A more perfect mask

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An important factor in the failure to limit the spread of COVID-19 early in the pandemic was confusion about how the virus spread from person-to-person. Emphasis was initially on transmission via touch – hence a massive focus on handwashing and sanitizing surfaces. While it rapidly became clear that transmission through the air was important, the significance of this transmission was slow to enter the public health discourse. Does the virus travel from an infected person to a healthy person in a visible spray of tiny drops ("droplets") or does an infected person exhale an invisible mist ("aerosol") of even tinier drops that remain airborne for hours, much like cigarette smoke? This distinction took time to unravel because people are often contagious even when they feel fine and don't show symptoms and, unfortunately, because of some amount of intellectual inertia on the part of public health agencies.

It is now clear that transmission by touch is likely a small contributor, and that the dominant mode of transmission is via aerosols and not through sprays of droplets flying between people. An infected person *does* produce a spray as they speak or sing, and especially when they sneeze or cough. But this mode of transmission is controlled with self-isolation by people with symptoms, and with social distancing together with the use of ordinary masks, which work both by inhibiting the larger drops exhaled and limiting similar sized inhaled drops. But mostly they suppress the air jets produced by speech or a cough or sneeze.

Aerosol transmission is *not* efficiently controlled by such means even as it is reduced. Infected people without symptoms create aerosols. Social distancing fails in poorly ventilated rooms where the aerosol can spread to you from anyone else in the room given enough time. Social distancing *does* work outdoors because the aerosol gets diluted by fresh air and blown away even by gentle breezes –transmission outdoors is rare.

What more can be done to protect against indoor aerosol transmission?

Indoor ventilation with cleaned air would be extremely useful – in homes and public settings, such as restaurants, where continuous masking is not possible. Even where this cannot be done, portable air purifiers could be used to direct streams of sanitized air to a user and we encourage the testing and use of such devices. Also, inexpensive aerosol monitors and carbon dioxide detectors can be used to assess air quality relative to fresh air.

For people at high risk for COVID-19 or whose work brings them in frequent contact with others, better masks are needed. We need masks that provide excellent filtration of aerosols, a very good fit against the face so that the aerosol can't leak in, *and* which are comfortable to wear for extended periods. N95 respirators, leaving aside their availability, do filter well the air inhaled through the

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mask but are uncomfortable for long periods of use, and many users have difficulty ensuring a tight seal with the face. They work well for medical professionals but are not user friendly.

There is a better solution – "civilian grade" powered air-purified respirator (PAPR) devices, which are the gold standard of protection in medical and pharmaceutical settings and may be familiar by sight to many. These devices use a fan to push air through a HEPA filter and into an N95, or equivalent, mask that sits snugly against the face. The inhaled air is filtered much better than any mask *even* if the mask fits imperfectly. Exhaled air in the PAPR is filtered through the mask itself, together with excess cleaned air flow, protecting others against a virus we may have. If the mask fits imperfectly, some air potentially exits without passing through the mask, but the overpressure between face and mask prevents *inflow* of aerosol-containing virus from the surrounding air. Moreover, the supply of fresh air reduces the sense of stuffiness. One of us recently wore such a device for 16 hours on an international flight and through the airports. We judge these PAPRs are an improvement over nearly all commonly used masks – even N95 masks -- they leave the user better off without making anyone else worse off.

Consumer-oriented PAPRs are readily available in the United States (see this and this) where we have bought them for personal use and for friends and family. A company in Delhi sells a similar product. Based on information provided by the manufacturers on tests conducted in China we estimate that these can provide better than N95 mask-level performance – more than 98% or better of the aerosol will be filtered out, making them 25 times less transmissive of aerosols than cloth masks where one might estimate about 50% efficiency. Thus, wearing a PAPR you could be equally safe for 25 times longer than when wearing a cloth mask. In settings involving shared spaces – transport, shopping, professional visits, and social visits – PAPR usage could return life to near normal for people without symptomatic disease.

These PAPRs are simple, effective, and inexpensive, and we urge their large-scale adoption by those older than 50 and by others in high-risk categories. Because they filter the air to be inhaled, protection is provided against all SARS-CoV-2 mutations *and* against other respiratory pathogens now and in the future. Making PAPRs standard equipment that people own and use as needed in "respiratory pathogen season" seems sensible to us. With vaccination programs under way, many countries may not need this help against COVID-19. Nevertheless, it may well be 2022 before everyone around the planet has access to the vaccines and even then there will be many at-risk who may find it problematic to take the vaccine or to generate the needed immune response because they have weakened immune systems.

Public confidence in PAPRs and similar devices would be boosted if laboratories in the United States would verify their performance on inward and outward airflow and filtering. We hope that can be done rapidly and published, together with much other data important to beating this pandemic. More generally, we urge the governments in major countries to develop a certification and standardization process for such devices. Additionally, we note that PAPRs using direct ultraviolet (UV-C) sterilization air supply to the mask may prove effective.

In the continuing efforts by governments around the world to quell this pandemic, it is essential to include physicians, epidemiologists, and scientists from a broad range of biological disciplines in

a focused and collegial fashion. It is essential also to tap information technologists and physical scientists and engineers if the management of this and future epidemics is to benefit from the full power of human talent in safeguarding public health.