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Commentary

Isolation anterooms: Important components of airborne infection control

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Comprehensive airborne infection control systems in health care settings encompass engineering controls, administrative controls, work practice controls, and personal protective equipment. No one of these elements is failure-proof but a redundancy of controls provides the most beneficial strategy. The Centers for Disease Control and Prevention recommends administrative measures, respiratory protection, and engineering (or environmental) controls for preventing the transmission of tuberculosis, the prototypical airborne infection, in health care settings.[1] In its "hierarchy of controls" to deal with workplace hazards, the Occupational Safety and Health Administration recommends engineering measures be prioritized above others.[2] However, the health care environment differs from other industries in that the source and nature of the inhalation hazard (eg, infectious aerosols) is usually not immediately defined. Hence, a major goal of administrative control measures in health care settings is to place potentially infectious patients in appropriate environments where engineering controls and personal respiratory protection can be implemented. Engineering controls support the implementation of permanent changes that are independent of human behavior and most cost effective.[2] Airborne infection isolation rooms (AIIRs), and the anterooms adjacent to AIIRS, clearly fall in the category of engineering controls.

Despite their importance, guidance on the construction of anterooms is less than clear. We provide arguments in support of building anterooms alongside AIIRs. We also review the guidance by various organizations on this topic and urge that the guidelines be made firmer in support of the construction of anterooms for AIIRs.

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IMPORTANCE OF AIIRS AND ANTEROOMS

Anterooms provide a permanent fixture to prevent or minimize escape of contaminated air from AIIRs when the doors are opened and closed. If used properly they can buffer an AIIR from pressure fluctuations in the corridor.[1] Anterooms serve as an additional protective barrier when there is an unintentional entry of personnel without adequate personal respiratory protection into an AIIR. Finally, they serve as a dedicated location for health care personnel to don and doff equipment, thus eliminating unnecessary traffic into an AIIR, and also giving engineers the flexibility to convert negative-pressure rooms to mixed isolation rooms when necessary.

AIIRs are used to house patients with respiratory infections such as tuberculosis, measles, varicella, and other diseases transmitted by the airborne route. AIIRs are maintained at a negative pressure relative to their surroundings so that air flows into the room and not in the opposite direction, theoretically preventing escape of infectious aerosols from the AIIR. Unfortunately, these isolation rooms are not always maintained at a negative pressure. As reported by several studies, AIIRs intermittently develop positive or neutral ventilation pressures.[3-6] One of the most common reasons cited as responsible for loss of pressure differential in isolation rooms is the opening and closing of doors, which happens routinely.[7,8] Simply opening and closing of doors may move tracer gases and particles, surrogates for infectious aerosols, out of patient rooms into the adjacent hallways.[8-10] Even with a negative pressure differential, airflow across open doorways can be counteracted by the turbulence routinely created by the movement of doors and people. Such bidirectional airflows have been shown in laboratory studies to depend on temperature, air density, velocity of door-opening, and the angle to which the door is opened.[11,12]

A demonstration study conducted in a fully operational health care setting evaluated an AIIR's performance while a human subject made routine movements. The presence of an anteroom in this setting reduced the net migration of particles from the isolation

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room into the corridor.[8] Another study demonstrated that air exchange from an AIIR to the surrounding areas often occurs during routine entry or exit, concluding that an anteroom enhances containment.[9] Further, spaces equipped with anterooms have been shown to more effectively maintain a negative pressure differential than spaces without anterooms.[13]

However, critics of anterooms cite a lack of clinical evidence on their effectiveness. There are no published clinical or epidemiologic studies conclusively showing that anterooms diminish or prevent the spread of lab-confirmed airborne infectious human illnesses. Current scientific evidence in favor of anterooms is solely based on models or simulated human traffic where tracer gases and fluorescent microspheres have been used as surrogates of small infectious particles. More studies on AIIR containment efficacy in realistic hospital environments, with and without anterooms, would be the most ideal. Unfortunately, studies requiring realistic clinical data, which might be more convincing, are challenging and expensive. Many of these studies are ethically questionable because they call for exposing human beings to different standards of protection in the presence of human pathogens. But still, “absence of evidence is not evidence of absence.”[14]

The general perceived notion about these rooms is that they are an extra space that is of not much use. Some opponents of anterooms also cite the added cost ($5,000-$20,000) required for their construction as an additional burden on already stringent budgets. On the other hand, if a facility’s risk assessment has determined a need to build AIIRs to protect staff and patients, it would be imprudent, perhaps even disingenuous, to build isolation rooms that are known to fall short of expectations, especially when the cost of building anterooms is modest compared with the cost of a whole facility or the cost of adverse clinical outcomes over the entire lifespan of a building.

A CASE STUDY

Although the above arguments may be valid, the case study described below further signifies the possible role anterooms may play in hospital infection control.

In a recent case in the United Kingdom a 62-year old white man was hospitalized with a severe case of chickenpox that required intensive care.[12] Despite aggressive treatment that drew on all available resources, the patient’s pneumonia relentlessly progressed and he died of multi-organ failure. Hospital staff members caring for this man followed infection control precautions carefully, including observing a policy permitting only those who were chickenpox-immune to enter his room. Yet 1 nurse who worked in the same intensive care unit developed chickenpox 10 days after this patient was hospitalized. Importantly, this nurse did not have a personal history of chickenpox, so he made certain to never enter the room housing the patient infected with the chickenpox virus. This nurse did acknowledge that he handed equipment to coworkers several times per day through the open doorway of the isolation room housing the patient with chickenpox. He did not wear personal protective equipment because the patient’s room was equipped with negative pressure ventilation, drawing air away from the hallway into the patient’s room in a fashion that should have spared this nurse any exposure. However, laboratory analyses strongly suggested nosocomial transmission, and modeling revealed that opening the patient’s door may have resulted in retrograde airflow and inadvertent exposure, despite the use of negative pressure ventilation.[12] Even though the room was maintained at a negative pressure differential of 3 Pa, rapid door opening may have caused the pressure gradient to transiently reverse.[12] The patient room in this case did not have an anteroom. The fundamental question is, What if the AIIR had been equipped with an anteroom? Would an anteroom have prevented inadvertent exposures in this setting? And what if the patient had been infected with H5N1 influenza, severe acute respiratory syndrome, smallpox, or another deadly virus; would the absence of an anteroom have been acceptable?

We propose that anterooms are key components of infection prevention and control and must always be considered in the design and operation of AIIRs in the setting of health care delivery.

GUIDANCE ON ANTEROOM USE

There is a lack of consistency in construction guidance for AIIR anterooms across various professional organizations and federal agencies. Table 1 summarizes the recommendations by various US and international agencies and organizations on isolation anteroom requirements.[15-20] Negative pressure isolation rooms in both the United Kingdom and some states of Australia are required to have anterooms between patient AIIRs and adjacent corridors, but in the United States they are not required. A recent recommendation in the UK incorporates a modified design of an isolation room called a Positive Pressure Ventilated Lobby room.[12] If anterooms are included in the design, US guidelines, similar to Australian guidelines, call for isolation rooms to be maintained at a negative pressure compared with the anteroom and, in turn, the anteroom to be maintained at a net negative pressure compared with the corridor.

In contrast, UK guidelines call for the anteroom referred to as “vestibule or lobby” to be positively pressurized (at 10 Pa) compared with both the corridor and the isolation room, positioning the lobby to act as an air-block (ie, barrier) that prevents movement of contaminated air between the isolation room and corridor. In this case, the isolation room is maintained at a quantitatively neutral pressure with respect to the corridor, whereas the en-suite (ie, private bathroom) is negatively pressurized. This arrangement positions the lobby to serve as a barrier to particles passing in either direction—into or out of the room—making the space suitable for use as an AIIR, protective environment, or AIIR/protective environment room.

Even though anteroom inclusion makes intuitive sense, US professional organizations do not categorically call for their inclusion in isolation room design, even when housing patients with airborne-transmissible infections. Instead, US guidelines generally leave the decisions to each local facility based on their perceived need. According to the Facility Guidelines Institute, “[an] anteroom is not required for airborne infection isolation (AII) rooms”[15]; however, if an anteroom is part of the original design, the Institute still specifies these requirements. American Society of Heating, Refrigerating and Air Conditioning Engineers guidance states “[an] anteroom is not required [but] some isolation rooms may be provided with a separate anteroom,”[16] whereas the Centers for Disease Control and Prevention/Healthcare Infection Control Practices Advisory Committee guidelines state “AII rooms can be constructed either with or without an anteroom.”[17] One instance when anterooms are recognized as essential by most of these organizations is when combination airborne isolation and protective environment rooms are used to house infected patients with dysfunctional immune systems.

Despite available evidence showing the value of anterooms, the ambiguous nature of recommendations by various agencies for inclusion of anterooms leads many decision makers to undervalue their inclusion. Such decisions may be unwise and might prove costly if a highly virulent pathogen is encountered—anterooms might offer an added layer of protection.

Table 1
Airborne infection isolation room (AIIR) anteroom requirements recommended by various organizations

Organization	Recommendations for anteroom	Pressure recommendations
The Facility Guidelines Institute (2010)[15] Includes ANSI/ASHRAE/ASHE Standard 170-2008, Ventilation of Health Care Facilities	• Anteroom is not required for AIIRs; however, if anteroom is part of the design concept, it specifies requirements (Page 49, Section 2.1-2.4.2.3) • Anteroom is required for combination AIIR/PE room that houses profoundly immunosuppressed patients with prolonged neutropenia (eg, patients undergoing allogenic or autologous bone marrow/stem cell transplants) who have an airborne infectious disease (Page 92, Section 2.2-2.2.4.5)	• When an anteroom is provided for an AIIR, airflow shall be from the corridor into the anteroom and from the anteroom into the patient room (Page 65, Section 2.1-8.2.2.1) • The airflow pattern for a AIIR/PE anteroom will either be from the anteroom to both the patient room and the corridor, or from both the patient room and the corridor into the anteroom (Page 172, Section 2.2-8.2.2.3) • For other ventilation requirements refer to Part 6, ASHRAE 170
ASHRAE170 Ventilation of Health Care Facilities,[16] ANSI/ASHRAE/ASHE approved (2008)	• Anteroom is not required by this standard. Some isolation rooms may be provided with a separate anteroom (Section 7.1, Part e) • If the design criteria indicate that AIIR is necessary for PE patients, an anteroom should be provided. Rooms with reversible airflow provisions for purpose of switching between protective environment and AIIR functions shall not be permitted (Section 7.1, Part t) • The AIIR described in this standard shall be used for isolating the airborne spread of infectious diseases, such as measles, varicella, or tuberculosis (Section 7.1, Part u)	• For AIIRs pressure relationship to adjacent areas must be negative and shall have a minimum of -0.01 water gauge (-2.5 Pa) minimum outdoor ACH is 2 and minimum total ACH is 12 (Table 7-1, Section 7.2.1) • For isolation anteroom no requirements are mentioned for pressure relationship to adjacent areas and no minimum outdoor ACH. However minimum total ACH is 10 (Table 7-1)
CDC/HICPAC Guidelines for Environmental Infection Control in Health-Care Facilities (2003)[17]	• Recommends negative pressure rooms or AIIRs with anterooms for patients with viral hemorrhagic fever (Page 12) • AIIRs can be constructed either with or without an anteroom (Page 36)	AIIR with anterooms (Pages 37-38) • Pressure differential of 2.5 Pa (0.01-in water gauge) measured at the door between patient room and anteroom • ACH $\geq$12 (for renovation or new construction), 6 for existing areas • Clean-to-dirty airflow
AIA Guidelines for Design and Construction of Healthcare Facilities (2006)[18]	• The anteroom concept should remain an option (ie, not required) and should be designed so as to prevent air from the patient room from escaping to the corridor or other common areas (A3.2.2.4[4]) • Anteroom required when an immunosuppressed patient requires airborne infection isolation (protective environment/airborne infection isolation) (A3.2.3b, Page 44)	• Anteroom for an AIIR/PE room can be ventilated with either of following airflow patterns (A3.2.3c, Page 44): 1) Airflows from anteroom, to patient room and the corridor, or 2) Airflows from the patient room and the corridor, into the anteroom 3) Minimum total ACH is 10 (Table 2.1-2) • Pressure differentials for AIIRs shall be a minimum of 0.01-in water gauge (2.5 Pa). Air movement relationship to adjacent areas is into the room. Minimum total ACH is 12. Minimum outdoor ACH is 2 (Table 2.1-2, Pages 130 and 132)
National Health Service (United Kingdom standard) Isolation facilities in acute settings (2005)[19]	• Isolation room is known as positive pressure ventilated lobby room. It is an enhanced single room with a positive pressure ventilated entry lobby and en-suite facilities (with extract ventilation) that enables the suite to be used for both source and protective isolation without need for switchable ventilation (Sections 1.6 and 2.9)	• Isolation room pressure differential to corridor is nominally 0, ACH 10 • Lobby/vestibule pressure differential with respect to corridor is +10 Pa, ACH 63 (for bed access lobby) and ACH 69 (for personnel access lobby) • En-suite pressure differential to isolation room is negative, ACH 10 • Ventilated lobby acts as barrier to contamination passing in or out of isolation room (Table 1 Chapter 4)
Victorian Advisory Committee on Infection Control (Australian standard) Guidelines for the classification and design of isolation rooms in health care facilities (2007)[20]	• Recommends an anteroom for Class N (negative pressure) rooms. Negative pressure rooms are used for persons known or suspected to have infections requiring airborne precautions (eg, chicken pox, measles and infectious pulmonary and laryngeal tuberculosis) (Summary, Table 1, Section 4.3) • Negative pressure gradient must be maintained from the room to the anteroom and the ambient air (Section 2.2)	• The minimum differential pressure between the isolation room and adjacent ambient pressure areas should be 30 Pa if the room has an anteroom, and 15 Pa if the room does not have an anteroom. The gradient between successive pressure areas should not be less than 15 Pa (Section 5.2) • Recommends ACH 12 for negative pressure rooms(Section 2.2)

ACH, air change per hour; *AIA*, American Institute of Architects; *ANSI/ASHRAE/ASHE*, American National Standards Institute/American Society of Heating, Refrigerating, and Air-Conditioning Engineers/American Society for Healthcare Engineering of the American Hospital Association; *CDC/HICPAC*, Centers for Disease Control and Prevention/Healthcare Infection Control Practices Advisory Committee; *PE*, protective environment.

CONCLUSIONS

The emergence of drug-resistant tuberculosis and the unexpected occurrences of the severe acute respiratory syndrome epidemic and the H1N1 influenza pandemic unequivocally affirm the importance of sound airborne infection prevention and control programs. The insidious threats of another influenza pandemic, bioterrorism, or the emergence of a novel airborne virus with a high fatality rate should be sufficient to convince health care administrators to ensure their facilities are equipped with robust and redundant isolation and infection prevention capabilities. AIIR anterooms may not be the single most important defense against airborne infections, but available evidence indicates they play an important role. Health care facilities must adopt a precautionary approach and include anterooms in the design and planned construction of isolation rooms. We call on the different professional and regulatory agencies to revise their guidelines and firmly require anterooms for all AIIRs.

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