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EDITORIAL

A physics-based mathematical model to understand the aerosol transmission risk of COVID-19

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Assessment of risk of transmission is an important preventive medicine issue when a patient is identified as having COVID-19 infection. Understanding this risk particularly in the early phase of infection is very important to formulate public health policies in the community. The factors influencing the airborne spread are not completely understood and hence assessment of risk of transmission continues to be a challenge to the medical community. The challenge stems due to the fact that the risk of transmission is influenced by complex inter-related factors that involving virology to fluid-dynamics of the aerosol. Recent research, demonstrating the air-borne transport as the most important mechanism for disease transmission, has significant implications to the practice of preventive medicine. The foremost of the various metrics to quantify the risk of transmission for a COVID-19 patient is the - viral load – a quantitative measure that will assist the clinicians in choosing the viable therapies for the patient. By definition, the viral load is the amount of virus produced in someone's body after they are infected. In this report, an engineering approach to determine the number of the infected virus particles that a person is exposed to due to the air-borne spread of the disease from a symptomatic patient is discussed, and the relevance to clinical protocols is hypothesized [1]. In this commentary, the viral dose - how much virus someone is exposed to when they are infected – is used as a metric to quantify the spread of the infection.

A symptomatic patient with cough or sneeze, releases respiratory droplets that contain infectious virus particles. In the past decade, there have been a number of studies that clearly indicated that for person infected by respiratory disease, such as influenza, releases a cough-jet with a high number of infective particles. The average number of particles expelled by each cough for an infected patient can range from 900 to 302,200 [2]. Furthermore, these particles have a wide range of sizes, with different transport characteristics. Heavier particles slump quickly and are not transported, however, lighter particles (less than a micron) are buoyant and they ride the air currents. Ongoing research on coronavirus has suggested that the cough-jet of a corona-infected patient could consist of aerosols, small particles suspended in air; these particles can survive in the air for several hours [3].

A recent study demonstrated that COVID-19 can live up to 4 days depending on the surface; the life span on cardboard is 24 hours, on plastic 2-3 days, and on glass 4 days [3]. It is very likely that the virus has a similar time frame for survival on the ground outdoors.

Engineering and scientific studies based on robust mathematical models have proven that virus particles released from cough jets are transported by circulating air. The air-borne transmission in enclosed spaces, such as airplanes, residential areas, can extend up to a distance of 6 ft from the infected person. More recently, a landmark study by this author shows that with combination of weather conditions, including, light winds with low gusts, and for a stable atmospheric conditions such as morning time or late evenings, the virus particles disperse in air up to distance 18 ft before they get completely diluted by the air-currents [1]. The study was conducted by solving close to 100,000 simultaneous mathematical equations based on scientific laws of physics to obtain the solution of the number of virus participles as a function of space and time and the real-time wind velocity, direction, air-temperature. The accuracy of a numerical model is driven by certain assumptions with respect to properties of the virus particles that are released into the space. The important of these assumptions are the size and shape of the particles, the half-life of the particles and the number of particles released during the expectorant event. The assumptions have been obtained from the results of other recent studies. Based on these, the released particles are spherical in shape, with a diameter of 0.125 μm and a density of 1.7 g cm^{-3}. The half-life of released particles is about 30 minutes and a total of 90,000 particles are released into the atmosphere during cough. The infected particles that are light (smaller than few microns), due to the buoyancy forces mix with the air-circulations and propagate spatially, and the extent of this propagation is based on wind speed, air temperatures and stability of the environment.

The significance of above analysis is that the infected particles that have the propensity to propagate spatially are of size less than a few microns, and these small particles, are very likely to be deposited in the lower respiratory duct. Infection control guidelines indicate that "few pathogens such as *Mycobacterium tuberculosis*, are particles sized 5 μm or smaller that are deposited in the lower respiratory duct" [4]. It is very likely that the manner in which infection enters the body of an exposed individual by air-borne spread of COVID19 is similar to that of such pathogens [4]. There is strong indication that it is the smaller sized particles that have contributed to the spreading of the infection to the exposed individuals through air-borne route and resulting in the super-spreading of the disease.

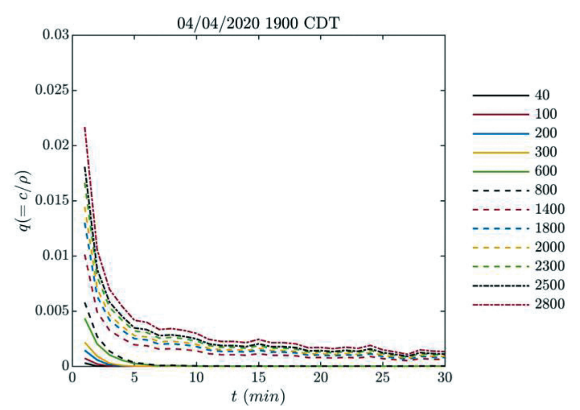

Figure 1: The fraction of the viral dose that persists as a function of time (from the time of release) for different initial number of released particles.

Studies have linked the number of particles released by an infected person to the severity of the disease [5]. Figure 1 simulates the varying load of particles released by the expectorant (i.e. cough) of patients with varying severity of infection. The number of particles is varied from 40 particles/sec – 2800 particles/ sec released per cough event. For severe infections i.e. for the case of 2800 particles/sec, after 5 minutes the exposed individual has 0.5 % of the original viral dose, whereas, for the intermediate cases i.e. for the case of 1400 particles/sec, the viral load is only 0.025% of the original value. For very mild cases, the dispersion rate is very high and viral dose drops to a negligible value very quickly. The results indicate that for severe and moderate infection levels, the significant amount of viral dose is transmitted through air-borne route for a longer distance and lingers on for a longer period of time.

In summary, the scientific analysis which sheds light on the possible mechanism of the spread of COVID-19 has significant implications to clinical management and protocols. In particular, the infected particles that are transmitted are small-size particles with less than a few microns in size. Symptomatic patients with severe and medium degrees of infection release infected particles that are transmitted through air-currents with non-trivial viral dose for up to 5-10 minutes after the release of the expectorant. This mathematical analysis strengthens the scientific basis of quarantine policy of patients with moderate and severe infections. It also emphasizes the importance of using protective face masks and design of these masks to protect the individual from the small sized particles which seem to be clinically relevant.

Conflicts of interest

Author declares no conflicts of interest.

References

[1] Bhaganagar K, Bhimireddy S. Local atmospheric factors that enhance air-borne dispersion of coronavirus - high-fidelity numerical simulation of COVID19 case study in real-time. Environ. Res. 2020; 191:110170.

[2] Lindsley WG, Blachere FM, Thewlis RE, Vishnu A, Davis KA, et al. Measurements of airborne influenza virus in aerosol particles from human coughs. PLoS One. 2010; 5(11): e15100.

[3] Doremalen NV, Bushmaker T, Morris DH, Holbrook MG, Gamble A, et al, Aerosol and surface stability of SARS-CoV-2 as compared with SARS-CoV-1. N Engl J Med. 2020; 382(16):1564–1567.

[4] Fennelly KP. Particle sizes of infectious aerosols: implications for infection control. Lancet Respir Med. 2020; 8(9):914–924.

[5] Liu Y, Yan LM, Wan L, Xiang TX, Le A, et al. Viral dynamics in mild and severe cases of COVID-19. Lancet Infect Dis. 2020; 20(6):856–657.