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Washing hands and the face may reduce COVID-19 infection

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ABSTRACT

The contribution of various modes of transmission of SARS-CoV-2 has been the subject of recent intensive debate. The predominant route of the viral transmission is via exhaled droplets of different sizes which can be inhaled by nearby exposed individuals or deposited on peoples and surfaces. Touching contaminated surfaces followed by hand to facial transfer has been identified as a potential infection route. As humans involuntarily touch their faces over 20 times per hour a hand washing with soap and water is recommended to avoid hands to face transmission. To date however, there is no clear explanation how the viruses arrive form the face into the nose and the lung. Our hypothesis is that during the physiological nasal air inspiration the virion particles attached on the face close to the nose are resuspended in the air and then are inhaled into the nose. Our preliminary fluid dynamics simulations confirm our hypothesis. Further experimental and computational studies are warranted.

Introduction

A novel severe acute respiratory syndrome coronavirus (SARS-CoV-2) has recently emerged from Wuhan in China and spread into a worldwide pandemic into 216 counties with a total of 17 million confirmed cases and 668,910 deaths (as of July 30, 2020) [1]. As with the previous SARS and MERS coronavirus epidemics, SARS-CoV-2 causes respiratory tract infections with variable symptoms ranging from mild flu-like symptoms in children to severe pneumonia, even death for older population with underlying medical conditions such as diabetes, heart, lung, or kidney disease [2]. In spite of current limited understanding of respiratory viral transmission mechanisms, it has been generally accepted that exhaled bioaerosol particles are an important transmission vector [3,4]. Respiratory viral transmission routes include: large droplets generated by infected person's cough and impacting susceptible individuals and fomites, fine particle aerosols generated during physiological breathing and exhalation, touching contaminated surfaces followed by hand to facial mucosa contact, and potentially via fecal to oral or nasal transmission [2–4]. Although the relative importance between these modes of infection is highly variable with many unknown, we may guess that the final respiratory virus inoculation step occurs via nasal inhalation of virions from the surrounding air or from contaminated face. How virions are transmitted from the contaminated face to respiratory mucosa remains unknown. Moreover, it is not known what is the facial area from where the virus can enter the nose during normal breathing. This note attempts to explain the face to nose viral transmission process in a quantitate way using principles of fundamental physics.

Transmission of viral bioaerosols

Normal mouth or nose breathing continuously emits large number of small airborne droplets (less than 1 μm in size) which, due to buoyancy and convention, can float in the surrounding air for long periods of time and translocate to long distances [5]. On the other hand, coughing and sneezing last only a fraction of a second but creates a high-speed aerosol jets (~20 m/s and 60 m/s, respectively) carrying huge number of droplets with sizes varying from submicron to few millimeters [6]. The ejected droplets can impact other humans or settle on fomites at a distance between 1 and 2 m from the emitting person. The exhaled respiratory droplets contain a variety of biomolecules, mucins, as well as trapped viral payloads. Given the dimension of the coronavirus of ~120 nm, each cough or sneeze droplet can project huge number of viral particles on the surrounding targets, including facial areas of susceptible individuals. Because viruses can survive on fomites for a prolonged period of time [7–9] the susceptible individuals can also contaminate their hands and then deposit the viral particles on their faces. In fact, hands are considered a major vector for the transmission of healthcare associated infections [10,11]. If there are no viral aerosols in the air surrounding the susceptible person the only viral source is located on the subject's face previously contaminated by his hands.

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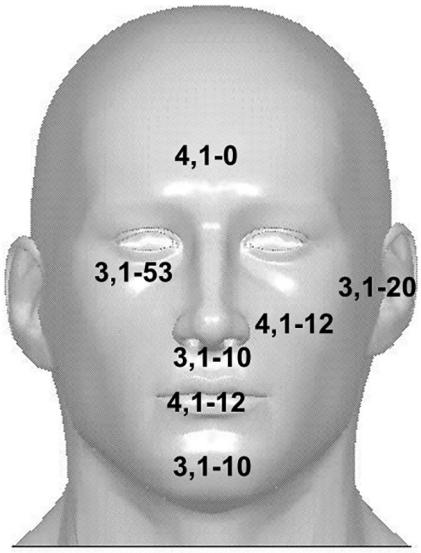

Fig. 1. Anatomical distribution of number of face touches and duration time range observed in a one-hour period [12,13].

Contaminated human face in the viral transmission path

Recent human behavioral observation studies reported that on average participants touched their faces between 17.8 and 23 times per hour [12,13]. Of all face touches, approximately 42–44% involved contact with the proximity of a mucous membrane. The relative percentage of facial mucosal touches are: 36% mouth, 31% nose, 27% eyes, and 6% face touches involving combination of the above [12]. Fig. 1 shows the spatial distribution of the frequency of face touched areas.

Enveloped viruses, such as influenza and coronavirus, may find human facial regions a favorable environment for survival, probably better than on others body parts, including hands, due to more oily, warmer and humid conditions on the face around the nose. At the same time the viral particles in the proximity to nostrils will also experience periodic reciprocal inhale/exhale convective flows generated by the physiological respiration process.

Simulation of face to nose viral transmission

The goal of our simulations is to determine the spatial distribution of wall shear stresses on the human face around the nose. High shear stress may be responsible of the viral particle resuspension from the face into the air and subsequent inhalation. We conducted 3-Dimensional (3D) Computational Fluid Dynamics (CFD) simulations of the air flow into the human nostrils during the inspiration period. A 3D anatomic geometry of a human face is used with two nostrils identified as inhalation flow boundary condition regions. The rest of the face is treated as no slip surface. A 3D rectangular box of the air surrounding the human face is used as a simulation domain.

An octree mesh of ~150,000 control volumes was constructed around the human face, nose and in the nostrils. All free boundaries of the box were described using extrapolated pressure boundary conditions. The transient laminar air flow is simulated by solving 3D Navier-Stokes and mass continuity equations using CoBi tools [14,15]. The goal is to determine the spatial distribution of wall shear stresses on the human face around the nose. It has been well documented that wall shear stress is directly related to particle re-suspension form a surface into the flow stream [16,17].

Fig. 2 shows the flow velocities close to the nostrils and contour maps of the wall shear stress on the face for a physiological breathing with flow rate of 0.4 L/min. The velocity flow pattern is typical for a potential flow drawing the air from the stagnant environment into the nostrils. Fig. 2 shows color maps of the wall shear stress, τ_w, on the human face defined as, $\tau_W = -\mu \partial \vec{v}_t / \partial n$ a product of air viscosity and tangential velocity gradient normal to the facial surface, non-dimensionalized by the maximum $\tau_{w,\max}$ value in the nostril entry. For better visualization, the nondimensional wall shear stresses on the human face are shown in two levels of magnitude: the higher level (0.01–1.0, Fig. 2a) and the lower (0.001–0.01, Fig. 2b). Note that the highest face surface shear stresses are located directly under and inside the nostrils. The lower shear stress level extends over a significant area of the human face. The wall shear stress is a driving force affecting particle re-suspension.

The facial area from where the viral particle can resuspend depends on the virion particle and facial skin physical status. Once resuspended from the skin into the air in the nasal vicinity the small virion particle will almost certainly enter through the nostrils into the lungs. Virus size nanoparticles, some containing virion agglomerates, can penetrate deep into the lung and deposit in the alveolar sacks. Quantitative prediction of the viral particle resuspension region is theoretically possible but

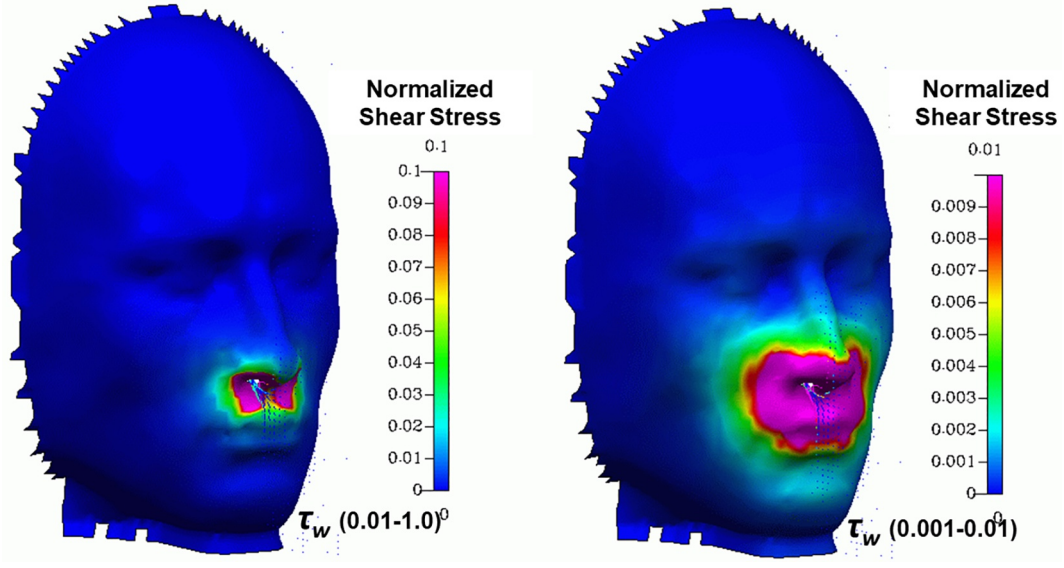

Fig. 2. Predicted contours of nondimensional wall shear stress, τ_w, on a human face during physiological air inspiration.

would require experimental data for model calibration.

Conclusions

The results presented here indicate that part of the human face close to the nostrils could be a source of viral self-inoculation. The amount of inhaled viral load depends on the accumulated facial surface coverage of particles and on the breathing flow rate. We believe that similar to hand washing, periodic cleaning of the facial area, shown in Fig. 2b could prevent viral self-infection. It is plausible that virion nuclei suspended in droplets on the face cannot resuspend. Hence, another more practical protection practice may involve periodic facial misting with water. To verify theses hypotheses further experimental and computational studies are warranted.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.mehy.2020.110261.

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