Infection Control Factors in Hospital Building Maintenance and Operations

a report by
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Comfort is a dominant concern for the indoor environment. The healing indoor environment needed in healthcare must consider infection control safety for patients and staff as an added factor for a safe environment of care. Due to the continuous occupancy of hospitals, challenges for upgrading utilities and installing new medical technology cause a potential problematic disruption. During these disruptions, exposure can occur due to a lack of infectious disease controls. These controls are associated with airborne-spread infectious diseases, which must be recognised and mitigated for patient safety.

Airborne-spread diseases (see *Table 1*), while rare in most patient and healthcare employee work environments, must be factored into operations of facilites and their management. As medical technology has advanced, immune suppression becomes part of the treatment process – immune suppression that compromises patients' ability to resist common bacterial and fungal environmental microbes. Aspergillosis and legionellosis both originate from environmental sources. Tuberculosis (TB), an airborne bacterium found worldwide, spreads human-to-human infectious disease. New emerging infectious diseases such as severe acute respiratory syndrome (SARS), caused local reaction to quell a potential pandemic in the global community.

The healthcare facility's mission is to diagnose and provide therapeutic treatment to cure disease. Proper environmental management is essential for appropriate reactions to the challenges of infectious diseases. Ventilation plays a role in infectious disease management. Clusters of infection have been reported in facilities due to an imbalance of ventilation systems.[2] These clusters have been associated with environmental and patient-spread infectious agents,[3,4] due to improper ventilation from construction practice or lack of local mechanical control. Future challenges of global mobility and emerging infectious diseases, coupled with biological terrorism, mandates infection control for ventilation and related mechanical systems. The respective government guidelines have proved design criteria for infectious disease management in many developed countries (see *Table 2*).[1,5,6]

While these respective national agency documents have specific ventilation criteria to be maintained, there is a question over what provisions there are to assure their validity. In an editorial "In With the Good Air"[7] the author challenged facility management teams to verify respective ventilation parameters necessary for infectious disease management in their respective hospitals – this article was directed at medical staff (epidemiologists) who are responsible for infectious disease management. The true responsibility falls on the facility manager, however, with co-ordination from the infection control professional.

The facility manager should understand the

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1. *Centers for Disease Control and Prevention, "Guidelines for Environmental Infection Control in healthcare facilities",* MMWR Recommendations and Reports *(2003), 52: pp. 1–42.*
2. *Thio C, Smith D, Merz W et al., "Refinement of environmental assessment during an outbreak investigation of invasive aspergillosis in a leukemia and bone marrow transplant unit",* Infect. Control. Hosp. Epidemiol. *(2000), 21: pp. 18–23.*
3. *LeClair J, Zaia, J, Levin M, Congdon R, Goldmann D, "Airborne transmission of chicken pox in a hospital",* N. Engl. J. Med. *(1980), 302: pp. 450–453.*
4. *Patterson J, Peters J, Calhoon J et al., "Investigation and control of aspergillosis and other filamentous fungal infections in solid organ transplant recipients",* Transpl. Infect. Dis. *(2000), 2: pp. 22–28.*
5. *"Mechanically Ventilated Isolation Rooms; Best Practice Standards for Capital Planning", Health Estates: Dept. of Health, Social Services and Public Safety, Regional Advisory Committee on Communicable Disease Control, Belfast (December 2003).*
6. *"Guidelines for the Classification and Design of Isolation Rooms in Health Care Facilities", Standing Committee on Infection Control, Dept of Human Services, Victoria (1999).*
7. *Streifel A, "In with the good air (editorial)",* ICHE *(2002), 23;9: pp. 488–491.*

Table 1: Micro-organisms Associated with Airborne Transmission CDC-EIC 2003[1]*

	Fungi	***Bacteria***	***Viruses***
Numerous reports in healthcare facilities	Aspergillus spp.+ *Mucorales (*Rhizopus spp.*)*	Mycobacterium Tuberculosis+	*Measles (rubeola) virus* *Varicella-zoster virus*
Atypical, occasional reports	Acremonium spp. Fusarium spp. Pseudoallescheria boydii Scedosporium spp. Sporothrix cyanescens¶	Acinetobacter spp. Bacillus spp¶ Brucella spp.** Staphylococcus aureus *Group A Streptococcus*	*Smallpox virus (variola)§* *Influenza viruses* *Respiratory syncytial virus* *Adenoviruses* *Norwalk-like virus*
Airborne in nature; airborne transmission in healthcare settings not described	Coccidioides immitis Cryptococcus spp. Histoplasma capsulatum	Coxiella burnetii *(Q fever)*	*Hantaviruses* *Lassa virus* *Marburg virus* *Ebola virus* *Crimean-Congo virus*
Under investigation	Pneumocystis carinii		

** This list excludes micro-organisms transmitted from aerosols derived from water; + Refer to the text for references for these disease agents; § Airborne transmission of smallpox is infrequent. Potential for airborne transmission increases with patients who are effective disseminators present in facilities with low relative humidity in the air and faulty ventilation; ¶ Documentation of pseudoepidemic during construction; ** Airborne transmission documented in the laboratory but not in a clinical setting.*

ventilation limits for respective special ventilation areas within the hospital. Often, priorities associated with ventilation management are established without understanding the risk implications of emerging infectious diseases. These decisions to not respond to mechanical ventilation deficiencies, especially during construction, may result in opportunistic infections and/or litigation.[8] Airborne infectious disease management is difficult, due to the unseen presence of the respective disease agents (spores or droplet nuclei) along with the difficulty of diagnosing patients with TB or aspergillosis.

An assessment of the current ventilation condition before construction will help to avoid discovery of ventilation deficiency.[4,9] The ventilation parameters, which are established in many countries, have some consistency in some parameters from country to country. The pressure differential, however, is quite varied, from a low-end US 2.5Pa to the Australian 30Pa pressure differential. The pressure differential represents the velocity of the air, which is measured and translated to pressure. The pressure 2.5Pa represents 2.0m/s, while 30Pa is approximately 6.5m/s. The question of what velocity is sufficient to prevent infectious particle movement remains unanswered. Note nuisance 'wind' whistle begins to be noticed at about 5.0m/s.

Each respective country's infectious disease management guidelines note important adjuncts to airborne infectious disease control. Self-closing doors, closed windows and a tight room are essential for pressure management. The concept of an air-tight room is debated and was recently defined in the Centers for Disease Control (CDC) Guidelines for Environmental Infection Control as 464cm^2. These numbers were developed by comparing the offset of air volume supply versus exhaust with the pressure differential and applying a calculation based on the leakage area within a special ventilation area. A reasonable offset between the supply and exhaust (3.3m^3/minute) should be considered with an appropriate method for sealing the room.

While such efforts can be specified, the reality is that construction management rarely applies such criteria for final commissioning of that space to the desired ventilation parameters. Even if such specifications are verified, it is questionable as to whether facilities actually manage the special ventilation areas to those design parameters.

Special tools are necessary to determine those ventilation parameters. The air exchange analysis uses air volume hoods to determine the volumes of the room supply and exhaust to set the air exchange rate. This device does not measure pressure but does establish the air–volume balance to create the pressure. The pressure is measured using a micromonometre sensitive to <0.25Pa. At this point, the questions of how room leakage affects the pressure, and what is used to measure leakage, arise. Rice reported[10] using a blower door to establish a

8. *"Medical Malpractice: Construction Related Infection at Surgery Site",* Massachusetts Lawyers Weekly Verdicts and Settlements *(1999): 27.*
9. *Rhame F, Streifel A et al., "Extrinsic risk factors for pneumonia in patient at high risk of infection",* Am. J. Med. *76 (5A): pp. 42–52.*
10. *Rice N, Streifel A, Vesley D, "An evaluation of hospital special ventilation room pressures",* ICHE *(2001), 22;1: pp. 19–23.*

Table 2: Selected International Special Ventilation Room Parameters

	Protected Environment (PE)			Airborne Infection Isolation (AII)		
Location	AC/hr[1]	Filtration[2]	Pressure[3]	Ac/hr[1]	Filtration[2]	Pressure[3]
US	>12	99.97	2.5	>12	90%[4]	2.5
UK	>12	99.97	15	15	90%	15
AUST	>12	99.97	15	>12	90%	30

1. Air exchanges/hour; 2. percentage efficiency; 3. differential pressure in Pascals; 4. 90% supply filter efficiency 99.97% exhaust or return air efficiency.

pressure of 50Pa to determine leakage in special ventilation rooms. In that study, a room intended for protective patient conditions for the pressure measuring device indicated a airflow of 4.2m^3/minute while the infectious disease isolation room indicated a leakage of 42m^3/min – a significant airflow difference. The leakage was associated with the ceilings. The protected environment (PE) room had solid caulked ceilings while the airborne infection isolation (AII) room had metal perforated ceilings with insulation on top; such was the lack of knowledge of design for special ventilation rooms for hospitals in 1985 when the University of Minnesota Hospital was constructed. Since then, the room ceilings have been sealed to establish the appropriate pressures.

Filtration efficacy can be measured with a particle counter. The most common particle size to determine the filtration efficacy is more than 0.5µm in diameter. The filters are evaluated either across the filter bank in the supply fan or from the diffuser in the patient room. If the filters are working properly a percentage reduction of particles of more than 0.5µm should be similar to the filter rating. For example, if the filter is rated at 90% efficient, the reduction of particles from outdoor comparison should be approximately 90%. Unfortunately, in the author's experience the filters, while having a high rating, may not fit the filter rack originally installed in that supply fan. The size of the filter, the seal on the housing and spacers installed for fit may all contribute to assuring that airflow passes through the filter media and not around the filter media.

If the filters do not fit the rack, they do not remove critical particles that could be infectious. In the 60+ hospital filtration systems evaluated using a particle counter, over half had indications of excess leakage around the filter bank. It must be remembered that these microbes have only recently taken advantage of the immune compromised status of specific patient groups (e.g., cancer, transplant or immature babies amongst others).

Facility managers have specific needs to demonstrate to assure infection control in the operation of hospital ventilation systems. All of the design parameters put forth by the respective countries make sense, although the consideration for pressure is quite varied and controversial.[11,12] The need for a sealed room with emphasis on self-closing doors and sealed windows is logical for any kind of control. The pressure relationship should be considered a factor of consistency rather than intensity, because if data logging a PE and AII room recorded the pressure relationship at time intervals, high variability of a large pressure differential in the PE room[10] study rarely deviated from the intended airflow direction (out of room). The lesser pressure differential noted in the AII rooms, however, did deviate from the intended airflow (into room) direction. A question now arises of whether the intensity of the air velocity makes the difference. With current knowledge, the velocity at 2.5Pa may not be sufficient to control infectious particles, but the velocity at 30Pa may be excessive. If the issue is ventilation consistency, then concern should focus on minimising the deviations due to external climate conditions and internal variations due to variable volume fans, elevator movement and door openings/closings. The use of a self-closing doors will help control room pressure. When litigation becomes a factor, due to nosocomial or occupational airborne infection, verification of that control will be necessary to rule out ventilation as a potential source of that infection. Often, some hospitals do not verify. Professional experience in evaluating infection clusters in over 100 hospitals has repeatedly revealed a lack of ventilation control. This is especially true around construction projects. Likewise, over 200 additional hospitals have been inspected to determine parameters for an environment of care statement of condition representing mechanical ventilation control. This experience has revealed few hospitals in compliance with the parameters designated for infection management, especially airborne infection isolation areas. In the US this is truly a sign of the unpreparedness towards emerging infectious disease management currently being addressed by the

11. *Humpherys H, "Positive pressure isolation and the prevention of invasive aspergillosis. What is the evidence?",* J Hospital Infection *(2004), 56: pp. 93–100.*

12. *Rydock J, Eian P, "Containment testing of isolation rooms",* J. Hospital Infection *(2004), 57: pp. 228–232.*

13. *National Bioterrorism Hospital Preparedness Program, Health Resources Service Administration (2003), US Dept. of Health and Human Services.*

Department of Homeland Security and the Hospital Preparedness Program in preparation for bioterrorist activity.[13] The task is large, although the US spends billions each year on fire management, which has successfully reduced the number of deaths to a handful of cases. Due to the effort being made to provide infection control, assurance should be given to hospitals that critical ventilation is working as specified.

These criteria are available, although many hospitals may not realise their own mechanical deficiencies. Priorities, such as hospital management providing a budget to assure these parameters, must be identified and verified for hospitals to be prepared for management of infectious diseases as they emerge. A global economy and terrorism all play into the need for consistent control when ventilation management is needed. Preparedness must not be construed as regulation for such a critical factor as public health in healthcare facilities. ■