Aerosol Generation During Exercise

Implications for Preventing Viral Transmission In and Out of the Exercise Laboratory

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One of the silver linings of the COVID-19 pandemic has been the explosion of research on respiratory virus transmission mechanisms. The insights garnered from these studies have overturned deeply entrenched assumptions that have governed infection control practices for decades.

Both the US Centers for Disease Control and Prevention (CDC) and the World Health Organization (WHO) have traditionally divided contagious respiratory pathogens into two transmission categories: droplet and airborne. Droplet pathogens are said to spread via large respiratory particles that rapidly fall to the ground within a few feet of the source individual. Surgical masks are recommended for providers seeing patients on droplet precautions. Most respiratory viruses, including influenza, and for much of the past year, SARS-CoV-2, have been classified as pathogens that spread via droplets. Airborne infections, by contrast, are said to spread via aerosols. These are smaller and lighter respiratory particles that can remain suspended in the air for long periods, penetrate the gaps between surgical masks and wearers' faces, and spread throughout a room and beyond. N95 respirators or their equivalents are therefore advised for providers seeing patients on airborne precautions. Examples include measles and TB.

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There is an important exception to CDC's and WHO's general guidance to use surgical masks when seeing patients on droplet precautions. N95 respirators or their equivalents are recommended for patients with influenza or SARS-CoV-2 undergoing so-called "aerosol-generating procedures," such as intubation, noninvasive positive-pressure ventilation, and tracheotomy, because these procedures have been presumed to produce aerosols and because case-control studies from SARS-CoV-1 reported associations between these procedures and health care worker infections.[1] CDC and WHO also recommend conducting aerosol-generating procedures in negative-pressure rooms with high air turnover whenever possible to minimize the amount of infectious aerosols in the room and to prevent their spread outside the room.

Determining which procedures belong on lists of aerosol-generating procedures has been contentious.[2] Hospitals and public health authorities created lists of presumed aerosol-generating procedures early in the pandemic, based on very little evidence. Specialties jockeyed to have "their" procedures included in the lists, often with no more evidence than "an abundance of caution." Hospitals felt compelled to draw the line, particularly early in the pandemic when N95 supplies were scarce, and many therefore excluded coughing, heavy exercise, and labored breathing. In some cases, this led to denying providers access to N95 respirators or negative-pressure spaces when seeing patients with these findings.[3]

The wealth of data generated by the pandemic has now made it clear that just about all the preceding assumptions were wrong. The distinction between droplet- and aerosol-based transmission is artificial and misleading. People routinely produce respiratory particles in a continuum of sizes.[4] Most are in the aerosol range, but there is no clear dividing line between droplets and aerosols. Respiratory particles of all sizes can potentially carry all types of respiratory viruses and infect others.[5] A surgical mask alone does not provide adequate protection against infection.[6,7] Most of the

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FINANCIAL/NONFINANCIAL DISCLOSURES: The authors have reported to CHEST the following: M. K. and C. R. have received grant funding from the CDC to conduct research on COVID-19 and royalties from UpToDate, Inc., for chapters on unrelated topics.

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DOI: https://doi.org/10.1016/j.chest.2021.05.065

procedures on so-called aerosol-generating procedure lists do not generate aerosols—the risk of infection associated with these procedures is more likely attributable to patient and provider factors (viral load, symptoms, proximity, and duration of exposure) rather than to the procedures themselves.[8]

Two new studies in this issue of *CHEST* shed further light on aerosol generation and mitigation, particularly in the context of exercise and labored breathing.[9,10] Dr Sajgalik and colleagues[9] arranged for eight healthy subjects to undergo a graded-intensity ride on a stationary bicycle within a small, enclosed space with no air turnover. They documented an exponential increase in aerosols with increasing exercise intensity, reaching about 30-fold more aerosols at peak vs baseline. Further key insights included the following: (1) the quantity of small aerosols increased at a greater rate than that of larger respiratory particles; (2) the concentration of aerosols was similar throughout the enclosed space, including behind the test subject; and (3) aerosol generation rates varied substantially between subjects.

The same group then evaluated the utility of adding portable high-efficiency particulate absorbing (HEPA) filters to mitigate aerosol concentrations during exercise.[10] Placing a portable HEPA filter into their exercise chamber reduced the peak concentration of aerosols during exercise by 98%, bringing the concentration down to essentially the same level one would expect in the absence of exercise. Likewise, they showed that adding a HEPA filter to a clinical exercise laboratory with 9 to 12 air changes per hour could reduce the time needed to clear 99.9% of an artificially generated aerosol cloud from approximately 20 minutes to 10 minutes.

These two studies clearly demonstrate that heavy exercise is indeed aerosol-generating. The investigators only studied healthy subjects, so they were unable to prove that these aerosols carry virus or that they increase infection risk, but the observation that intense exercise generates large amounts of aerosols helps to explain multiple large clusters of SARS-CoV-2 infections associated with fitness centers, cycling classes, and sports events.[11,12] Simultaneously, the second study suggests a practical strategy to mitigate the risk of aerosol transmission to health care workers and to patients that might have to enter a room immediately after a patient who has been exercising, namely, adding a portable HEPA filter. We further recommend that providers wear N95s or equivalent respirators during exercise testing when the community incidence of SARS-CoV-2 is high, particularly when seeing untested patients.

More broadly, we believe the principles highlighted by these two studies apply beyond the exercise laboratory to the general care of patients with any possible or confirmed respiratory viral infection. These studies affirm the dominant role of aerosols in human respiratory emissions and the outsized role of rapid and labored breathing in increasing aerosol generation. The amount of aerosols produced by heavy breathing and coughing far exceeds the marginal amounts generated by intubation, noninvasive positive-pressure ventilation, and high-flow nasal cannula.[13,14] The implication is that N95s and negative-pressure rooms should be prioritized based on patients' viral load, symptoms, and activities rather than on the basis of procedures. We further advocate N95s or their equivalents to care for all patients with possible or confirmed respiratory viruses, because all respiratory viruses are carried by aerosols, not just SARS-CoV-2.[5]

The COVID-19 pandemic has been revolutionary in so many respects, but one clear benefit has been the wealth of studies that have refined our understanding of respiratory physiology and how it contributes to viral transmission. We must now take this knowledge and use it to better protect health care workers and patients against all respiratory viruses.

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