Don't Rebreath the Coronavirus: New Mask Designs

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A strategy to reduce COVID transmission is to wear a mask. However, for a person who is sick, wearing a standard mask can lead to increased rebreathing of viral particles. Here we consider designing masks to prevent rebreathing both when in public places, and more generally. We note that asymptomatic individuals may already be infected during a pre-symptomatic period. A non-rebreathing mask may be helpful for them instead of the usual masks.

Rebreathing coronavirus particles by an infected individual who exhales them may be harmful in accelerating COVID-19 progression. Infections initially occur due to inhaling coronavirus particles or touching the face. Once the infection is established in the nose or lungs, the virus replicates and particles are sneezed, coughed or breathed out. These particles are capable of infecting others, and can also be rebreathed. Disease progression is a competition between viral replication and elimination by the immune system. Rebreathing increases the amount of virus (viral load), and can add new locations of infection in the lung. This is like long range travel between communities in society. Indeed, CT scans show multiple locations of viral damage in the lung.* Since 80% of cases are mild, reduced rebreathing may increase this percentage, decreasing the number of individuals who progress to severe cases and the overall impact of this disease.

Among the ways to reduce rebreathing and other forms of exposure are the usual recommendations to breath fresh air, frequently wash hands, clean surfaces and wash laundry. HEPA air filters can also be helpful both during the day and at night. A targeted approach is to regularly breathe out in one direction and breath in in another, especially in the outdoors or through an open window.

Design requirements for a non-rebreathing mask include: Flows of air, filters and other means to reduce the likelihood that viral particles exhaled, coughed or sneezed by an individual are subsequently rebreathed.

We consider several types of mask design and implementation suited for different uses: (1) DIY improvised designs, (2) Homemade sewn masks, (3) Modifications of standard surgical or N95 masks, (4) Specially engineered masks. Each of these may be useful for different populations. Our purpose is both to point to principles and brainstorming of a few simple design ideas to fertilize the innovation process.

The central principle is to enable air flow in and out to pass through different channels that include filters. The inflow filter prevents infection from the outside, while the outflow filter prevents infection of others. The combination of both filters prevents rebreathing. Enhancements can include: (a) Directing the flow of air in and out in different directions. (b) A mechanism to kill viral particles, on the way out or in, using salt, soap or copper impregnated filters or pre-filter cages. If outflow and inflow are separated the use of a viral killing agent has less potential of harming the lungs. Enhancements may also be used independently to reduce rebreathing.

A key design question is whether outflow and inflow can be performed through both the nose and the mouth, which would require one way valves. An alternative approach separates the air to/from the nose and to/from the mouth. In this case, the individual would be instructed to consistently breathe in through the nose and out of the mouth, or vice versa. We note that because the receptors bound by the coronavirus have a high density in the nose [2], the first locus of infection is likely there. Breathing in through the mouth and out through the nose may be better than the usual opposite advice. The mask filter can substitute for the air filtering function of the nose. For non-rebreathing filters that use boundaries between nose and mouth breathing flows, the boundary should extend from the upper lip laterally far enough so air cannot flow around it.

- Improvised DIY —consider a homemade mask, scarf or bandana. After placing the mask on the face, a string or elastic can be tied around the head so that it rests on the upper lip. This string separates the air pocket of the mask between the nose and the mouth. Alternatively two fabric wraps can be for nose and mouth separately.
- Homemade mask—a mask with pleats and two pairs of ties for the top and bottom of the mask, can be modified to add a third pair of ties to one of the pleats to apply tension just below the nose.
- Surgical mask—use a pre-attached adhesive strip or double sided adhesive tape to stick the mask to the upper lip so that there are two separated pockets for the nose and mouth.
- Engineered masks—for modified N95 filters or designs based upon snorkeling masks, use one way air valves (check valves) with distinct filters or areas of the same filter for the outflow and inflow. Optimally the flow of air is highly directional so that incoming air and outgoing air do not mix, e.g. with inlet at the top and outlet at the bottom of the mask.

These ideas are ideas for brainstorming and actual implementations must be developed.

We note that some N95 respirator masks allow outflow of unfiltered air through valves, such masks should not be used for COVID-19 as the environment would be contaminated by pre-symptomatic individuals.

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References

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[2] Huang, S. COVID-19: Why we should all wear masks ? There is new scientific rationale, Medium https://medium.com/@Cancerwarrior/covid-19-why-we-should-all-wear-masks-there-is-new-scientific-rationale-280e08ceee71

*A reasonable question is whether the primary mechanism of spread is through inhalation or transport through the blood. Evidence on 9 hospitalized patients indicates that the virus eventually penetrates into the blood (seroconversion), but this occurred after 7 days for 50% of patients, and took up to 14 days for others [1]. Viral shedding in the airways continues throughout and begins prior to symptom onset.