A performance assessment of airborne infection isolation rooms

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Background: Airborne infection isolation rooms (AIIRs) help prevent the spread of infectious agents in hospitals. The performance of 678 AIIRs was evaluated and compared with construction design guidelines.

Methods: The pressure differentials (ΔP) between the isolation rooms and adjacent areas were measured, and ventilation and construction details were recorded for each room. Ultrafine particle concentrations were evaluated in the rooms, surrounding areas, and ventilation systems serving the rooms. Measurements were analyzed as a function of room parameters.

Results: Only 32% of the isolation rooms achieved the recommended ΔP of −2.5 Pascals (Pa) relative to surrounding areas. AIIRs with solid ceilings had an average ΔP of −4.4 Pa, which was significantly higher than the average ΔP of −2.0 Pa for rooms with dropped ceilings (P = .0002). Isolation room ultrafine particle concentrations were more highly correlated with particle levels in surrounding areas ($R^2 = 0.817$) than in the ventilation systems serving the rooms ($R^2 = 0.441$). Almost all ventilation filters serving AIIRs collected fewer particles than anticipated.

Conclusion: The results indicate that hospitals are not all maintaining AIIRs to correspond with current guidelines. The findings also support the contention that having tightly sealed rooms helps maintain appropriate pressure differentials. (Am J Infect Control 2007;35:324-31.)

To limit airborne transmission of infectious agents in health care facilities, heating, ventilating, and air-conditioning (HVAC) systems are used to establish airborne infection isolation rooms (AIIRs). Properly functioning AIIRs require consistent negative-pressure differentials relative to the surrounding areas and sufficient air changes per hour.

HVAC systems provide fresh, conditioned, and filtered air to a building through supply ducts. Air-handling units move air through the system. Filters in an air-handling unit are a main line of defense against the spread of infectious disease in hospitals. Filter manufacturers rate their products according to the type of test conducted to determine the efficiency of the filters. The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) dust spot efficiency rating measures a filter's ability to capture atmospheric dust particles.[1] The rating is given as the percentage of particles collected. Generally, standard prefilters are rated between 20% and 40%, whereas final filters may be rated above 80%. High-efficiency particulate air (HEPA) filters capture at least 99.97% of 0.3-μm diameter particles.

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In addition to the supply ductwork, a system of return or exhaust ductwork is also found within a building. At many facilities, air exhausted from AIIRs is expelled directly outdoors. In others, exhausted air is passed through HEPA filters before it is returned to the supply system to limit the spread of infectious agents within the facility. AIIRs operate by having the return ducts remove air from the rooms at higher rates than the supply ducts add air. To balance the flows, air enters from outside an AIIR through cracks under doors or other points of entry. This creates a slight negative pressure within the AIIR relative to the surrounding areas.

Streifel and Marshall[2] indicated that the most important parameters for an AIIR are room pressure, room ventilation rate, filtration, and directed airflow. Streifel et al[3] concluded that self-closing doors and permanently sealed windows are critical for maintaining adequate pressure differential. The American Institute of Architects (AIA),[4] which publishes design guidelines considered to be the standard of care for new isolation rooms, stressed these parameters and others considered essential for construction or renovation of AIIRs. The Centers for Disease Control and Prevention (CDC)[5] also emphasized ventilation controls and recommended infection control procedures that should be implemented when patients require these rooms.

A few researchers have investigated the performance of AIIRs. Using smoke sticks, Fraser et al[6] found that 45% of 115 negative-pressure isolation rooms tested were actually positively pressured relative to surrounding areas. When evaluating tuberculosis isolation rooms, Sutton et al[7] determined that 28% of 25 rooms evaluated were positively pressured. Similar qualitative analyses by Pavelchak et al[8] indicated that 38% of the 140 AIIRs they evaluated exhibited outward flow from under the door. One deficiency that contributed to problems in these rooms was that continuous airflow monitoring equipment did not function properly. Using a micromanometer, Rice et al[9] measured pressure differentials for 4 AIIRs for 2- to 3-month periods in both summer and winter. Although the mean pressure difference was −0.3 Pa, measurements ranged from −1.3 Pa to +0.7 Pa. All of these studies indicated that improperly functioning AIIRs are common.

With increasing concerns about bioterrorism and emerging infectious diseases, more attention has been given to the proper functioning of AIIRs in preparation for disease outbreaks. The purpose of this study was to evaluate the operation of AIIRs in hospitals in a post-9/11 environment and in comparison with the most recent recommendations issued by the AIA and the CDC. To fulfill this purpose, the study had 4 specific aims: (1) establish benchmarks to evaluate AIIR performance; (2) develop a questionnaire to provide preliminary information about participating hospitals, their HVAC systems, and their AIIRs; (3) visit each participating hospital to make measurements and record observations; and (4) analyze data from the questionnaires and site visits.

METHODS

The first 3 aims were data collection steps. Methods for accomplishing these aims will be discussed first. Approaches for analyzing the data, the fourth aim, will be discussed afterward.

Data collection

Benchmarks for AIIR performance were based on what the authors viewed as the most critical parameters in AIA and CDC recommendations.[4,5] These 6 "essential" parameters are shown in Table 1.

The next task was to develop an on-line questionnaire for hospitals to complete before site visits. The purpose of this questionnaire was to acquire important information regarding a hospital and its AIIRs before a site visit to help plan the visit and decrease the time needed for the visit. Because the questionnaire was used for broader purposes than the study discussed here, it contained sections not only about AIIRs in emergency departments and other patient care areas but also sections on portable HEPA filter machines, portable anterooms, mobile isolation transport systems, surge capacity areas, and emergency department triage and holding areas.

Table 1. Critical parameters for benchmarking AIIR performance.

All AIIRs should ...
1. Have a negative pressure differential between the isolation room and the surrounding areas of at least 2.5 Pa[4,5]
2. Have at least 12 air changes per hour[4,5]
3. Have self-closing doors leading into the isolation rooms[4,5]
4. Have a permanently installed pressure monitor[4]
5. Not have a system installed allowing the room to switch from negative to positive pressure or function as both an isolation room and a protective environment room[4,5]
6. Have ASHRAE dust spot tested filters of at least 90% efficiency installed in the supply air unit that serves the AIIR[4,5]

Performance relative to parameters 2 and 4 in Table 1 was self-reported by the hospitals on the survey. Air changes per hour (ACH) in the AIIRs were self-reported by the hospitals rather than being measured during the site visit because of time considerations. In some cases, the ACH were measured by facility staff. In others, the reported values were design specifications. However, many facilities had no information about the air-change rates in their AIIRs.

Upon completion of the surveys, site visits were conducted. The AIIRs and air-handling units serving them were inspected visually and measurements were taken by the researchers to assess parameters 1, 3, 5, and 6 in Table 1 and to confirm responses for parameter 4. Other nonessential parameters, discussed below, were measured as well.

The pressure differential was measured using a DG-700 Pressure and Flow Gauge (The Energy Conservatory, Minneapolis, MN) sensitive to 0.1 Pa. A 6-inch metal probe was attached to the unit by a 12-inch length of tubing. The probe was inserted through the undercut of the closed door leading to the area that was to be measured. After the instrument came to equilibrium, a 5-second average of the pressure differential was recorded. The pressure differentials for all of the doors leading to the isolation room were measured, including the door from the corridor to the anteroom, when present, and the door from the anteroom to the isolation room. If the AIIR had doors to both an anteroom and a hallway, the pressure differential to the hallway was recorded. When access to an AIIR was strictly through an anteroom, the pressure differential for the AIIR was recorded as the greater of the differential from the hallway to the anteroom or the differential from the anteroom to the isolation room.

In addition to measuring the pressure differential of the isolation room, particle number concentrations were measured inside the isolation rooms using a P-Trak Ultrafine Particle Counter (TSI Inc., Shoreview, MN), which counts particles with diameters ranging from approximately 0.02 to 1 μm. This size range includes individual viruses and smaller bacteria. Particles were measured in occupied isolation rooms by inserting a telescoping wand that adjusts from 18 inches to 3 feet through the undercut of the door. The real-time particle concentrations were observed until the displayed concentration was steady, after which a 10-second average measurement was taken. For AIIRs that were not occupied, the room was entered, the particle counter was allowed to come to equilibrium, and a measurement was collected. Particles were also measured in the corridor outside of the isolation room.

Room parameters relevant to the AIIRs were recorded. The ceiling type of the isolation room, anteroom, and bathroom were observed and recorded as either dropped (acoustic laid in) or solid (hard or plaster). The type of ventilation serving the isolation room, anteroom, and bathroom was also recorded, eg, supply only, supply and exhaust, exhaust only, or none. Whether the door leading to the isolation room was self-closing or not was marked. Finally, whether the room was used as a protective environment for immunocompromised patients as well as an AIIR was recorded.

Air-handling units that served 1 or some of the patient care areas in the hospitals were inspected. The facilities engineer was asked for the percentage of air being recirculated in the system versus fresh air, the ASHRAE-rated filtration efficiency of the installed filters, and the areas served by the air-handling unit. The efficiency of the filters in the air-handling units was measured using the P-Trak. For air-handling units with predrilled service ports, the probe of the particle counter was inserted into the duct and allowed to come to equilibrium. A 10-second average concentration was then measured. For units that did not have predrilled ports, measurements were collected from the downstream side of the filter bank with the access door slightly ajar to allow the probe into the unit. Air downstream from the filter flowed out of the door with sufficient velocity to prevent any contaminant air from the surrounding area to enter and skew the results. Measurements were not collected from the mixing chambers upstream from the filter bank if access ports were not available because of the drawing of air from outside of the system. For sufficiently large ventilation systems, the unit was physically entered and the door closed. Ten-second average measurements were then measured after the P-Trak had come to equilibrium.

Data analysis

The data set included measurements and observations for 678 AIIRs. Only partial data were available for many of the rooms.

Summary statistics were calculated for the factors evaluated. For pressure differential and ACH, the percentages of rooms meeting the recommendations, average values, and standard deviations were determined. For self-closing doors, permanently installed pressure monitors, rooms that switched from negative to positive pressure, and air-handling units having ASHRAE-tested filters of at least 90% dust spot efficiency installed, the percentages of rooms meeting the recommendations were determined.

The efficiencies of the filters installed in the air-handling systems measured using the P-Trak were calculated using the equation

$$\eta_{\text{filter}} = 100\times\left(\frac{c_{\text{pre}}-c_{\text{post}}}{c_{\text{pre}}}\right) \quad (1)$$

in which η_{filter} is the filter efficiency, c_{pre} is the particle concentration upstream from the filters, and c_{post} is the particle concentration downstream from the filters.

An initial data set including the first 55 AIIRs visited was evaluated statistically to determine whether any correlations existed between pressure differential or isolation room particle concentrations and various room parameters. Based on these results, the null hypotheses shown in Table 2 were developed and tested with data from as many AIIRs as possible from the full data set.

Hypothesis 1 was tested using both a 2-sample *t* test assuming unequal variances and the Mann-Whitney *U* nonparametric test. For hypotheses 2 to 5, relationships between variables were compared using linear regression. *P* values for slope and intercept were calculated, and correlation coefficients (R^2) were determined. Particle concentration data used to test hypotheses 3 and 4 were converted to the logarithm of particle concentration because the readings appeared to be distributed lognormally. For the single data point with zero particles, which would be undefined when its logarithm was taken, a particle concentration of 0.5 particle/cm^3 was utilized for conversion to a logarithmic value. Most air-handling units served more than 1 isolation room. Therefore, to test hypothesis 3, the logarithm of particle concentration downstream from an air-handling unit was compared with the logarithm of the average of the particle concentrations in the rooms served by that air handler. For hypotheses 6 to 9, χ^2 analyses were used to determine whether meeting the guidelines for various room variables had a significant impact on meeting the recommended pressure differential of -2.5 Pa.

The numbers of rooms for which data were available for each test are listed in Table 2. These numbers are lower than the 678 rooms in the database because of incomplete self-reporting of data by the hospitals and, in just a few cases, errors in measurements. The number of comparisons for hypothesis 3 is small because of the aforementioned averaging of particle concentrations for AIIRs served by a single air-handling unit.

RESULTS

The data collected from all hospitals were compared against the current design guidelines[4,5] to determine the percentages of isolation rooms operating according to current standards. These results are presented in Table 3. Only 32% of the rooms assessed were found to have the recommended pressure differential of −2.5 Pa. In addition, 58 rooms, approximately 9% of those evaluated, were positively pressurized.

Isolation rooms with solid ceilings had an average pressure differential of −4.4 Pa, which was significantly higher than the differential of −2.0 Pa measured for rooms with drop ceilings according to the 2-sample *t* test with unequal variances ($P = .0002$). The difference in the distribution of pressure differentials was also significant by the Mann-Whitney *U* test ($P = .0002$). The pressure differentials for isolation rooms with solid ceilings were found to have a significantly higher variance, 56.3 Pa^2, than those for rooms with drop ceilings, 12.2 Pa^2 ($P < .0001$).

A regression was performed to determine whether ACH was a significant predictor of pressure differential (ΔP). When this relationship was evaluated for 366 rooms that had data for both ΔP and ACH, a significant relationship was found ($P = .021$). However, the relationship with air-change rate explained only a small portion of the variance in ΔP for the complete data set ($R^2 = 0.015$). Figure 1 shows the data for pressure differential plotted against air-change rate. The regression line for the data is shown together with a dark shaded region representing the 95% confidence band for the prediction of the line. The lighter shaded region represents the 95% prediction band for estimating ΔP for a single AIIR if information about its ACH already exists.

We conducted χ^2 tests to determine whether room and ventilation parameters could affect the likelihood that AIIRs achieve the recommended pressure differential of −2.5 Pa. The associations of 2 parameters with pressure differential were significant statistically. Rooms with at least the recommended 12 ACH achieved the recommended pressure differential 37.6% of the time, whereas rooms with less than 12 ACH achieved the recommended pressure only 22.8% of the time ($\chi^2 = 9.56$, $P = .0020$). In addition, 43.3% of AIIRs with solid ceilings achieved the recommended pressure differential compared with only 28.5% of rooms with drop ceilings ($\chi^2 = 11.86$, $P = .0006$). Significant associations with meeting the recommended pressure differential were not found for having permanently sealed windows ($\chi^2 = 2.15$, $P = .14$) or for the presence of an anteroom ($\chi^2 = 0.05$, $P = .83$).

Table 2. Null hypotheses tested statistically and number of observations used in each analysis

1	The type of ceiling does not influence the negative pressure differential of the isolation room.	n = 634
2	Air changes per hour do not influence the negative-pressure differential of the isolation room.	n = 366
3	Isolation room particle concentrations are not influenced by particle concentrations in the air that is supplied to the room.	n = 107
4	Isolation room particle concentrations are not influenced by particle concentrations in air from surrounding areas, eg, anterooms or corridors.	n = 569
5	Filtration efficiency measured with the P-Trak corresponds to the ASHRAE-rated filter efficiency.	n = 112
6	Having the recommended ACH does not have a significant influence on achieving the recommended pressure differential.	n = 366
7	Having an anteroom does not have a significant influence on achieving the recommended pressure differential.	n = 666
8	Having permanently sealed windows does not have a significant influence on achieving the recommended pressure differential.	n = 582
9	Having solid ceilings does not have a significant influence on achieving the recommended pressure differential.	n = 634

Airflow relationships were studied further by investigating ultrafine particle concentrations. The relationship between logarithms of particle concentrations in the isolation rooms and logarithms of particle concentrations directly after the final filters in air-handling units supplying the rooms was analyzed. The relationship, shown in Fig 2 for a total of 107 pairs of data, was significant ($P < .0001$) with an R^2 of 0.441. The Figure shows the data, a 1:1 line, and a regression line for the data with 95% confidence bands. The AIIR particle concentrations were generally higher than the postfilter concentrations, especially when the postfilter counts were low. The regression line was significantly different from the 1:1 line.

The relationship between logarithms of particle concentrations in hallways or anterooms adjacent to the door of the AIIRs was also compared with the logarithms of particle concentrations in the AIIRs. Results are presented in Fig 3 for the 569 pairs of data. The relationship was significant ($P < .0001$) with $R^2 = 0.817$. The 1:1 line falls within the narrow 95% confidence bands for the regression line.

Although 93% of the air-handling systems assessed had the proper ASHRAE-rated final filters installed, few of these filters performed at the rated filtration efficiency. The filter efficiency calculated according to

Table 3. Performance of AIIRs agent functional criteria

Functional criteria	Percentage of rooms meeting the functional criteria (n = number of rooms evaluated for a criterion)
Pressure differential between isolation room and surrounding areas greater (more negative) than 2.5 Pa	32% (n = 672)
At least 12 air changes per hour	51% (n = 370)
Permanently installed pressure monitor	76% (n = 566)
Ventilation system does not allow room to be used for infectious isolation and protective isolation	90% (n = 560)
Self-closing doors are installed	36% (n = 621)
Final filters are rated at ≥90% efficient	93% (n = 403)

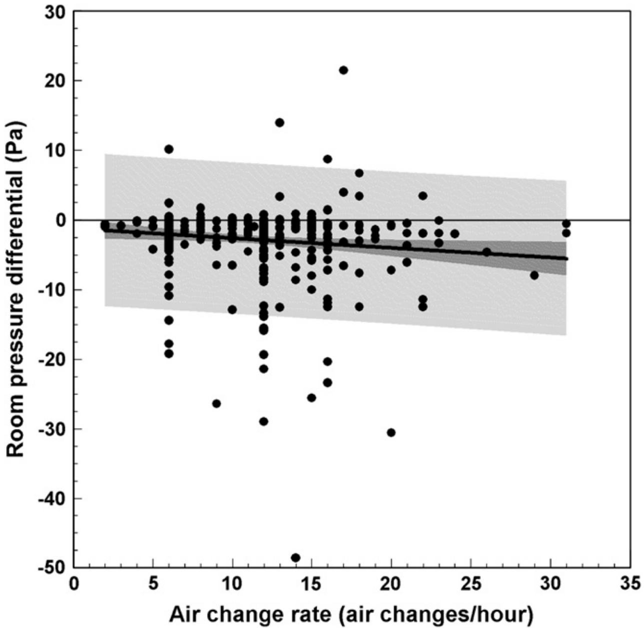

Fig 1. Pressure differential versus air changes per hour. The thick line represents the regression between the 2 variables. The dark shaded region is the 95% confidence band for the mean value of pressure differential at each air-change rate. The light shaded region is the 95% prediction band for an individual room's pressure differential if the air-change rate for the room is known.

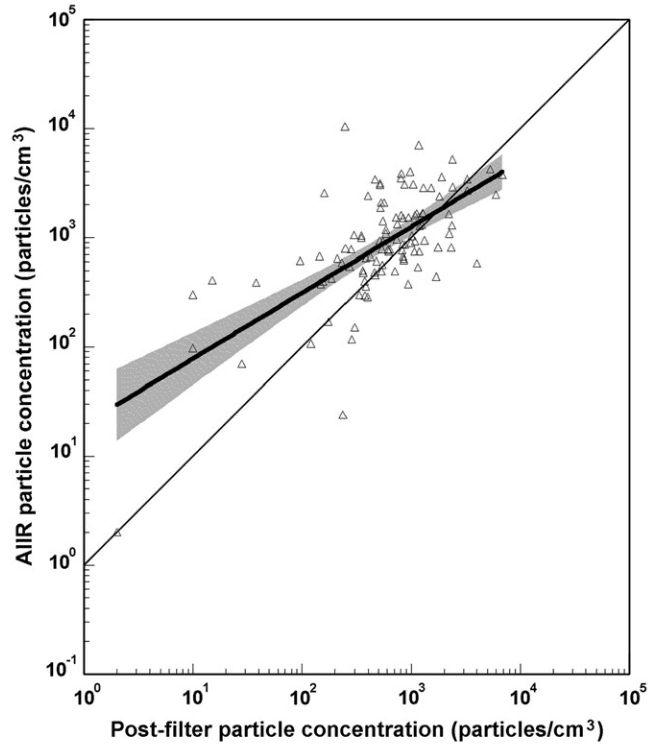

Fig 2. Open triangles represent particle concentrations in the AIIRs versus particle concentrations immediately downstream from the filters in the air-handling units serving the AIIRs. The thick line represents the regression between the 2 variables. The shaded region is the 95% confidence band for the regression line. The 1:1 line is also displayed.

equation 1 was less than the rated efficiency for 107 of 112 filter banks tested. A geometric average of the change in particle penetration indicated that filters allowed, on average, 437% more particles to penetrate than ratings would have indicated. This value was significant statistically ($P < .0001$). Figure 4 shows the relationship between measured and rated efficiencies of the filters.

The trend indicating that installed filters are not operating as specified was particularly noticeable for the HEPA filters that were tested. Of 9 filter banks with HEPA filtration, none reached the 99.97% efficiency required for HEPA status, although 1 was close. In fact, only 4 of the 9 filter banks achieved 99% efficiency.

DISCUSSION

Results in Table 3 indicate that not all hospitals are operating AIIRs that meet today's standards. If it is accepted that the current standards reflect essential

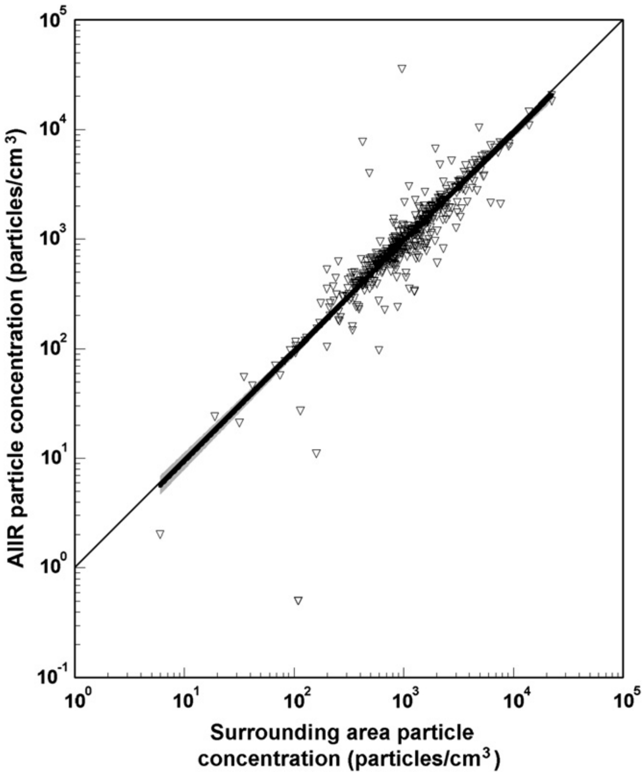

Fig 3. Open triangles represent particle concentrations in the AIIRs versus particle concentrations in the areas adjacent to the AIIRs. The thick line represents the regression between the 2 variables. The shaded region is the 95% confidence band for the regression line. The 1:1 line is also displayed.

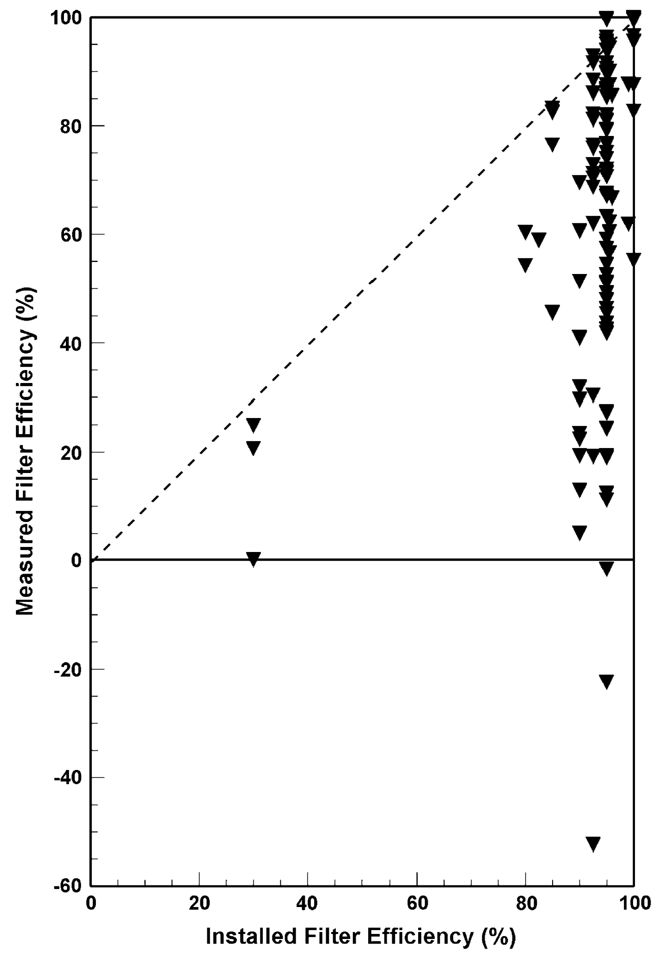

Fig 4. Triangles represent measured filter bank efficiency in air-handling units serving AIIRs versus dust spot efficiency reported by manufacturers. The dashed line is a 1:1 relationship between measured efficiency and manufacturer-reported efficiency.

criteria, facility managers should assure the functionality of their AIIRs. Hospitals should strive to achieve the ventilation criteria recommended by the AIA and the CDC, an effort that is sometimes difficult because of the expense of renovations versus the expected risk related to the current condition of their AIIRs. However, a response is too late once an infectious patient enters a health care facility. Best practice includes preparation and response development appropriate to the risk. Although risks are uncertain for many infectious agents, risk management principles are already used to prepare protocols for more common agents, such as *Mycobacterium tuberculosis*, to assure that infectious disease management components are ready at any time.

Although the finding that 9% of rooms were positively pressurized is disturbing, this value is an improvement over the percentages of rooms measured as positively pressured in earlier investigations.[6-8] One possible explanation for this reduction in the percentage of positively pressured rooms is that hospitals are learning over time how to make their AIIRs function more effectively. Other potential explanations include the better pressure measurement techniques used in this study and the capabilities and resources of the population of hospitals evaluated in this study.

Rooms with laid-in ceilings are more likely to have air leakage because of wire chases and pipe runs. This may be the reason that AIIRs with solid ceilings have a higher pressure differential on average. Tighter construction in AIIRs may help hospitals attain the desired pressure differential.

The poor correlation between ΔP and ACH suggests that, despite the statistically significant relationship, air-change rate was not a good predictor for pressure differential. In Fig 1, the narrowness of the confidence band indicates that the mean value of ΔP at each ACH is well understood for the AIIRs tested. However, like the poor correlation coefficient, the width of the prediction band indicates that air-change rate is almost useless for predicting the pressure differential for an individual room. These results indicate that simply increasing exhaust flow from an AIIR, which increases ACH, in an attempt to increase pressure differential may be ineffective.

Although having a high air-change rate in an AIIR does not by itself mean that the room will adequately protect health facility staff, patients, and visitors, high ventilation flows may have other important benefits. Facilities that exceed the recommended 12 ACH should be able to achieve the recommended negative-pressure differential of −2.5 Pa by checking for leakage and sealing areas in the room while adjusting the ventilation balance, if necessary. Having more airflow to work with should allow a ventilation system balancer to achieve the recommended negative ΔP more easily. In addition, adequate airflows are important for minimizing air migration out of AIIRs when their doors are opened.[10]

Although results from the χ^2 tests show that anterooms may not significantly influence the steady-state pressure differential of AIIRs, their importance in limiting the migration of air from the AIIR to the corridor when doors are opened has been documented.[3]

Figures 2 and 3 indicate that AIIR particle concentrations are more closely related to particle concentrations in surrounding areas than to concentrations in the air supplied to the rooms by the HVAC system. Experimental factors may have influenced this result. Some unoccupied isolation rooms were entered, and the measured particle counts may reflect the air that was drawn into the room when the door was opened. For those rooms that were not entered, the probe was inserted through the undercut of the door. The particles sampled in this way may reflect concentrations influenced more directly by air penetrating under the door than concentrations in the rest of the room.

The apparent influence of surrounding area particle levels on the isolation room concentrations is important from an infection control standpoint. The closer correlation between AIIR and surrounding area particle concentrations than between AIIR and postfilter concentrations suggests that more of the air entering the AIIR is coming from the surrounding areas than from the supply air. This, in turn, suggests that typical AIIRs have many leaks where air can enter the room. Such leaks make the attainment of a satisfactory pressure differential difficult, limit the maximum pressure differential that can be attained, and require the use of a greater exhaust flow than would otherwise be necessary. The result also suggests that the areas surrounding AIIRs should be supplied with air that has passed through 90% efficient filters.

The filter efficiencies measured in the air-handling units are typically lower than the efficiencies indicated by manufacturers. Some of the lower measured efficiency may be linked to the utilization of the ultrafine particle counter to evaluate efficiency in this study versus methodology for the ASHRAE dust spot efficiency rating. Although the diameters of particles measured during the dust spot procedure and using the P-Trak overlap, the particle sizes assessed using the P-Trak are smaller on average. Whether this particle size difference has a positive, a negative, or no bias on the relationship of the 2 efficiency measures is uncertain. However, the anticipated extent of any measurement bias cannot account fully for the differences observed in Fig 4.

Much of the reduction in filtration efficiency of the tested filters is likely due to predictable changes in the efficiency of HVAC filters. Raynor and Chae[11] found that, over a 19-week period, filters made from synthetic fibers that carry electrostatic charges exhibited substantial efficiency losses as they became loaded with particles in an operating HVAC system. The findings could also mean that filters are not being installed properly, leaving gaps between filter housing and filter racks through which particles can penetrate. As hospitals install higher efficiency filters, this becomes even more important because of the greater pressure drop across the higher efficiency filters. Increased pressure drop will cause air to bypass the filters via gaps between filters and degraded filter seals more easily than with less efficient filters with lower pressure drop.

For several points in Fig 4, the measured efficiency was found to be less than zero, indicating the possibility of particle resuspension or generation downstream from filter banks. This could be related to unclean ductwork or overly dusty filters.

The finding that even HEPA filters are not reducing particle levels as much as anticipated may have important consequences for those hospitals that use HEPA filtration before recirculating potentially contaminated air exhausted from AIIRs to hospital environments. If this air is not being filtered properly, opportunities for airborne transmission are more likely. In addition, HEPA filters are counted on in other parts of hospitals to reduce levels of infectious agents. For example, HEPA filters are used in operating suites to protect patients from airborne agents. A significant health concern may be posed if users assume these filters collect all particles with at least 99.97% efficiency. The installation of HEPA filters in operating suites must be managed to ensure an aseptic environment for the patient.

CONCLUSION

Not all hospitals are prepared to meet current airborne infectious disease standards. This is not necessarily surprising given the fact that there are no rules or incentives in place for hospitals to make these expensive renovations. The organizations responsible for accrediting health care facilities should consider inspecting some of the important ventilation parameters involved with AIIRs.

The majority of AIIRs tested in this study did not achieve the negative-pressure differential of 2.5 Pa recommended by the AIA. In addition, results indicated that AIIRs with drop ceilings are less likely to achieve the recommended pressure differential than those with solid ceilings. The "tightness" of the room should be considered when constructing or renovating AIIRs.

It is a concern that hospital ventilation systems are often not filtering particles at the expected efficiency for the installed filters. Means and methods for facilities and infection control staff should be developed to ensure that the air filters are properly installed in their HVAC systems and that they are changed at regular intervals.

The information obtained from this study is valuable in developing a risk mitigation plan in case of emerging or pandemic infectious diseases. The federal Bioterrorism Hospital Preparedness Program provides incentives for AIIR preparedness because problems are difficult to fix in the middle of an incident.

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