

INFECTIOUS DISEASE CONTROL ISSUES PRINCIPLES OF ISOLATION ROOM DESIGN

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*"Evidence from many studies leaves no doubt that hospital air quality and ventilation play decisive roles in affecting air concentrations of pathogens... and, in this way, have major effects on infection rates"**

INTRODUCTION

Infectious diseases can spread from one person to another by aerosol droplets. The spread of Tuberculosis (TB), for example, occurs when an otherwise healthy individual inhales a sufficient number of tubercle bacilli that are expelled by a patient infected with pulmonary TB. An infected patient continuously expels these particles when coughing, sneezing, talking or spittingⁱ. The infectious particles are estimated to be approximately 1 to 5 μm in sizeⁱⁱ and normal room air currents can keep them airborne for long periods. These particles are easily spread about a room or building unless adequate protection and control is provided. A number of outbreaks of TB in hospitals in the 1980's and 1990'sⁱⁱⁱ prompted the Centers for Disease Control and Prevention (CDC) to issue a number of reports regarding the prevention of TB transmission in health care facilitiesⁱⁱ.

Infected patients are isolated from other individuals in hospitals and placed in special isolation rooms. A series of administrative and engineering controls are implemented to reduce airborne transmission.

The administrative controlsⁱⁱ include:

- 1) An infection control program identifying individuals likely infected
- 2) Training
- 3) Medical surveillance of at-risk health care workers
- 4) Respiratory protection for those in immediate contact with infected patients.

The engineering controls recommended include:

- 1) The room should be at least 0.25 Pa (0.001-inch w.c.) negative pressure with respect to adjacent spaces
- 2) Airflow should be designed for and tested such that it travels from hallways or anterooms into the patient room
- 3) The exhaust flow should exceed supply air by 10% or a minimum of 0.02m³/s (50 cfm) within the patient isolation room
- 4) The velocity under the door when it is closed should be a minimum of 0.5m/s (100 fpm)
- 5) The dilution ventilation rate should be at least 6 air changes per hour (ACH) and 12 ACH in newer facilitiesⁱⁱⁱ.

The basic design philosophy of TB patient isolation rooms is relatively straightforward: a high ventilation rate within a room is used to dilute and flush the aerosol contaminants. ASHRAE (2003)^{iv} notes that "... The preferred design approach [to airborne infectious isolation rooms] emphasizes air mixing effectiveness and dilution ventilation without attempting to establish unidirectional airflow." The objective here is to maximize the mixing rate. By contrast, CAN/CSA standard Z317.2-01^{vii} requires that there is "b) directional airflow within the room such that clean supply of air flows first to parts of the room where workers or visitors are likely to be present, and then flows across the infection source (i.e., patient area) to the exhaust; c) non aspirating diffusers". This is the opposite to the ASHRAE approach.



Efforts are made to prevent the airborne contaminants from escaping the room by ensuring a net flow into the room at all times and, in some cases, the presence of an anteroom serves as an airlock. In cases where it is not possible to provide adequate dilution, or where additional preventative measures are desired, high efficiency particulate air (HEPA) filtering and ultra-violet germicidal irradiation (UVGI) can be employed.

INFECTION CONTROL

The required performance of a patient isolation room ventilation system is related to providing adequate dilution to reduce the risk that a caregiver may be exposed to an infectious dose. Kowalski et al. (1999)^v provide references that suggest that the infective dose for *M. tuberculosis* is between one and ten bacilli. The number of aerosol particles in the 1 to 5 µm aerosol particle range released by a sneeze is approximately 100,000 and a cough is approximately 1,000 particles^{vi}.

Considering the volume of a typical cough as 0.5 l (0.02 ft³), a patient coughing once in a minute in a typical private room, produces 0.5 l/min. of air laden with 1,000 contaminated particles. A care giver inhales approximately 10 l (0.04 ft³) in a minute. Therefore, to reduce the average number of particles inhaled to 1 per minute, the ventilation system must supply 10,000 l/min (353 cfm) of clean air. For a typical private patient room with a volume of 47 m³ (1,660 ft³) this would result in more than 12 ACH. If every particle coming from the patient is contaminated with between 1 and 10 bacilli, then the risk of infection approaches 1 for a caregiver in the room without personal protection. The model of TB infection rate

by Gammaitoni and Nucciⁱ illustrates this as well. This points out the necessity of having respiratory protection for the caregiver. However, the low level of protection afforded by surgical masksⁱ (<50%) or even HEPA filtered masksⁱ (<98% including leakage) requires an excellent level of ventilation if the combined system is to be successful.

Higher levels of protection and, consequently, lower levels of infection could be obtained if ventilation methods similar to clean room ventilation were employed. However, achieving physical isolation of the patient from the caregiver through air flow is much more difficult than placing a few laminar diffusers above the bed. Entrainment and obstructions can usually create counter flows that negate the desired barrier effect. Similarly, the use of a high ventilation rate in a room does not guarantee that all regions of the room are ventilated at a high rate. Stagnant zones, isolated corners and short-circuiting can lead to a reduction in ventilation efficiency and, as a result, lower effective ventilation rates in large sections of a ventilated room.

In companion Technote #23, the performance of two ventilation designs, one using laminar flow diffusers, and one using high induction diffusers, will be described. The technote illustrates the difficulty with these two methods. It is the opinion of the authors that much more should be done in developing a true particulate barrier between the patient and the caregiver. The barrier must accommodate the procedures to be carried out while maintaining barrier integrity. The most effective method may be a combination of solid barrier and air curtain technologies.

ⁱGammaitoni, Laura & Nucci, Maria Clara 1997.

Using a Mathematical Model to Evaluate the Efficacy of TB Control Measures, *Emerging Infectious Diseases*, Vol. 3, No. 3, pages 335 - 342.

ⁱⁱCDC, 1994.

Guidelines for Preventing the Transmission of Mycobacterium Tuberculosis in Health-Care Facilities, Center for Disease Control and Prevention 1994. MMWR 1994;43(No.RR-13).

ⁱⁱⁱConroy, L.M., Franke, J.E., Dimos, J., Vittallo, J.A., & Lee, S.C. 1997.

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^{iv}ASHRAE, 2003.

HVAC Design Manual for Hospitals and Clinics, Atlanta: American Society of Heating Refrigerating and Air Conditioning Engineers (ASHRAE).

^vKowalski, Wladyslaw, Bahnfleth, William P. & Whittam, T.S.1999.

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^{vi}Duguid, J. P. 1945.

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^{vii}CSA Z317.2 (2003) Special requirements for Heating, Ventilation and Air Conditioning (HVAC) Systems in Healthcare Facilities, Mississauga, Ontario. Canadian Standards Association.

^{viii}Roger Ulrich, Xiaobo Quan, Center for Health Systems and Design, College of Architecture, Texas A & M University. Craig Zimring, Anjali Joseph, Ruchi Choudhary, College of Architecture, Georgia Institute of Technology. Report to The Center for Health Design for the "Designing the 21st Century Hospital Project". This project is funded by the Robert Wood Johnson Foundation. September 2004.



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