undergo antigenic shifts or mutate and cause a pandemic [42,43]. In 2013, the H7N9 strain from infected poultry caused severe respiratory infections in humans in eastern China and is a special concern to public health as having the greatest potential to cause a pandemic [44].

The highly variable genetic material due to antigenic drift of the genes that encode for the H and N antigens on the surface of the virus leads to mutations that results in outbreaks of seasonal influenza [45]. But, it is antigenic shifts that may arise from the reassortment of two different viruses that infect the identical host creating a novel influenza strain that leads to a pandemic. Human-to-human viral transmission occurs without the ability to create immunity and a pandemic arises as there is no vaccine to mitigate viral transmission [40,46].

In 2010, 12,000 to 61,000 deaths were reported in the United States [47]. In 2018-2019, 35 million influenza cases were reported resulting in 490,600 hospital admissions and 34,200 deaths in the United States [48]. Annual vaccination is the most important strategy in the prevention of contracting the influenza virus. Vaccination usually starts in August and continues through the month of January and later as the influenza virus is contagious. The Centers for Disease Control and Prevention recommends that individuals 6 months and older get vaccinated for the upcoming influenza season. Although all 50 states require childhood vaccinations as a condition of attending school, adult vaccination is not required. Vaccination coverage will decrease hospitalizations and deaths during the influenza season while Covid-19 continues to circulate in communities across the United States [49]. Vaccination can decrease the risk of influenza-related illness 40-60% when the vaccine is well-matched to the influenza A virus [50].

Differentiating between Covid-19 and influenza infection is extremely important. Patients infected with SARS-CoV-2 and mistakenly believe they are suffering from the influenza virus may not place themselves in isolation to prevent viral transmission in the community [47-49]. As symptoms for both viral diseases are similar, testing for SARS-CoV-2 and influenza will be important. For patients infected with the influenza virus, treatment is available. There are four antiviral medications in the United States for treatment and chemoprophylaxis of the influenza virus: oseltamivir phosphate (Tamiflu); zanamivir (Relenza); peramivir (Rapivab) and baloxavir marboxil (Xofluza) [50].

Although measles was declared eliminated in the United States in 2000, measles remains endemic in many parts of the world [51]. Measles is a recognizable and highly contagious disease that causes a febrile illness typically observed in young children [52]. It is a single-stranded RNA virus that is easily transmitted by inhalation of respiratory droplets and aerosols that can float in the air for hours [53,54]. The virus is also transmitted by direct surface contact [55].

Measles outbreaks usually occur during the Winter and Spring months facilitated by closed environments such as homes, health care facilities and especially socializing among students at school [56]. Globally, it is estimated that 7 million cases of measles are diagnosed annually [57]. In 2017, there were 109,000 deaths world-wide from the measles virus [55,57]. Unvaccinated people have a 90% chance of becoming infected when exposed to a measles infected carrier. With a basic reproduction number (R_0) of 9 to 18, each case of measles has the potential to spread to 9 to 18 other people in an unvaccinated and susceptible population [55,58]. Therefore, a single case of measles could result in a large outbreak should the virus enter a community where vaccination coverage is below to establish herd immunity [59]. In one school in New York City, an unvaccinated student with measles transmitted the measles virus to 25 other students. Such super-spreading event resulted in measles being transmitted beyond the school into the community.

Periodic measles outbreaks are a constant threat to the United States due to travel-related international importation [57,60]. In New York City, importation of measles occurs on a regular basis due to global air travel from Europe [61]. The most recent outbreak in New York City occurred in 2018 and was the largest measles outbreak in the United States since 1992 [59,62]. From January 1 to April 26, 2019, 704 cases of measles were reported in 22 states [60]. The median patient age was 5 years (1-year to 18.5 years). Countries of importation included the Philippines, Ukraine, Israel, Thailand, Vietnam, Germany, Russian, United Kingdom and India.

Measles and deaths from this contagious virus can be prevented with vaccination to obtain herd immunity in the community. Before the introduction of the measles vaccine in 1963, over 30 million cases and greater than 2 million deaths occurred annually [63]. Since 2000, measles vaccination has prevented over 21 million deaths globally [57]. Measles vaccination is often combined with live attenuated vaccines containing rubella and mumps (MMR) that will provide life-long immunity and up to 97% herd immunity. Measles elimination from the population requires two doses of the vaccine at 12 to 15 months and 4 to 6 years of age [51,52,55].

To interrupt measles transmission does not require immunity in all individuals in the community [64]. It is estimated that 89-94% of the population needs to be immunized or exposed and recovered from measles to obtain herd immunity (the percent population needed to stop measles transmission) [52,55,57,59]. The vaccine is also recommended prophylactically to people who have not had the vaccine and exposed to the virus within 72 hours of exposure.

Face Coverings (Masks) and Face Shields

There is a paucity of evidence on the efficiency of various cloth masks and their ability to filtrate particles of various sizes to protect the public from respiratory viruses, including Covid-19 [65,66]. The limited data of evidenced based science has created controversy and disagreement among public health policy administrators regarding the universal wearing of face coverings. The confusion was further sparked by the World Health Organization (WHO) recommending against the wearing of face coverings because of the lack of evidence of protection against the coronavirus [67,68]. Cloth masks have been shown to be less effective than medical masks used by healthcare personnel in the prevention of transmitting and acquiring respiratory viruses and other microbial pathogens [69]. Moreover, poor-fitting masks due to gaps between the face and masks severely affects the efficiency of protection for the user.

The Center for Disease Control and Prevention recommends the use of face coverings when out in public for source control, as speaking and coughing results in a combination of both respiratory droplets and aerosols of all sizes [70]. Respiratory secretions are capable of traveling 27 feet and remain suspended in air transmitting respiratory infections to others [8,71]. Other respiratory viruses have also been shown to remain suspended in air for hours after sneezing and coughing, including the influenza and measles virus [72].

Although cloth masks are less effective than medical masks for preventing communicable respiratory diseases, in an in-vitro study cloth masks demonstrated the ability to provide some filtration protection of aerosol particles less than 5 micrometers in size [69]. The policy of universal masking in a health care system was associated with a constant decline in the number of reported Covid-19 positive tests [73]. Face coverings have been shown to reduce the detection of influenza virus RNA in respiratory droplets and SARS-CoV-2 RNA aerosols [74]. Recently, Wang, et al. demonstrated that universal masking in both healthcare personnel and patients can reduce coronavirus transmission [73].

Respiratory aerosols that contain viral particles less than 5 micrometers in size are the primary source of disease transmission in respiratory infections [1,75,76]. As the coronavirus sheds at high concentrations from the nasal cavity before the onset of symptoms, asymptomatic or presymptomatic individuals could be potential super-spreaders of the stealth coronavirus as they are indistinguishable from healthy individuals in the community [70]. It has also been demonstrated that the coronavirus could be detected on the outer surface of both surgical and cotton face masks for up to 7 days increasing the risk of viral infection to others [77,78]. Masking to cover the oral cavity and nose may provide protection from inhaling any pathogenic microbes and source control to protect other people from exposure to infectious microbes expelled during respiration [1,76].

As a result of these recent findings regarding small particle aerosol respiratory transmission, the author recommends the simultaneous use of plastic face shields with other personal protective equipment (PPE) to reduce viral transmission in the community. In a study of community health workers assigned to counsel asymptomatic individuals exposed to SARS-CoV-2 infected family members, the authors concluded that the use of face shields resulted in protection of viral transmission [79]. Implementing face shields with traditional non-pharmaceutical intervention measures and PPE such as face masks, gloves, shoe covers with good hand washing found no SARS-CoV-2 infections among community health workers based on self-reported symptoms and weekly polymerase chain reaction (PCR) testing. Use of a face shield may change the trajectory of viral transmission around the face shield instead of directly to the face. Such additional protective barrier effectively reduced the R_0 to less than 1.

In a simulation study by Lindsley et al. [80] the use of face shields was able to decrease the amount of inhalation exposure of the influenza virus by 96% when coughing 18 inches away. The protective effect of face shields even after 30 minutes was evident as 80% of the virus was prevented from contacting the user. At physical distancing of 6 feet, face shields reduced viral exposure by 92%. This study also demonstrated the importance of physical distancing in preventing viral transmission.

Conclusion

The potential of a pandemic developing depends on the virulence of the virus and its transmissibility in the community. Individuals infected with any of the three viruses presented in this paper are extremely contagious and can release a high viral load when talking, sneezing and coughing. It is now established that small viral aerosol particles 5 micrometers or less in size can remain suspended in air for several hours and inhaled effectively reaching the lungs causing severe illness and potentially death. Therefore, the author recommends the universal use of face shields and face coverings with other personal protective equipment to reduce viral transmission and provide protection for all individuals.

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