The HVAC System’s Role in Environmental Infection Control for Hospitals

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Current state of affairs

(March 2020) As this article was being written, world healthcare providers were experiencing a burdening demand for their skills, expertise and services perhaps like never experienced before. My guess is as you read this now, that situation remains the same. The introduction of the coronavirus disease (the virus SARS-CoV-2) (the disease COVID-19) to our global population has caused both illness and death, producing not only a worldwide healthcare pandemic but also widespread disruption, concern, fear, and panic.

What we currently know

While it appears that recent research into the COVID-19 disease has narrowed to that of “transmission by droplet”, we still do not understand all the ways COVID-19 may be acquired or transmitted among individuals. What we do know, according to the U.S. Department of Health and Human Services Centers for Disease Control and Prevention (CDC), is that biological contaminants occur in the air as aerosols and may include potentially viable organisms, including viruses. Aerosols may be characterized as solid or liquid (droplet) particles suspended in the air. Droplets include those of a larger diameter (micron-size) which, after expulsion from an infectious individual may drop to the ground or surface to be “removed” through traditional cleaning and disinfection methods. They also include those which may immediately evaporate (desiccate) and become airborne droplet nuclei.

Talking for 5 minutes and coughing each can produce 3,000 droplet nuclei, sneezing can generate approximately 40,000 droplets which then may evaporate to particles in the size range of 0.5-12 µm (microns). These airborne droplet nuclei can remain suspended in the environment indefinitely and be transported over great distances. Respiratory infections can be acquired from exposure to pathogens contained in droplets or droplet nuclei, and the spread of airborne infectious disease in this manner is a form of indirect transmission (See figure 1).

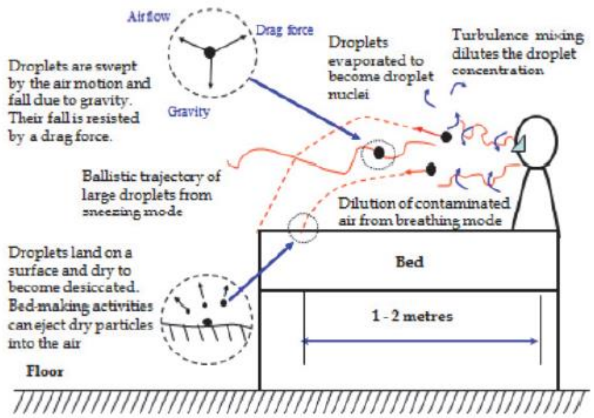

Figure 1 Droplet suspension: illustration of the aerobiology of droplets and small airborne particles produced by an infected patient.

[2] Cough particle size distributions are likely to vary based on the infected person's viscosity of secretions, anatomical structures in the oropharynx (roughly meaning throat) and airways, and disease characteristics.

Source: ASHRAE Position Document on Airborne Infectious Disease.

What we are finding out

In one recent medical report, the peak concentration of SARS-CoV-2 aerosols appeared in two distinct size ranges, one in the submicron region with aerodynamic diameter dominant between 0.25 to 1.0 µm, and the other peak in supermicron region with diameter larger than 2.5 µm. According to a new study from National Institutes of Health, CDC, UCLA and Princeton University scientists published in *The New England Journal of Medicine,* the virus that causes coronavirus disease is stable for several hours to days in aerosols and on surfaces. The scientists found that severe acute respiratory syndrome was detectable in aerosols for up to three hours and suggests that people may acquire the virus through the air and after touching contaminated objects. This study went on to conclude that stability of SARS-CoV-2 in aerosols and on surfaces likely contributes to transmission of the virus in healthcare settings.

In a joint study by the University of Nebraska Medical Center (UNMC), the National Strategic Research Institute at the University of Nebraska and others, researchers looking to better understand viral shedding and how it related to the novel virus, took air and surface samples from 11 patients' rooms during the initial isolation of 13 people who tested positive for COVID-19. The researchers found virus genetic material on commonly used items such as toilets, but also in air samples, thus indicating that "SARS-CoV-2 is widely disseminated in the environment."

Not only was the virus detected within COVID-19 patients' rooms, air samplers from hallways outside of rooms where [the] staff was moving in and out of doors were also positive. The data is also suggestive that viral aerosol particles are produced by individuals that have the COVID-19 disease, even in the absence of cough. "These findings indicate that disease might be spread through both direct (droplet and person-to-person) as well as indirect contact (contaminated objects and airborne transmission) and suggests airborne isolation precautions could be appropriate," they concluded, noting that the findings also suggest that COVID-19 patients, even those who are only mildly ill, "may create aerosols of virus and contaminate surfaces that may pose a risk for transmission." For those of us serving this industry, this is an unsettling thought.

Where we currently are

It's too early yet for evidence based research to prove that the SARS-CoV-2 virus can be circulated throughout a building, or distributed in the air delivered by its HVAC system, although this mode is likely. While it is probably not the predominant mode of transmission, this does not eliminate reason for concern. We do know that biological contaminants that occur in the air as droplet nuclei are particularly alarming as they may represent pathogens which can survive long periods and be carried considerable distances via air while still remaining viable. They may also settle on surfaces and become airborne again, as secondary aerosols, during certain activities.

The CDC has strict guidelines for HVAC systems installed in healthcare facilities to ensure these systems are designed to remove contaminated air from various spaces. They also provide air-handling recommendations that help protect susceptible staff and patients from airborne healthcare associated pathogens while minimizing the risk for transmission from infected patients, stating that if improperly designed, installed, or maintained, the HVAC system "can contribute to the spread of healthcare associated airborne infections". The CDC guidelines cover recommendations for designing healthcare facility HVAC systems to included engineering controls that can contain or prevent the spread of airborne contaminants through measures including local exhaust, general ventilation, space pressurization, and air cleaning. Filtration, defined as the physical removal of particulates from the air, is described to be the first step in achieving acceptable indoor air quality.

ANSI/ASHRAE/ASHE Standard 170, Ventilation of Health Care Facilities is considered the cornerstone of healthcare ventilation design in the U.S. and comprises a set of minimum requirements that define ventilation system design which helps provide environmental control for comfort, asepsis, and odor in health care facilities. It can also be (and is) adopted by code-enforcing agencies.

Section 7 Space Ventilation — Hospital Spaces

7.1 General Requirements. Spaces shall be ventilated according to Table 7.1.

Table 7.1 Design Parameters – Hospital Spaces

Function of Space	Pressure Relationship to Adjacent Areas (n)	Minimum Outdoor ach	Minimum Total ach	All Room Air Exhausted Directly to Outdoors (j)	AirRecirculated by Means of Room Units (a)	Design Relative Humidity (k), %	Design Temperature (l), °F/°C
SURGERY AND CRITICAL CARE							
Critical and intensive care	NR	2	6	NR	No	30–60	70–75/21–24
Delivery room (Caesarean) (m), (o)	Positive	4	20	NR	No	20–60	68–75/20–24
Emergency department decontamination	Negative	2	12	Yes	No	NR	NR
Emergency department exam/treatment room (p)	NR	2	6	NR	NR	Max 60	70–75/21–24
Emergency department public waiting area	Negative	2	12	Yes (q)	NR	Max 65	70–75/21–24
Intermediate care (s)	NR	2	6	NR	NR	Max 60	70–75/21–24
Laser eye room	Positive	3	15	NR	No	20–60	70–75/21–24
Medical/anesthesia gas storage (r)	Negative	NR	8	Yes	NR	NR	NR
Newborn intensive care	Positive	2	6	NR	No	30–60	72–78/22–26
Operating room (m), (o)	Positive	4	20	NR	No	20–60	68–75/20–24
Operating/surgical cystoscopic rooms (m), (o)	Positive	4	20	NR	No	20–60	68–75/20–24
Procedure room (o), (d)	Positive	3	15	NR	No	20–60	70–75/21–24
Radiology waiting rooms	Negative	2	12	Yes (q), (w)	NR	Max 60	70–75/21–24
Recovery room	NR	2	6	NR	No	20–60	70–75/21–24
Substerile service area	NR	2	6	NR	No	NR	NR
Trauma room (crisis or shock) (c)	Positive	3	15	NR	No	20–60	70–75/21–24
Treatment room (p)	NR	2	6	NR	NR	20–60	70–75/21–24
Triage	Negative	2	12	Yes (q)	NR	Max 60	70–75/21–24
Wound intensive care (burn unit)	NR	2	6	NR	No	40–60	70–75/21–24
INPATIENT NURSING							
AII anteroom (u)	(e)	NR	10	Yes	No	NR	NR
AII room (u)	Negative	2	12	Yes	No	Max 60	70–75/21–24
Combination AII/PE anteroom	(e)	NR	10	Yes	No	NR	NR
Combination AII/PE room	Positive	2	12	Yes	No	Max 60	70-75/21-24

Note: NR = no requirement

Source: Carrier Engineering Newsletter: Air-Conditioning for the Environment of Care.

The Standard includes three tables which define the design parameters for healthcare ventilation systems based on various occupancy classifications. Table 7.1 (2017) details the Requirements for Hospitals. ASHRAE Standard 170 also includes specific minimum design criteria for both temperature and relative humidity in these spaces to help ensure staff and patient comfort while helping to minimize infection.

Where we are going?

In light of current events, this is a perfect time to (at the very least) diligently inspect your existing healthcare facilities HVAC system to ensure “fresh” outdoor building ventilation airflows are as originally designed, and that the proper MERV rated air-filters are clean and properly installed. But these simple measures alone may not fill voids which limit your hospitals HVAC system from performing on the “frontline-of-defense” against the transmission and spread of airborne viruses and pathogens of concern. In addition to the guidelines and recommendations listed by the credible sources mentioned, what alternatives should be included as “best practice”, moving your facility towards improved environmental performance and better patient outcomes? A few suggestions follow:

High-Efficiency Particulate Arrestance (HEPA) filters are at least 99.97% efficient in removing particles of 0.30 µm, becoming even more efficient in removing both larger-and-smaller particles. Aspergillus mold spores are 2.5 - 3.0 µm in diameter, with viruses ranging from 0.02 - 0.30 µm. These contaminants are of particular concern because they are found in many indoor environments, easily proliferating within HVAC systems, and can be life-threatening or deadly upon exposure to immunocompromised patients within healthcare settings. Ultra Low Penetration Air (ULPA) filter media is also available with an efficiency rating in excess of 99.999% at 0.12 µm. Both HEPA and ULPA filters should be applied carefully, with consideration of the additional airside pressure drop they may add to the HVAC air-handling system.

Ultraviolet Germicidal Irradiation (UVGI) is a recognized technology which has proven to help provide surface disinfection which limits the growth of bacteria and mold-containing bio films on damp or wet componentry within air-handling units (AHUs). UVGI lamp systems are typically located immediately downstream of cooling coil and drain pan areas, where UVGI energy directed on these surfaces helps to disable various organisms so that they are unable to replicate and potentially cause disease.

Upper Air UVGI Devices are similar to those described above, but the fixture is located within the occupied environment, designed and installed to irradiate only air in the upper region of the space. Efficacy of this technology relies on fixture placement and the adequacy of air currents in bringing contaminated air into the upper UV zone. In buildings with continuous occupancy and/or with immunocompromised populations, such as healthcare environments, upper air UVC systems can help control transmission of airborne pathogens at their source. Studies have shown that in combination with appropriate room ventilation measures, it can be effective at helping to reduce or eliminate the spread of certain airborne infectious diseases.

Needlepoint Bi-Polar Air Ionization (NPBI) not only helps eliminate mold growth in HVAC air-handing systems, but may also address a variety of IAQ issues including contaminants brought in from outdoors (allergens, motor vehicle exhaust, gasoline vapors, chemicals, helipad and emergency generator exhaust), as well as certain viruses and VOCs occurring within the space. NPBI allows the removal of harmful substances by creating cold-plasma that splits water molecules in the air, producing positive and negative ions which surround certain harmful particles and pathogens, producing a reaction at the molecular level which deprives them of life-sustaining hydrogen and prevents reproduction. Similarly, these ions surround various VOCs (odors), causing the compound to break-down into one or more of four basic elements of the atmosphere.

Humidification and keeping the relative humidity in the buildings breathing zone between the ranges of 40%-60% RH, can have a profound effect on limiting the spread of airborne viruses. If the air is too dry, infectious droplets expelled by sick individuals can quickly evaporate and shrink. These tiny desiccated particles can be suspended in the air, where they may travel by air currents into an HVAC system and re-infect people in distant locations, having had no immediate contact with a sick individual. Research from NIH [National Institute of Health], Princeton, and Harvard show that the infectivity of viruses in the air and on surfaces can be reduced when the proper relative humidity is maintained in this range. Data also shows that when people within the built environment are exposed to indoor relative humidity at 40%-60%, their “human-mechanisms” for physiological defense are improved.

HVAC Technologies to Kill COVID-19 are not yet available (to the best of my knowledge) with reliable testing to back up this claim. Until now, this specific virus was not available for study. With the understanding that it can take more than a year to get a viral claim approved by regulatory agencies, the United States Environmental Protection Agency (EPA) has enacted a “hierarchy-based” policy. This means if a company’s product has been found to be effective against harder-to-kill viruses, its “likely” to kill a virus like COVID-19. A product that is likely to provide the greatest protection to you from COVID-19 will have claims against at least one non-enveloped virus such as Norovirus, Feline Calicivirus, Poliovirus, Rhinovirus, or Reovirus. Once we have products available with “evidence based” test results our options will be more clearly defined, but this may take a while. It’s always best to use products that have been qualified for the specific viral pathogen of concern. Until then, the EPA says that if you cannot obtain those products, then use products that are effective at killing Human Coronavirus because it’s expected those products will also be effective against SARS-CoV-2.

Closing thoughts

Healthcare facility design can be a blend of code and standards compliance along with a healthy dose of engineering best practice. There is probably no other industry in the world so heavily governed and regulated. Professionals involved in the design of these complex facilities must keep abreast of ever-changing needs and requirements while taking keen interest in the rapid evolvement of the healthcare process. Many hospitals are financially incentivized to improve the patient experience, placing tremendous value on the environment of care in which these individuals reside.

After the events of the worldwide coronavirus disease 2019 pandemic, the healthcare industry will never return to status quo. Engineers responsible for the systems which produce the temperature, humidity, air movement, ventilation and filtration within these environments are under increased pressure to assure facility owners and operators that their designs meet stringent code mandates while also contributing to the complex dynamics of staff and patient wellbeing and improved outcome.

References:

1. U.S. Department of Health and Human Services Centers for Disease Control and Prevention (CDC): Guidelines for Environmental Infection Control in Health-Care Facilities.
2. ASHRAE Position Document on Airborne Infectious Disease.
3. Carrier Engineering Newsletter Volume 6, Issue1| Air-Conditioning for the Environment of Care.
4. ASHRAE Journal Magazine October 2019, David N. Schurk | Hospital ORs, Conditioning for the Environment of Care.
5. Aerodynamic Characteristics and RNA Concentration of SARS-CoV-2 Aerosol in Wuhan Hospitals during COVID-19 Outbreak, by Y Liu | Mar 7, 2020.
6. Center for Biocide Chemistries Answers Your Questions about COVID-19 by Sarah J. Scruggs | March 11, 2020.
7. Transmission Potential of SARS-CoV-2 in Viral Shedding Observed at the University of Nebraska Medical Center.
8. Coronavirus Could be Airborne, Study Suggests, by Madeline Farber | Fox News

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