Studies Show Great Variation in Contact Precautions, Impact on Patients and Care Delivery

By Kelly M. Pyrek

Editor's note: This is a two-part series examining viral size, transmission of disease, and implications for respiratory protection worn by healthcare workers.

Clinicians and infection preventionists may need to rethink what they currently know about respiratory protection in light of several recent studies indicating that the influenza virus can be carried in smaller particles than previously thought. Additionally, there is debate over airborne transmission and what kind of PPE healthcare workers should don in these situations where exposure is imminent. As Lindsley and Blachere, et al. (2010) explain, "Although influenza is known to be transmitted by infectious secretions, these secretions can be transferred from person to person in many different ways, and the relative importance of the different pathways is not known. The likelihood of the airborne transmission of influenza virus by infectious aerosols is particularly unclear, with some investigators concluding that airborne transmission is a key route, while others maintain that it rarely, if ever, occurs. The question of airborne transmission is especially important in healthcare facilities, where influenza patients tend to congregate during influenza season, because it directly impacts the infection control and personal protective measures that should be taken by healthcare workers. During the 2009 H1N1 pandemic, for example, a United States Institute of Medicine (IOM) panel recommended that healthcare workers in close contact with influenza patients wear respirators to avoid infectious aerosols. This recommendation was subsequently adopted by some health authorities such as the Centers for Disease Control and Prevention (CDC), but not by others, such as the World Health Organization (WHO). The IOM panel also noted that many questions about the airborne transmission of influenza are unresolved, and the issue remains controversial."

One recent study published in the Journal of Infectious Diseases suggests that patients with influenza can emit small virus-containing particles into the surrounding air during routine patient care, potentially exposing healthcare providers to influenza. Published in The, the findings raise the possibility that current influenza infection control recommendations may not always be adequate to protect providers from influenza during routine patient care in hospitals.

Werner E. Bischoff, MD, PhD, and colleagues from the Wake Forest School of Medicine in North Carolina screened 94 patients for flu-like symptoms during the 2010-2011 influenza season. Study participants had been admitted to the emergency department (52 patients) or an inpatient care unit (42 patients) of Wake Forest Baptist Medical Center, where vaccination for influenza is mandatory for healthcare providers. Nasopharyngeal swabs were collected from each patient. Samples were analyzed by rapid testing and by PCR analysis. Air samples were obtained by placing three six-stage air samplers from within 1 foot, 3 feet, and 6 feet of patients. No aerosol-generating procedures—such as bronchoscopy, sputum induction, intubation, or cardiopulmonary resuscitation—were conducted while air sampling took place. During air sampling, the number of patients' coughs and sneezes were counted and assessed for severity. Patients also completed a questionnaire at admission to report symptoms and the number of days they were sick.

Of the 94 patients enrolled, 61 patients (65 percent) tested positive for influenza virus. Twenty-six (43 percent) released influenza virus into the air. Five patients (19 percent) emitted up to 32 times more virus than others. This group of patients with influenza, described by the researchers as "super-emitters," suggested that some patients may be more likely to transmit influenza than others. High concentration of influenza virus released into the air was associated with high viral loads in nasopharyngeal samples. Patients who emitted more virus also reported greater severity of illness.

The current belief is that influenza virus is spread primarily by large particles traveling up to a maximum of 3 feet to 6 feet from an infected person. Recommended precautions for health providers focus on preventing transmission by large droplets and following special instructions during aerosol-generating procedures. In this study, Bischoff and his team discovered that the majority of influenza virus in the air samples analyzed was found in small particles during non-aerosol-generating activities up to a 6-foot distance from the patient's head, and that concentrations of virus decreased with distance. The study addressed only the presence of influenza-containing particles near patients during routine care, not the actual transmission of influenza infection to others.

As Bischoff, et al. (2013) explain, "Influenza virus can be transmitted by air. Breathing, talking, coughing, and sneezing release influenza virus into air, with sizes ranging from submicron particles (during breathing) to large droplets (during

coughing/sneezing). The Centers for Disease Control and Prevention (CDC), the Institute of Medicine, the European Centre for Disease Control and Control, and the World Health Organization (WHO) have expressed lack of knowledge and the urgent need for research in influenza virus transmission routes. CDC and WHO state that influenza virus transmission primarily occurs by large-particle respiratory droplets traveling within a short distance of the source and that such particles are blocked during encounters between patients and healthcare professionals (HCPs) by face masks worn by HCP." Fit-tested respirators are only required during aerosol-generating procedures such as bronchoscopy. During routine, non-aerosol-generating patient care, the current precautions recommend that providers wear a non-fitted face mask.

The researchers add, "The size of airborne particles determines how influenza virus is transmitted. Large particles (diameter, ≥20 μm) have limited travel distance, while smaller particles (diameter, <5 μm) stay airborne longer and spread widely. We found that up to 89 percent of influenza virus–carrying particles were <4.7 μm in diameter. Notably, no aerosol-generating procedures were undertaken during air sampling. The predominance of small particles has been reported previously, with influenza virus detected in the exhaled breath of 4 of 12 subjects (33%) breathing normally. Although the majority of particles (>87%) were <1 μm in diameter, the sizes containing virus were not identified. The effect of coughing was studied in 47 influenza virus–positive patients. Thirty-eight (81 percent) released influenza virus, with 65 percent of RNA contained in particles <4 μm in diameter. The published data and our findings indicate that small particles carry the majority of influenza virus other than virus released during aerosol-generating procedures. We consider it unlikely that, during routine care, influenza virus is transmitted solely by droplet-sized particles."

Based on their findings, Bischoff and investigators are concerned that providers may still be exposed to infectious dosages of influenza virus up to 6 feet from patients with small wide-spreading particles potentially exceeding the current suggested exposure zones. These findings suggest that current infection control recommendations may need to be reevaluated, the study authors say.

Another recent study suggests that people may more likely be exposed to the flu through airborne virus than previously thought, according to new research from the University of Maryland School of Public Health. The study also found that when flu patients wear a surgical mask, the release of virus in even the smallest airborne droplets can be significantly reduced.

"People are generally surprised to learn that scientists don't know for sure how flu spreads," says Donald Milton, MD, DrPH, who directs the Maryland Institute for Applied Environmental Health and led the study of influenza virus aerosols published in the journal PLOS Pathogens on March 7, 2013. "Our study provides new evidence that there is nearly nine times more influenza virus present the smallest airborne droplets in the breath exhaled from those infected with flu than in the larger droplets that would be expected to carry more virus," explains Milton. "This has important implications for how we prevent the spread of flu."

Routes of flu transmission include: 1) direct or indirect (e.g., doorknobs, keyboards) contact with an infected person, 2) contact via large droplet spray from a respiratory fluid (via coughs and sneezes), and 3) inhalation of fine airborne particles, which are generated by the release of smaller, virus-containing droplets via normal breathing and coughing. The relative importance of these modes of influenza transmission has not been well understood, but is critical in devising effective interventions to protect healthcare workers and vulnerable people, such as infants and the elderly. The Centers for Disease Control and Prevention (CDC) recommends that persons with influenza wear surgical masks to prevent transmission to susceptible individuals. Yet, this recommendation has been supported so far by only one study of mask impact on the containment of large droplet spray during influenza infection. Maryland's study is the first to provide data showing that using a surgical mask can reduce the release of even the smallest droplets containing infectious virus. For this reason, healthcare facilities should put surgical masks on those suspected of having influenza, and individuals with influenza can protect their families by wearing a mask.

Milton and his research team, including scientists from Harvard and Boston University Schools of Public Health and the University of Hong Kong, collected the exhaled breath from 38 flu patients and tested both the coarse (≥ 5 μm) and fine (< 5 μm) particles for the number of viruses using molecular methods. They found that the fine particles had 8.8 times more virus than the coarse particles (larger but still airborne droplets). They also tested the airborne droplets for "culturable" virus and found that virus was not only abundant in some cases, but infectious. However, there was a big range of how many viruses people put into the air – some were undetectable while others put out over 100,000 every 30 minutes. The researchers also tested the impact of wearing a surgical mask on the virus shedding into airborne droplets. Wearing a surgical mask significantly decreased the presence of virus in airborne droplets from exhaled breath. There was a 2.8 fold reduction in the amount of virus shed into the smallest droplets, and a 3.4 fold overall reduction in virus shed in both the coarse and fine and airborne particles. As Milton, et al. (2013) note, "Surgical masks reduced the overall number of RNA copies by 3.4 fold. These results suggest an important role for aerosols in transmission of influenza virus and that surgical facemasks worn by infected persons are potentially an effective means of limiting the spread of influenza."

The researchers report that when study volunteers were not wearing surgical masks, they detected virus RNA in

coarse particles exhaled by 43 percent and in fine particles exhaled by 92 percent of influenza patients. Milton, et al. (2013) say their findings contrast with a study by Johnson et al. (2009), who detected influenza virus RNA in cough generated large droplet spray from 100 percent of influenza patients over two brief sampling trials, and from 78 percent on each trial. "These discrepant findings are likely due to the very different collection techniques and particle sizes collected in these two studies," the researchers explain. "We used a specially designed aerosol sampler to collect particles from 0.05 to 50 µm in diameter. Johnson et al., by contrast, used simple deposition on petri dishes, and based on particle settling rates and collection times, that method would have been unlikely to collect particles with diameters of less than approximately 50 µm because smaller particles would have remained suspended in air and flowed around the petri dishes. We view results from Johnson et al and the present study as complementary. Together the studies show that surgical masks can limit the emission of large droplet spray and aerosol droplets larger than 5 µm. However, surgical masks are not as efficient at preventing release of very small particles. It is well known that surgical masks are not effective for preventing exposure to fine particles when worn as personal protection. We had hypothesized that when used as source control, exhaled droplets might be large enough prior to evaporation to be effectively captured, primarily through impaction. This appears to be true for virus carried in coarse particles. But the majority of virus in the exhaled aerosol appear to be in the fine fraction that is not well contained. Nevertheless, the overall 3.4 fold reduction in aerosol copy numbers we observed combined with a nearly complete elimination of large droplet spray demonstrated by Johnson et al. suggests that surgical masks worn by infected persons could have a clinically significant impact on transmission. For example if one hypothesized that all transmission were due to aerosol particles <50 µm, and estimated a reproductive number of 1.5 for influenza (i.e. each infection generates 1.5 new infections on average at the start of the epidemic) [19], then the use of surgical masks by every infected case could reduce the reproductive number below 1. Compliance, however, would be a major limitation resulting in lower efficacy in real-world practice."

Milton, et al. (2013) add, "While it is generally assumed that large droplets shed from the respiratory tract contain infectious virus, there are limited data that indicate that fine particle aerosols released from the human respiratory tract contain infectious virus. In one previous study by Lindsley et al. (2010), infectious virus was detected in 2 of 21 cough aerosol samples, once with a sampler that did not discriminate between coarse and fine particles and once in the coarse particle fraction of a second instrument. This observation, along with our observation that it was possible to recover culturable virus from the fine-particle fraction using our device demonstrates that humans generate infectious influenza aerosols in both coarse and fine particle fractions. This lends support to the hypothesis that aerosols may be a common pathway for influenza transmission among humans. However, a clear test of the hypothesis requires intervention studies that can interrupt only one mode of transmission without interfering with others."

In that aforementioned study, Lindsley and Blachere, et al. (2010) measured the amount and size of aerosol particles containing influenza virus that were produced by coughing. Subjects were recruited from patients presenting at a student health clinic with influenza-like symptoms. Nasopharyngeal swabs were collected from the volunteers and they were asked to cough three times into a spirometer. After each cough, the cough-generated aerosol was collected using a NIOSH two-stage bioaerosol cyclone sampler or an SKC BioSampler. The amount of influenza viral RNA contained in the samplers was analyzed using quantitative real-time reverse-transcription PCR (qPCR) targeting the matrix gene M1. For half of the subjects, viral plaque assays were performed on the nasopharyngeal swabs and cough aerosol samples to determine if viable virus was present. Fifty-eight subjects were tested, of whom 47 were positive for influenza virus by qPCR. Influenza viral RNA was detected in coughs from 38 of these subjects (81 percent). Thirty-five percent of the influenza RNA was contained in particles >4 µm in aerodynamic diameter, while 23 percent was in particles 1 to 4 µm and 42 percent in particles <1 µm. Viable influenza virus was detected in the cough aerosols from 2 of 21 subjects with influenza. These results show that coughing by influenza patients emits aerosol particles containing influenza virus and that much of the viral RNA is contained within particles in the respirable size range. Lindsley and Blachere, et al. (2010) say their results support the idea that the airborne route may be a pathway for influenza transmission, especially in the immediate vicinity of an influenza patient. They say that additional research is needed on the viability of airborne influenza viruses and the risk of transmission.

Milton, et al. (2013) note that in their study, the lack of strong correlation between the viral load in the nasopharyngeal and aerosol samples may of interest: "This may merely be a result of nasopharyngeal sample variability; in future studies, control for sample quality by PCR of a cellular gene may be helpful. Our sampler, as is the case with all samplers for fine and ultrafine particles, has an upper limit to the size droplet that can be pulled into its inlet airstream. Thus, a second possible explanation for the lack of correlation is that the nasopharynx is primarily a source for very large droplets (>50 µm) that we would not have detected. Furthermore, none of our subjects sneezed; an efficient method of generating droplets from the upper respiratory tract. This may imply that the smaller droplets we detected were generated in the lower respiratory tract and that the viral load at that location is not strongly correlated with the nasopharyngeal load. Alternatively, shedding into aerosol droplets may be driven by other host factors (e.g. asthma, symptom severity, and immune response), co-infection with other agents, virus factors affecting release from the epithelium, or the nature of the

resident microbiome. If shedding into aerosol is determined in large part by the location of infection in the respiratory tract, this may have implications for experimental studies of transmission. Such studies will need to monitor aerosol shedding to determine whether nasal inoculation of donors results in aerosol shedding that mimics naturally acquired infection to validate the experimental design and aid the interpretation of results."

The viral size debate begs the question of what to do about individuals who produce and are able to spread an inordinate number of virus particles. The detection of "super-emitters" raises concerns about how individuals with high viral load may impact the spread of influenza, Bischoff, et al. (2013) emphasize. "Our study offers new evidence of the natural emission of influenza and may provide a better understanding of how to best protect health care providers during routine care activities," the study authors write. However, studies of influenza virus transmission will be necessary before the role of super-emitters can be firmly established, they note.

The issue of super-emitters or super-shedders received attention in 2003-2004 when the rapid spread of severe acute respiratory syndrome (SARS) was aided by "numerous 'superspreading events' in which certain individuals infected unusually large numbers of secondary cases," according to Lloyd-Smith, et al. (2005) who add that superspreading is a normal feature of disease transmission. As Galvani and May (2005) note, "Initial work in this area largely treated individuals in populations as having an equal chance of transmitting disease — that is, as being homogeneous — and ignored stochastic fluctuations in transmission capability. However, studies of gonorrhea and of HIV/AIDS could not explain epidemiological patterns without acknowledging heterogeneities in patterns of sexual-partner acquisition, including the disproportionate influence of superspreaders ... These observations led to the proposal of the 20/80 rule, which suggests that roughly 20 percent of the most infectious individuals are responsible for 80 percent of the transmission. This rule has been applied mainly to helminthic and sexually transmitted diseases; for other directly transmitted diseases, such as smallpox or influenza, heterogeneity in infectiousness has been neglected. The superspreading that seemed to fuel the 2003 SARS epidemic was largely treated as anomalous in most models, but it highlighted the need for a reassessment of heterogeneous infectiousness."

Lloyd-Smith et al.(2005) addressed this point by posing infectiousness as a continuous variable and formulating an unambiguous and universally applicable definition of superspreaders as those who transmit more infection than is predicted by a homogeneous 'null model'. In their study, the researchers analyzed data from eight human infections, including SARS, measles, smallpox, monkeypox and pneumonic plague, to show that superspreading occurs across the board, although to a greater or lesser extent depending on the disease. They indicated that heterogeneity is greatest for SARS and least for Ebola haemorrhagic fever.

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Q&A With Werner E. Bischoff, MD, PhD

Q: What prompted you to conduct your study?

A: There is only limited knowledge of how influenza is transmitted. Based on the explosive nature of influenza epidemics and pandemics the airborne route appears to play a major role in the transmission of this pathogen.

We decided to determine the virus load present in the environment that healthcare providers are exposed to during their routine care activities. This will help to better understand how we can best protect our healthcare providers against influenza.

Q: Do you believe that there are more "super-emitters" in the patient population/community population than healthcare providers are currently aware of, and how can awareness be raised?

A: The presence of "super-spreaders" has been suggested in other respiratory viruses such as SARS. However, we did not assess transmission but only release of influenza (emission). The transmission aspect needs to be confirmed before the importance of our findings can be determined. If the 20/80 rule of 20 percent of infectious individuals cause 80 percent of infections applies to influenza, our findings may reflect the true percentage of "super-spreaders." At this point any changes in infection prevention measures including staff behavior should be very carefully considered based on our results.

Q: Should greater attention be paid to measuring viral loads so that these super emitters can be identified more rapidly and precautions be taken? Given the workload of most healthcare providers and crushing workloads on labs, is this even feasible?

A: We looked at factors that may help identify super-emitters. However, due to the small number of these individuals (n=5) none were found. There is also no 'easy' laboratory test available. Since rapid identification of super-emitters is currently not available, the feasibility of these measures remains unclear.

Q: Your findings completely upset the long-standing belief that influenza virus is spread primarily by large particles traveling up to a maximum of 3 to 6 feet from an infected person -- what was the reaction to your findings in the medical community? Have you seen facilities re-considering what they formerly presumed about influenza transmission?

A: The main concern regarding our findings was the proof of transmission. We measured emission and subsequent environmental burden of influenza in a care setting but could not address if the viral loads we found at increasing distances from the source actually pose an infection risk. As outlined in our article our study offers new evidence of the transmission dynamics of influenza but requires further research to assess the role of super-emitters and distance in influenza transmission.

Q: In light of your findings, how would you suggest that hospitals approach influenza-transmission prevention strategies? Do you think current clinical thought regarding respiratory protection needs to be revamped?

A: Based on our findings and the new questions posed by it we believe that it would be too early to change influenza-transmission prevention strategies. Our study demonstrated that some influenza patients emit influenza in much higher concentration than others and that the current recommendations regarding distance may need to be revisited. This new evidence will hopefully help to promote additional research and funding opportunities that will build on our findings and answer questions regarding the efficacy of the current prevention and control measures recommended for our healthcare providers.

Q: You say that studies of influenza virus transmission will be necessary before the role of super-emitters can be firmly established – are you and your colleagues planning on conducting a follow-up study? What's next in your research?

A: We are currently working on follow-up studies looking into the characteristics of super-emitters and also the transmission of live influenza virus over distance. We hope that these projects will shed further light into the way influenza is spread.

Additional Research

NIOSH has undertaken a number of studies to help inform the debate about virus size and transmission.

- Bioaerosol Sampling for the Detection of Aerosolized Influenza Virus

Coughing, sneezing, talking, and breathing generate an aerosol of airborne particles with diameters that can range from a few millimeters to less than 1 µm. This study investigated the potential for influenza virus to be carried by small particles. Researchers at NIOSH developed a two-stage cyclone bioaerosol sampler that can collect air samples and separate airborne particles into three size fractions (greater than 4 µm, 1-4 µm, and less than 1 µm). Attenuated influenza virus was aerosolized in a laboratory calm-air settling chamber and airborne particles collected with the NIOSH bioaerosol

sampler were assayed for the presence of influenza virus. Particles less than 10 µm in diameter can remain airborne for hours and are easily inhaled deeply into the respiratory tract. This study addressed the potential for influenza virus to be carried and potentially transmitted by viral-laden particles in a healthcare setting. The researchers concluded that airborne particles were efficiently collected by the NIOSH sampler and 2009 H1N1 influenza and H3N2 influenza virus were predominately found in the 1-4 µm and less than 1 µm size fractions. The viability of the collected virus was not determined.

Reference: Blachere FM, Lindsley WG, Slaven JE, Green BJ, Anderson SE, Chen BT, Beezhold DH. Bioaerosol sampling for the detection of aerosolized influenza virus. Influenza and Other Respir Viruses 2007;1(3):113-120. http://www.ncbi.nlm.nih.gov/pubmed/19453416

- Detection of Airborne Influenza in Healthcare Facilities During Influenza Seasons

Two studies measuring the amount of airborne influenza viral RNA in healthcare facilities during influenza seasons were conducted. In 2008 and 2009, air samples were collected from the West Virginia University Hospital's emergency room and urgent care clinic, respectively, to determine the amount and size of airborne particles containing influenza and whether this correlated with the number and location of patients. These studies directly addressed whether influenza is present on respirable particles that could potentially place healthcare workers at risk for infection during influenza outbreaks. Both studies found that the highest concentrations of influenza RNA were detected in locations where, and during times when, the number of influenza patients was highest. The studies also found that 42 percent to 53 percent of the influenza viral RNA was contained in airborne particles less than 4 µm in aerodynamic diameter (the respirable size fraction). Aerosol particles in this size range are of particular concern because they can remain airborne for an extended time and because they can be drawn down into the alveolar region of the lungs during inhalation. The viability of the collected virus was not determined.

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1. Blachere FM, Lindsley WG, Pearce TA, Anderson SE, Fisher M, Khakoo R, Meade BJ, Lander O, Davis S, Thewlis RE, Celik I, Chen BT, Beezhold DH. Measurement of airborne influenza virus in a hospital emergency department. Clin Infect Dis 2009; 48:438–440. http://www.ncbi.nlm.nih.gov/pubmed/19133798.
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- Measurements of Airborne Influenza Virus in Aerosol Particles from Human Coughs

Researchers completed one influenza season measuring the amount and size distribution of aerosol particles containing influenza viral RNA that were produced by influenza patients as they coughed. This study addressed whether influenza patients could potentially place healthcare workers at risk for infection during a routine examination. Results show that influenza patients produce aerosol particles containing measurable amounts of influenza virus while coughing. Further, 65 percent of the viral RNA was contained within particles in the respirable size fraction. Our study was also able to demonstrate that at least some influenza patients expelled airborne particles containing viable virus.

Reference: Lindsley WG, Blachere FM, Thewlis RE, Vishnu A, Davis KA, Cao G, Palmer JE, Clark KE, Fisher MA, Khakoo R, Beezhold DH. Measurements of airborne influenza virus in aerosol particles from human coughs. PloS One 2010;5(11):1-6. http://www.ncbi.nlm.nih.gov/pubmed/21152051

- Cough Aerosol Particles Produced by Influenza Patients During and After Illness

Little is known about the quantity and size of potentially infectious airborne particles produced by people with influenza. Because respiratory infections generally increase airway mucus production, it is typically assumed that aerosol production also increases, but the actual amount of any change is unknown, and it is also unclear whether the particle size distribution of the aerosol is shifted. The purpose of this study was to measure and compare aerosol production by influenza patients while they were ill and after they had recovered. By performing the first direct comparison of respiratory aerosol production during and after illness, these results show more clearly how influenza affects aerosol generation. A better understanding of the effects of influenza on aerosol production will help with efforts to study the potential for the airborne transmission of this illness and to devise interventions to reduce its spread.

Individuals with influenza produce a significantly greater volume of aerosol when ill compared to afterwards. The number of particles produced per cough was also higher when subjects had influenza compared to afterwards, although the difference did not reach statistical significance. The average number of particles expelled per cough varied widely from patient to patient. When the subjects had influenza, an average of 60 percent of the cough aerosol particle volume was in the respirable size fraction, indicating that these particles could reach the alveolar region of the lungs if inhaled by another person. This enhancement in aerosol generation during illness may play an important role in influenza transmission.

Reference: Lindsley, WG, TA Pearce, JB Hudnall, KA Davis, SM Davis, MA Fisher, R Khakoo, JE Palmer, KE Clark, I Celik, CC Coffey, FM Blachere and DH Beezhold (2012). Quantity and size distribution of cough-generated aerosol particles produced by influenza patients during and after illness. J Occup Environ Hyg 9(7): 443-9.

- Factors Influencing the Transmission of Influenza

The overall purpose of this program is to develop improved methods for the collection and evaluation of virus-laden bioaerosols in order to better characterize the parameters that influence the transmission of the influenza virus. Studies are being conducted to measure and understand the parameters important for the persistence of infectivity of the influenza virus in aerosols. An environmental chamber has been built that contains a cough manikin that "coughs" influenza virus into the room to simulate a patient with influenza, and a breathing manikin to simulate a healthcare worker. The manikins can be outfitted with a mask or respirator to study how well they can protect workers. NIOSH aerosol samplers are used to collect the airborne particles containing influenza virus from the breathing manikin and at locations throughout the room. Specific questions being addressed include; how long does infectious influenza virus remain airborne, what is the distance over which infectious virus can be transmitted, and what is the effect of room temperature and humidity on infectivity of the virus? These studies will better our understanding of the mechanisms of transmission of influenza in occupational settings and directly assess the risk of infection when workers are exposed for short periods to infected individuals in a confined environment.

Extensive testing in the environmental chamber using potassium chloride aerosols indicate that the immediate exposure to aerosol particles from a cough depends on the location of the simulated healthcare worker, but within 5–10 minutes the particles are dispersed throughout the room and the worker is exposed regardless of location. As expected, N95 respirators reduced exposure levels to negligible levels, while surgical masks typically admitted 20 percent of the airborne particles even when the mask was sealed to the breathing machine head. This work has now been expanded to include testing using influenza virus. We have demonstrated that viable influenza was present in all three aerosol fractions collected and that surgical masks sealed to the manikin head admitted approximately 15% of viable virus while N95 respirators further significantly reduced exposure.

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