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Transmission of SARS-CoV-2 in schools

I am an engineering professor at the University of Colorado Boulder and an expert in engineering controls for mitigating airborne infectious diseases. I am one of the aerosol scientists that have been raising the alarm about airborne transmission since April. I was instrumental in helping open CU Boulder's campus safety this fall. We have had 50 cases of COVID-19 positive students in the classrooms and not a single case of transmission.

Respiratory Infections are transmitted between two people, when one is infectious and the other susceptible to infection. When the infected person breathes, talks or coughs they release a mist of particles made out of respiratory fluid that contain the virus. They can throw between 900 and 3 hundred thousand liquid particles from their mouth. These particles are less than 1 micron up to hundreds of microns in size. By comparison, the thickness of a human hair is about 100 microns.

Based on overwhelming accumulated scientific evidence, the main route of transmission is *airborne* or *aerosol transmission*. Some people think of an aerosol spray can of deodorant when they hear the word aerosol, but really an aerosol is just a bunch of particles suspended in air. Getting infected by this way could happen either when you are close to a person, called *short-range aerosol transmission,* and also when you are far from a person called *long-range aerosol transmission*. Animal studies, air sampling, and retrospective analyses of superspreading outbreaks show that SARs-CoV-2 is transmitted by breathing in aerosols.

SARS-CoV-2 is an over-dispersed pathogen, like SARS and measles. This means as few as 10% of people transmit 80% of the infections, and many people barely transmit. Most infections happen within households, where 1 or 2 other people may be infected within your own bubble. Also unique to SARS-CoV-2 is that many transmissions are *pre-symptomatic or asymptomatic,* so you literally have no idea who is infectious. People are most infectious right before they have symptoms of the disease.

To prevent infections, we must control both short-range and long-range airborne transmission. Short-range is what happens during close contact. If you are as close as 8 inches, then you can get infected by a spray of large particles landing on your face, but otherwise between 8 inches and 6 feet you will inhale the virus. Of course, these distances are not set in stone as particles can travel much further than 6 feet. But the point is that short-range exposure can happen when you are in someone's personal space. Someone who is very infectious yet showing no signs of COVID-19 may meet a few people for a short time or has dinner with the family, and shares the virus. This can happen in your home, your workplace, at a store, and almost always happens indoors.

Long-range aerosol transmission is how superspreading occurs, when you have a "series of unfortunate events" that happened all at once. A highly infectious person is indoors for a long time, shedding lots of virus, and there are also many susceptible people in the same space. The airborne virus begins to spread through the indoor space, and builds up to high levels, because there is poor ventilation, minimal surface deposition, possible strong air currents, and no air cleaning.

Why is this important? Because the way you minimize the risk is with different strategies. You will never prevent short-range aerosol transmission by applying engineering controls such as improving your ventilation or air cleaning. The only way to prevent it is by wearing a good fitting mask, staying socially distant from the person, quarantining upon possible exposure, and definitely when you start to show symptoms. The closer you are to someone, the more virus you will encounter, so try to stay at least 6 feet apart. This is why a national mask mandate is so important until everyone can get vaccinated.

To minimize the risk of long-range aerosol transmission and superspreading, we must treat this with ventilation and air cleaning, and still wear masks to reduce the amount of virus that you breathe in or that you may release. Reduce the number of people indoors, so that the chance that somebody is infected goes down.

You cannot ventilate your way out of a short-range transmission scenario! But you must ventilate your way out of a long-range aerosol transmission situation. And always use multiple strategies in case one fails.

Specific to getting kids back in schools across our nation, we must focus on these three important ideas:

1. There are devastating consequences to keeping kids remote and out of in-person school. This should be a NATIONAL priority.
2. Returning to in-person school should be prioritized over other aspects of the economy. They should be last to go remote and first to reopen for in-person learning; and
3. It cannot be school as usual. Schools need layered defense risk reduction strategies and should be funded to achieve these strategies.
   The infection fatality rate for kids is very low. Our overall risk lens has to include #1 above; and strategies in #3 are designed to protect both kids AND adults.

In schools, recent data from the UK shows that there is no evidence of difference in positivity rate between primary and secondary school teachers and their households, other key workers and their households, and other professions and their households.

On the national level, researchers at Brown University have been tracking K-12 opening plans across the country. As cited in a recent Washington Post report, over a two-week period beginning August 31, researchers found that 0.23% of students had a confirmed or probable case of COVID while among teachers it was 0.49%. This information, presented on the COVID-19 School Response Dashboard (described further here) lead one infectious disease expert to conclude in the same Washington Post report:

"Everyone had a fear there would be explosive outbreaks of transmission in the schools. In colleges, there have been. We have to say that, to date, we have not seen those in the younger kids, and that is a really important observation," said Michael Osterholm, director of the Center for Infectious Disease Research and Policy at the University of Minnesota.

Indeed, transmission within schools appears to be much lower than transmission that occurs outside of schools. A recent article reported that California has not seen a link between the reopening of k-12 schools for in-person learning and increased coronavirus transmission.

In a recent review of the literature Goldstein et al 2020 reported that susceptibility for children aged <10y is relatively low; susceptibility in adults aged >60y is higher; and mitigation measures should be implemented when opening schools, particularly secondary/high schools.

In England during the recent summer school session, they recorded only 0.51 outbreaks for each infection per 100,000 in the community. The infections and outbreaks were uncommon across all educational settings. Staff members had increased risk compared to students, and the majority of cases linked to outbreaks were in staff. The probable transmission direction for the 30 confirmed outbreaks was: staff-to-staff (15), staff-to-student (7), student-to-staff (6) and student-to-student (2) (Ismail et al. 2020).

Main factors that drove whether childcare workers got sick was the overall level of community transmission in the county where they lived and race/ethnicity – Black, Latino, Native American people more likely to test positive or be hospitalized. Both policy and social context affect people's risks and outcomes (Gilliam et al. 2020).

Early on schools were using the case rate per 100,000 or the positivity rate to decide when to go to remote learning. Now we know that this is not an appropriate metric for schools. Context of COVID-1 cases is important. Sadly, prisons, skilled nursing facilities and food processing plants have had strong surges. And also within household transmission in more crowded environments or during home gatherings. University campuses have had surges as well. But these are isolated outbreaks (if handled appropriately). So those raw case numbers can be misleading, and they hold no real "value" without that important context. Instead, we must look at all the available data that we have accrued over the past 9 months. We have not seen evidence of clusters of infections from open schools. Most teachers' infections can be traced to a spouse or community exposure.

The best metric for whether to have in-person learning is whether the school can implement appropriate safety measures. And these are mandatory mask wearing, reduced occupancy indoors, increased ventilation and supplement with filtration, use of carbon dioxide sensors to ensure adequate outside air ventilation and a good plan to contact trace. Applying more targeted quarantine guidelines is also important, to quarantine if in close contact for more than 15 min. This approach is detailed below.

Risk reduction strategies can be broken down into two types. The first strategy is for reducing short-range transmissions between staff and students and the second is for reducing long-range transmission. Short-range transmission strategies are:

- Provide 3-ply surgical masks weekly to all staff and students, mandate wearing at all times in building.
- Implement strict social distancing policies, e.g. no eating together in lunch room; eating outside, eating in small cohorts, no talking all facing the same direction and spaced apart if indoors; and
- Implement strict quarantine according to the new CDC guidelines that it is only needed if in close contact within 6 feet of an infected individual for more than 15 minutes.

Long-range transmissions strategies should be implemented in every school. Ventilation assessments must be completed to document how effective the building is at providing contaminant-free air into the occupied classrooms. This can be achieved by the school's facilities personnel or by working with an independent ventilation engineering firm. Once information has been gathered regarding the ventilation systems' capabilities schools must:

- Aggressively increase virus free ventilation rates to at least 5, ideally 6 air changes per hour outside air if they are below this level. This ventilation can be achieved by the following:
  - Windows/doors open to outside
  - Improved filtration using MERV 11 or higher in recirculated ventilation air
  - Increase outside air fraction of ventilation air
- Confirm that enough outdoor air is being supplied to the classroom by monitoring carbon dioxide, a surrogate for respiratory activity. This is an evidence-based technique that has been used for decades to establish effective health-based ventilation rates for buildings. Classrooms at high risk should be provided with carbon dioxide sensors at around $100 apiece to ensure that the rooms are adequately ventilated with outside air.
- Mandate additional air cleaning in every space that cannot achieve the above recommended ventilation rates and is occupied for > 1 hour by > 10 occupants.
  - Air cleaning should be achieved by evidence-based technology. This does NOT include ionizers, plasma air devices, spraying oxidants into the air, etc. Evidence based air cleaning includes HEPA filtration and ultraviolet germicidal air cleaning.
  - Room size key: 600-1000 ft^2 with 8-10 ft ceilings utilize stand-alone HEPA air cleaners. Use this calculator tool developed by Harvard and CU Boulder to use in schools for sizing air cleaners appropriately.
  - Larger rooms with higher ceilings can use upper room germicidal ultraviolet light.

Over the long-term schools must be provided with additional funding to improve their ventilation systems. Decades of inadequate funding to maintain our schools have resulted in deterioration of the buildings' basic functioning including providing healthy environments in classrooms. Poor ventilation in schools leads to increased illness absences and also poor learning outcomes. Recent evidence also points to decreased cognitive functioning in spaces with elevated carbon dioxide. We must reinvest in our school infrastructure. It will take years but it will be worth it with improved attendance and reduced adverse health effects including reducing the risk of airborne infections, and improved cognitive abilities.

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