What fluid dynamics can explain about COVID-19 spread—and how to protect yourself

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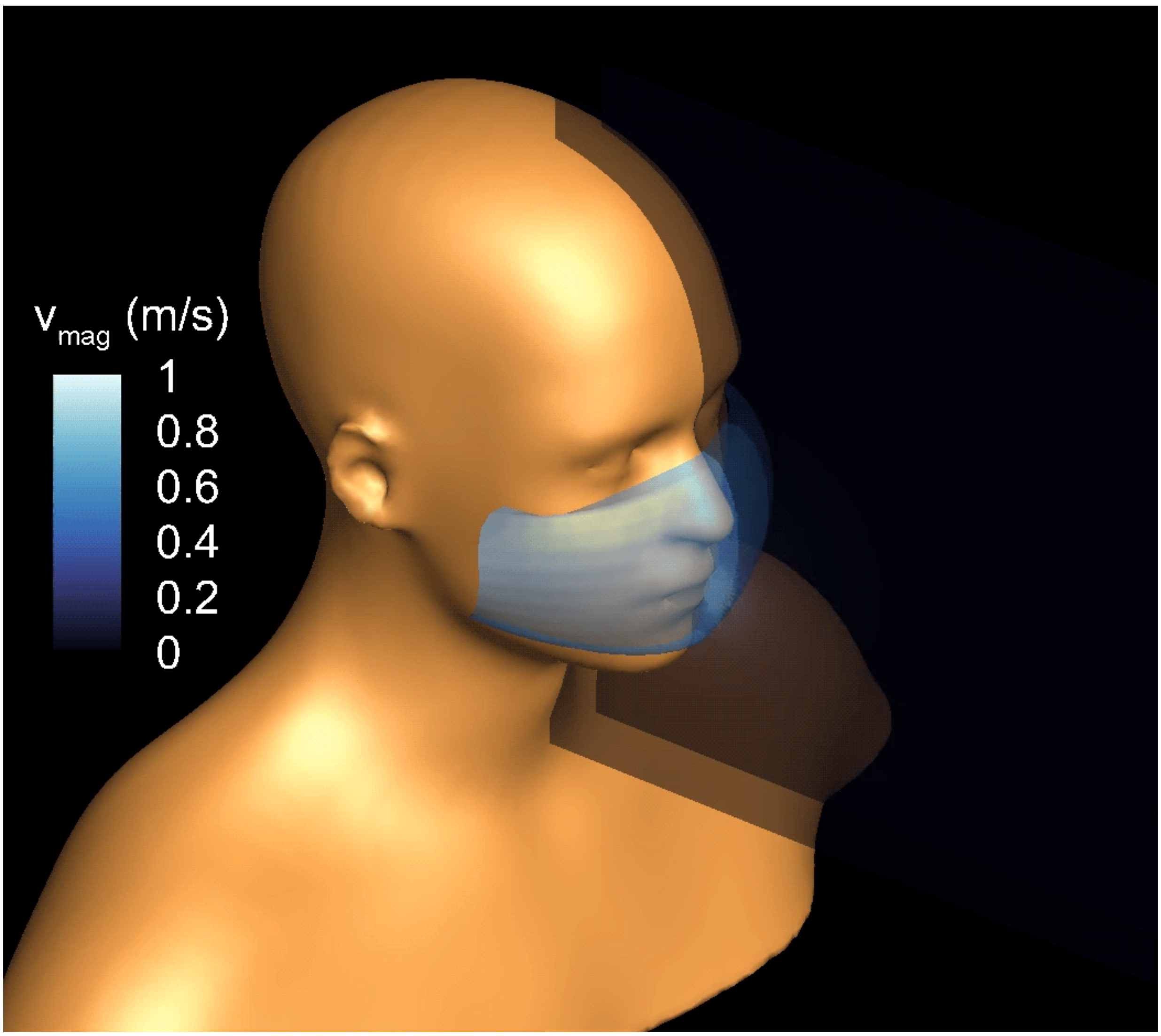

A computational simulation of a cough shows the airflow velocity of droplets moving through a simple face mask. Credit: Jung-Hee Seo

Public health advice for avoiding respiratory illness is largely unchanged since the Spanish flu of 1918, one of history's deadliest pandemics. Keep a safe distance from other people. Wash your hands frequently with soap and water to kill any germs you may have picked up. Cover your nose and mouth with a face mask—even one fashioned from a bandana will do. Such guidance is based on the understanding that respiratory infections spread through virus-carrying droplets that are expelled when infected people cough, sneeze, or breathe.

But more than a century after the Spanish flu killed 50 million people worldwide, how these fluid droplets behave remains largely a mystery. Rajat Mittal, a professor of mechanical engineering at the Whiting School of Engineering and an expert in computational fluid dynamics, believes further research into the flow physics of respiratory diseases will be key to containing the current coronavirus pandemic.

The idea occurred to Mittal during a recent visit to the grocery store, where he noticed shoppers wearing protective face masks. His mind went where researchers' minds usually go—to the science.

"I started wondering if there's any data out there about the aerodynamics of these masks to quantify what they are really doing," Mittal says. "As I started to dive into the literature, it became clear that fluid dynamics intersects with nearly every aspect of this pandemic. How droplets are formed and carried, how they infect others, the ventilators we use to treat patients with this disease, even preventive measures like face masks—many of these problems are ultimately related to fluid flow."

To help spur new thinking and research in this area, Mittal and a team of his faculty colleagues compiled an overview of the known fluid dynamics of COVID-19 and what questions remain. This report is published in the *Journal of Fluid Mechanics*.

Diving into droplets

Respiratory infections spread from person to person through virus-carrying droplets via airborne transmission or by contact with a surface contaminated by droplets. Infected persons often expel these droplets by coughing or sneezing—a telltale sign that others should steer clear to avoid infection. But transmission actually depends on a large range of factors, including the number of droplets, their size, and their velocity during expiratory events like coughing, sneezing, and breathing.

Sneezing, for example, can expel thousands of large droplets at a relatively high velocity, whereas coughing generates 10-100 times fewer droplets. Talking expels considerably fewer droplets still, about 50 per second, and they are smaller. These small droplets are more likely to suspend in the air, travel farther distances, and transmit infection once they are inhaled. Large droplets, on the other hand, are more likely to contaminate surfaces and transmit infection by touch.

As the team notes in the paper, many studies to accurately measure how droplets are generated and transported have already been conducted. However, consensus on droplet behavior remains elusive due to the complex nature of the phenomena, as well as the difficulty of making such measurements.

One area of interest for further research focuses on the formation of small droplets during normal activities such as breathing and talking. This may shed light on how COVID-19 is being transmitted by asymptomatic carriers who are talking or breathing normally.

"A hypothesis is that the virus is being carried by very fine airborne droplets," says multiphase flow expert Rui Ni, an assistant professor of mechanical engineering and a contributor to the paper. "Right now, we don't fully understand how this fine mist works in transporting the virus. And that has big implications for social distancing, if we are only basing those guidelines on an assumption that droplets can reach a certain distance."

In fact, one study cited in their paper shows that large droplets expelled from sneezes may travel 20 feet or more, so 6 feet might not be sufficient to eliminate the risk of transmission. According to the team, other issues that warrant deeper analysis are droplet evaporation and inhalation, how droplets behave in indoor versus outdoor environments, and how temperature and humidity affect transmission rates.

Simulating solutions

Containment strategies for COVID-19 are based on what policymakers think they know about flow physics. But Mittal and Ni caution that much of that is based on outdated information.

"We're advocating for better quantification, for really putting numbers behind these ideas," Mittal says. "Some of what we are doing now to combat COVID-19 in 2020 is based on science from papers published in the 1930s. We've learned so much since then, but policy needs to catch up."

For instance, even months into the pandemic, many questions still surround the use of face masks. Face masks are often designed to protect the person wearing the mask—think a construction worker trying to avoid inhaling dangerous dust, for instance. But face masks to combat COVID-19 transmission should offer both inward and outward protection, protecting others as much as it protects the wearer.

Scientists can better understand how to improve outward protection by simulating the flow leakage caused by gaps around the nose and mouth, says Jung-Hee Seo, associate research professor of mechanical engineering. He's working with Mittal and Koroush Shoele from Florida State University on state-of-the-art simulations to analyze air flow and droplet dispersion in face masks. Their simulations take into account different face shapes and mask structures, allowing them to evaluate the effectiveness of various mask designs.

The study is in its very early stages, but ultimately, these simulations could inform better designs for face masks, especially for those stitching masks at home, adds Mittal.

"If someone is making a face mask at home, can we tell them a simple step to make the face mask better at what it's supposed to do?" he asks.

Fluid dynamics in action

Like so many scientists—and policymakers and the public, for that matter—the team is already thinking ahead to a time when life will return to some sense of normalcy. They're wondering: How can that be done while still minimizing new transmissions?

Reopening decisions will benefit from new findings on the flow physics of COVID-19 transmission, the researchers say. "Think about students returning to a university campus. If we know more about the aerodynamics of droplet movement, we could potentially redesign HVAC systems to reduce the dispersion of droplets in a dorm, for example," Ni says. "The same idea could work with nursing homes. If we all wear masks, how does that affect the practice of social distancing? If we put more science behind this line of thinking, we can open the country in a safer way."

The new coronavirus is an evolving and complex challenge, and researchers in each discipline can address only a small aspect of the crisis. Still, Mittal sees a tremendous opportunity for those in the fluid dynamics field to contribute to a solution.

"This is front and center in our area of expertise," he says. "We can provide insights and tools that will ensure we are better prepared to tackle the next outbreak of COVID-19 or similar disease."

More information: Rajat Mittal et al. The flow physics of COVID-19, *Journal of Fluid Mechanics* (2020). DOI: 10.1017/jfm.2020.330

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