CONTROLLING COVID-19 TRANSFERENCE

Through Heating, Ventilation & Air-Conditioning Systems

By Christopher J. Colburn

While information regarding the exact mode of transmission of COVID-19 is limited, some cases demonstrate that the virus can be transferred as the result of virus-laden aerosolized droplets traveling through heating, ventilation and air-conditioning (HVAC) systems.

An outbreak of 2019 novel coronavirus disease (COVID-19) from Jan. 26 through Feb. 10, 2020, affected 10 people from three families who had eaten at the same air-conditioned restaurant in Guangzhou, China. On Jan. 23, 2020, a family had traveled from Wuhan and arrived in Guangzhou where they ate lunch in an air-conditioned restaurant on Jan. 24, 2020 (Figure 1, Table A). Two other families sat at neighboring tables (Figure 1, Tables B and C) at the same restaurant. Later in the day on Jan. 24, one of the family members (A1) became symptomatic. By Feb. 5, a total of nine others including members of the other two families had become ill with COVID-19. It was determined that the only known source of exposure was the first person who became symptomatic. The tables where the respective families were seated were separated by a distance of 1 meter (about 3 ft). The air outlet and the return air inlet of the central air conditioner were located above Table C (Figure 1).

On Jan. 24, a total of 91 people (customers and staff members) were in the restaurant at the time of exposure. Of these people, 83 had eaten lunch at 15 tables in the restaurant. Among the 83 customers, 10 became ill with COVID-19; the other 73 were identified as close contacts and quarantined for 14 days. During that period, no symptoms developed and COVID-19 test results were negative (Lu, Gu, Li et al., 2020).

This indicates that, while larger respiratory droplets (> 5 µm) remain in the air for a short time and travel for only a short distance, generally less than 1 meter, the distance between the infected person and the other infected person was greater than 1 meter. This indicates that virus-laden small (< 5 µm) aerosolized droplets can remain in the air and travel long distances. However, since no other diners or staff members were infected, it would indicate that the droplets did not travel greater than 5 meters from the source. The risk of becoming infected from an unprotected person at a distance more than 5 meters is 1.08×10^{-1} in the absence of any protective measures.

In the absence of detailed scientific data to provide more than cursory results, one can look to yet another airborne pathogen that has a transmission mobility similar to COVID-19. In a 2006 publication, CDC discusses prevention and control of tuberculosis. Tuberculosis is a well-researched and studied airborne pathogen with a similar mobility of transmission to COVID-19. It is reasonable to assume that the containment and control methodologies used for tuberculosis would likewise be applicable to COVID-19.

Engineering Controls

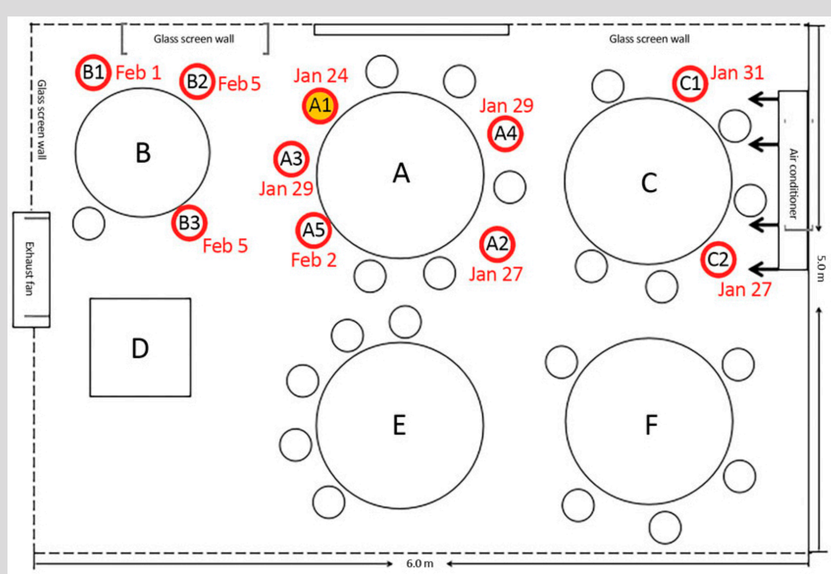
Based on the information in the aforementioned CDC (2006) document, a key element in the prevention of spread of this pathogen in an enclosed populated area is adequate ventilation. The document suggests that inadequate air changes per hour (ACH) can lead to the spread of these airborne pathogens. ACH is the ratio of the volume of air entering the room per hour to the volume of that room. It equals the exhaust airflow (Q) in cubic feet per minute (cfm) divided by the volume of the room (V) in cubic feet (ft^3) multiplied by 60 minutes per hour, as expressed thus:

$$ACH = \left(\frac{Q}{V}\right) \cdot 60$$

The most common minimum total ACH recommended for environments similar to an office environment with an HVAC system installed is 6 (CDC, 2006).

FIGURE 1
RESTAURANT SEATING SCHEMATIC

Sketch showing arrangement of restaurant tables and air-conditioning airflow at site of COVID-19 outbreak, Guangzhou, China, 2020. Red circles indicate seating of future case-patients; yellow-filled red circle indicates index case-patient.



Note. Reprinted from "COVID-19 Outbreak Associated With Air Conditioning in Restaurant, Guangzhou, China, 2020," by J. Lu, J. Gu, K. Li et al., 2020, *Emerging Infectious Diseases, 26*(7).

This is further substantiated by World Health Organization (WHO, 2020):

> Poorly ventilated buildings affect air quality and can contribute to the spread of disease. Microorganisms, such as those causing tuberculosis and legionellosis, can be transmitted by air-conditioning systems, particularly when they are poorly maintained or when the number of air exchanges per hour in a room is insufficient.

Table 1 illustrates the risk reduction as it relates to an increase of ACH for healthcare workers.

While the acceptable level of risk is defined by each respective organization, one would struggle to make an affirmative argument that ACH values of less than 6 are acceptable in environments supported by mechanical ventilation where there is known to be, or could potentially be, an active source of COVID-19 infection.

Air Sanitization

The concept of control layering dictates that to increase the probability of control success, redundancy is necessary. Therefore, in addition to adequate ACH, air sanitization must also be utilized to control the transference of COVID-19 through HVAC systems. The two predominant methods for sanitizing air in HVAC systems are 1) air filtration using high-efficiency particulate arrestance (HEPA) or ultra-low penetration air (ULPA) filters; and 2) ultraviolet (UV) germicidal irradiation systems.

Air Filtration

Fluid droplets from the cough or sneeze of an infected person are typically 5 microns (5 x 10^{-6} m) or larger. HEPA filters reliably capture 99.97% of particles that are 0.3 microns in diameter with efficiency increasing for both smaller and larger particles.

The smallest particle one might be concerned with is a single virion (unattached to any fluid droplet), having a diameter of approximately 0.12 microns. While these are conceivably filterable by a HEPA filter, ULPA filters are even better, catching 99.99% of particles 0.12 microns and larger. In theory, all COVID-19 virions could be filtered and captured, assuming that they can be brought into contact with an air filter (Elias & Bar-Yam, 2020).

Both HEPA and ULPA type filters are available for most industrial and residential HVAC systems and are more than adequate to capture and contain COVID-19 virus-laden particles. When selecting, one should note the minimum efficiency reporting value (MERV) assigned to the respective filter (EPA, 2020). The MERV rating indicates, on a scale of 1 to 16, how effectively a filter traps small particles (Figure 2).

UV Germicidal Irradiation Systems

Unlike a standard air filter or an electrostatic air cleaner, a UV air treatment system uses concentrated UV light to destroy a wide array of indoor air pollutants. These systems may also be equipped with an enhanced filter (e.g., HEPA) to provide additional protection against airborne dust, microorganisms and other particulates. UV light can harm several types of microorganisms including mold, mildew, fungi, bacteria and viruses by breaking down molecular bonds in their DNA. Exposure to UV light either kills the bio-contaminants or renders them unable to reproduce. The UV air treatment system works in tandem with the HVAC system and is mounted inside of the system's ductwork. When the air circulates through

TABLE 1

INFECTION RISK WITH VARIOUS VENTILATION RATES

Infection risk with 15 minutes exposure with different ventilation rates and quanta generation for an infector entering an enclosed space with a dimension 6 x 6.7 x 2.7 meters.

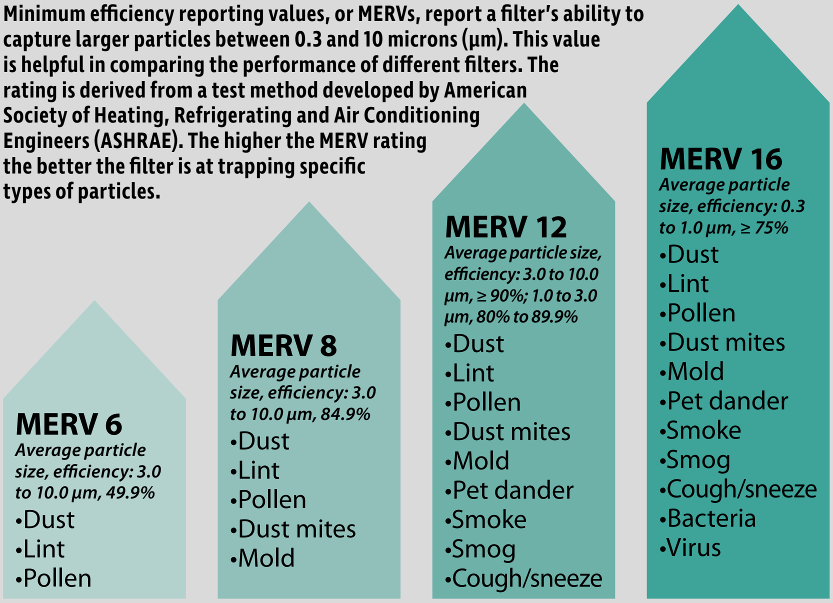
Quanta generation (quanta/min)	Ventilation rate (air changes per hour) (%)			
	1	6	18	30
1	0.05	0.01	0.00	0.00
7	0.30	0.06	0.02	0.01
14	0.51	0.11	0.04	0.02
20	0.64	0.16	0.06	0.04

Note. Data from "Natural Ventilation for Infection Control in Health-Care Settings," by WHO, 2009, Table E.2, p. 88.

FIGURE 2

MERV RATING

Minimum efficiency reporting values, or MERVs, report a filter's ability to capture larger particles between 0.3 and 10 microns (µm). This value is helpful in comparing the performance of different filters. The rating is derived from a test method developed by American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE). The higher the MERV rating the better the filter is at trapping specific types of particles.



Note. Adapted from "What Is a MERV Rating?" by EPA, 2020; and "Filtration/Disinfection Frequently Asked Questions and Glossary of Terms," by ASHRAE, 2020.

the ducts, pollutants are destroyed as the air passes through the UV rays (HVAC & Plumbing Unlimited, 2020).

Conclusion

Given the information discussed and data available, the best course of action to prevent the spread of COVID-19 via an HVAC unit is to 1) ensure that potentially infectious individuals are not within 5 meters (about 16.5 ft) of the HVAC inlet duct; 2) measure the ACH of each affected space and take necessary steps to achieve an ACH value of 6 or greater; and 3) install air sanitation filters, UV light systems (or both) on the inlet side of HVAC systems that recirculate air from inside the building. These tertiary controls should prove effective in preventing the transference of COVID-19 through HVAC systems. **PSJ**

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