IC implication of construction and construction measures in healthcare institution

Prof Dr Margreet C Vos
Dept of Medical Microbiology and Infectious Diseases
ErasmusMC, Rotterdam, The Netherlands
Infection prevention by design of the built environment and construction measures in the hospital

Prof Dr Margreet C Vos
Dept of Medical Microbiology and Infectious Diseases
ErasmusMC, Rotterdam, The Netherlands
<table>
<thead>
<tr>
<th>Disclosure of speaker’s interests</th>
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<td><strong>(Potential) conflict of interest</strong></td>
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<td><strong>Potentially relevant company relationships in connection with event</strong></td>
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Outline next 45 minutes

- Introduction design hospital
- Design of the (ICU) ward
- Isolation rooms
- Construction or renovation measures
DESIGN OF THE HOSPITAL: SOME HISTORY

Hospital of St. John, Bridgewater, 1219, Bishop Joscelin of Bath and Wells:

- “No lepers, lunatics, or persons having the falling sickness or other contagious disease, and no pregnant women or sucking infants, and no intolerable persons, even though they be poor and infirm, are to be admitted in the house; and if any such be admitted by mistake, they are to be expelled as soon as possible”
Design of the hospital: preventing hospital infection: four take home messages

- A functional design can promote skill, economy, conveniences, and comforts
- A non-functional design can impede activities of all types, detract from quality of care, and raise costs to intolerable levels
- Hospitals are the most complex of building types

- Built-in flexibility in design
  - technology is quickly obsolete
  - patient populations are constantly changing
  - today’s patient intensive care room may be tomorrow’s patient intervention room
Design of a hospital: basics

Based on functions:
- bed-related (inpatient) function
- Outpatient function
- Diagnostics and treatment functions
- Administrative functions
- Service function (kitchen, storage etc)
- Research and teaching functions

(nearly) all items have impact on infection prevention.
THE FUTURE: MORE CHALLENGES

- In 2050: 25% of the population > 65 years
- Chronic diseases
  - Frequent and longer hospital visits
  - Greater risk of hospital acquired infections
- Increasing multiresistant pathogens (MRSA, VRE, clos)
- Pandemics: influenza
- Increasing exotic diseases (travelling, mobility)
Design and people
Most important issues in design

- AIR
- SEPARATION IN CLEAN AND DIRTY; containment
- SEPARATION IN FUNCTION
Most important things to do for you!

→ As soon as you hear from any plans to build or to renovate; be there at the table!

- Infection prevention is important at all places. Routes and storages, air and water etc

- YOU have to convince the others

- Infection prevention is expensive at the short term but cheap on the long term
Evidence based design? Europe; any regulation?

Health Property Network (EuHPN)

Our Aim

- Our aim is to promote better standards and more effective investment in, and management of, health property throughout the EU, by using our network capability to enable members to pool and share knowledge, and to keep pace with leading edge developments in this central dimension of health care.
Conclusions:

Infection Control

- Infected patients or patients highly susceptible to infections need to be isolated in private rooms with proper ventilation systems and barrier protections in order to stop infection from spreading or to reduce the possibility of development of new infections. (Anderson et al., 1985; Muto et al. 2000; O’Connell & Humphreys, 2000; Sehulster & Chinn, 2003).

- Prolonged hospitalization is a risk factor for hospital-acquired infections. Additionally, intra-hospital spread of infection may result from patients being transferred to more than one ICU or more than one floor during their hospitalization.

- Patients length of stay in hospitals and cost is increased due to nosocomial infection (Zhan & Miller, 2003; Press Ganey Associates, 2003; Pittet, Tarara & Wenzel, 1994). Ongoing research is demonstrating that nosocomial infection rates are low in private rooms with proper design and ventilation systems (The Center for Health Design, 2003).
In the Netherlands;

Since 2009 the quality of healthcare buildings has to be looked after by the Health Care Inspectorate.

They mainly focus on the aspect of patient safety.

The Dutch organisations of healthcare institutions have been asked to develop building guidelines so the Inspectorate is able to examine the quality of the building.

Until now these organisations are not very willing to develop these guidelines.
2.1-2.4.3.1 General

(1) Capacity
   (a) Each room shall be for only one patient.
   (b) There shall be at least one seclusion room for each 24 beds or fewer and for each major fraction thereof on each psychiatric unit.
   (c) If a facility has more than one psychiatric nursing unit, the number of seclusion rooms shall be a function of the total number of psychiatric beds in the facility.

(2) Location
   (a) The room(s) shall be located to permit observation from the nurse station.
   (b) Seclusion rooms shall be permitted to be grouped together.

(3) Layout and access
   (a) Seclusion rooms shall be accessed by an anteroom or vestibule that also provides access to a toilet room.
   (b) The door openings to the anteroom and the toilet room shall have a minimum clear width of 3 feet 3 inches (1.12 meters).

2.1-2.4.3.2 Space requirements

(1) Seclusion rooms shall have a minimum clear floor area of 60 square feet (5.57 square meters) with a minimum wall length of 7 feet (2.13 meters) and a maximum wall length of 11 feet (3.35 meters).

(2) Where a room for restraining patients is provided, it shall have a minimum clear floor area of 80 square feet (7.43 square meters).

2.1-2.4.3.3 – 2.1-2.4.3.8 Reserved
*2.2-2.2 Medical/Surgical Nursing Unit

2.2-2.2.1 Reserved

2.2-2.2.2 Patient Room

See Section 2.1-2.2 (Patient Room) for requirements in addition to those in this section.

2.2-2.2.2.1 Capacity

(1) The maximum number of beds per room in a medical/surgical nursing unit shall be one unless the necessity of a two-bed arrangement has been demonstrated in the functional program. Two beds per room shall be permitted when approved by the authority having jurisdiction.

(2) Where renovation work is undertaken and the present capacity is more than one patient in each room, maximum room capacity shall be no more than the present capacity, with a maximum of four patients in each room.

2.2-2.2.2.2 Space requirements

*(1) Area

(a) Patient rooms shall be sized to accommodate the needs of the clinical services provided.

(b) Patient rooms shall have a minimum clear floor area of 120 square feet (11.15 square meters) in single-bed rooms and 100 square feet (9.29 square meters) per bed in multiple-bed rooms.

(2) Clearances (See "bed size" in the glossary.)

(a) The dimensions and arrangement of rooms shall provide a minimum clearance of 3 feet (91.44 centimeters) between the sides and foot of the bed and any wall or any other fixed obstruction.

(b) In multiple-bed rooms, a minimum clearance of 4 feet (1.22 meters) shall be available at the foot of each bed to permit the passage of equipment and beds.

(3) Where renovation work is undertaken and it is not possible to meet the above minimum standards, authorities having jurisdiction shall be permitted to grant approval to deviate from this requirement. In such cases, patient rooms shall have a minimum clear floor area of 100 square feet (9.29 square meters) in single-bed rooms and 80 square feet (7.43 square meters) per bed in multiple-bed areas.
KRINKO

- The German Commission for Hospital Hygiene and Infection Control (KRINKO)

→ recommends 10–20% single-patient rooms in a normal care unit
Conclusion introduction

- No European policy
- USA guideline of architects
- Hospital design is not evidence based:

A literature review of more than 3,800 references in the design and medical fields found good evidence that design affects HAI, but the exact cause is often hard to establish because an intervention often requires a system of solutions....
Outline

- Introduction design hospital
- Design of the (ICU) ward
- Isolation rooms
- Construction or renovation measures
The ward

- Transmission routes and the impact on ward design
  - general precautions
  - transmission-based precautions
  - high-risk situations

- Design
  - single rooms
  - containment
  - configuration
Design of the ward: routes of people and goods

- People:
  - Patients
  - HCWs
  - Visitors

- Goods
  - Clean
    - Sterile-non sterile
    - Linen
  - Dirty
    - readily available cleaning services (multiple-use equipment)
Design of the ICU ward: routes of people

- People:
  - Patients;
    - entrance per unit, single rooms,
    - some patient (isolation) rooms exit immediately to the hospital not along the corridor
  - HCWs;
    - patient care - not patient care rooms: clearly separated from each other (sitting room)
  - Visitors:
    - have to pass HCWs desk: extra measures, present infectious diseases
    - Ideally: Each ICU cluster a receptionist area to control visitor access and a visitors' entrance separate from that used by healthcare professionals and be securable
Design of the ward: routes of goods

- Goods
  - Clean
    - Sterile - non sterile
      - Storage rooms apart from each other
      - Sterile goods: positive pressure, self closing door, special designed storage systems, no tap water
  - Linen
    - Storage of medication including iv preparation: apart from all other functions
- Dirty
  - Can be combined, except patient material
Mock up in real and art impressions
Every detail is infection prevention
Before use; check on technical and environmental issues; air and water and the inventory and cleanliness; it takes more than 6 months ...
Why and what?

- Is there any evidence that infection control should be involved in design?
HOSPITAL ACQUIRED INFECTIONS
what can be prevented by design?

- Not all HAI are “preventable” by infection control measures:
  - endogenous: 60-70%
  - exogenous: 30-40%

- Micro organisms from other patients: (cross transmission)
  - 37% of all HAI-causing m.o are from "neighbour" patients (ICHE 2002,23:127-32)
  - 14% of all infection causing m.o: identical (Crit care med 2005,33)

- Sources: hands, indirect via environment (air and innate)
HOW DOES IT SPREAD?

- By air
- By splash accident
- Blood-borne
- Fecal-oral

No hand desinfection
Most doctors think they are not vulnerable!..
GENERAL (STANDARD) PRECAUTIONS

Those measures you always take:

- For you and your patient…

  - regardless of diagnosis, presumed infection status,
  - not pathogen or syndrome-based

  - apply to nonintact skin, mucous membranes, blood, all body fluids, secretions, and excretions except sweat, regardless of whether or not visible blood

→ yes or no impact on engineering or ward design??
GENERAL PRECAUTIONS: IMPACT ON DESIGN

- Impact on engineering or hospital/ward design:
  - design features can affect the risk of infection transmission

- 1 bed in a room and no more:
  - Enough space in between is not enough: a wall is needed to prevent
  - Dedicated medical devices and disposables
  - adequate floor space/space around each bed

- Ward:
  - Preparation of medications: separate and dedicated room
  - Sterile goods storage: separate + positive pressure
  - Mutual space relation of different functional rooms
back to the basics...
TRANSMISSION-BASED PRECAUTIONS

- for patients documented or suspected to be infected or colonized with:
  - pathogens requiring additional precautions beyond the standard precautions
    - → airborne, droplet, contact transmissions
    - → combination for multiple routes of transmission

- → yes or no impact on engineering or ward design?
Contact Transmission
- direct-contact transmission
  - direct body to body contact
- Indirect-contact transmission
  - contact with contaminated objects (hands)

Droplet Transmission
- generated by coughing, sneezing, talking, bronchoscopy.
- propelling a short distance
- deposite on conjunctivae, mucosa

Airborne Transmission
- dissemination of airborne droplet nuclei
  - = < 5 µm particle residue of evaporated droplets or dust
  - remain suspended in the air for long periods
  - depending on air currents \( \rightarrow \) long distances
## TRANSMISSION AND ISOLATION impact on hospital design

<table>
<thead>
<tr>
<th>Transmission</th>
<th>Isolation</th>
<th>Measures</th>
<th>Example m.o.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contact; Direct/indirect</td>
<td>Single room</td>
<td>Gloves/gowns</td>
<td>clostridium, ESBL, HSV</td>
</tr>
<tr>
<td>Droplet</td>
<td>Single room</td>
<td>Mask</td>
<td>pneumococci, streptococci, bordetella, meningococci</td>
</tr>
<tr>
<td>Airborne</td>
<td>Isolation room, air handling, special ventilation</td>
<td>FFP2 mask</td>
<td>TBC, varicella, measles, aspergillus</td>
</tr>
<tr>
<td>Combination: Direct/indirect/airborne</td>
<td>Strict, isolation room</td>
<td>Gloves/mask/gown</td>
<td>MRSA</td>
</tr>
</tbody>
</table>
BUILDING A NEW ICU
containment of an unit

- Lessons learned from SARS outbreak:
  - Single rooms with independent bathroom facilities in short supply
  - Facilities for gowing and de-gowning did not exist
  - Ventilation systems not designed to ensure that air flows from clean to contaminated areas
  - Hand washing and other sanitary facilities inadequate
BUILDING A NEW ICU
containment of an unit

- Lessons learned from SARS outbreak 2:

  Needed very urgently:
  - ICU unit designated to infected patients
  - ICU unit designated to non-infected patient
  - No contact between the two units
  - Independent functioning of each other at all levels

  A minimum distance between beds of ≤1m was a significant risk factor associated with health-care associated outbreaks of SARS at all participating hospital wards (OR 3.36, 95% CI: 1.38 to 8.16; P = 0.008). (Stiller ARIC 2016)
MOST IMPORTANT ISSUES IN DESIGN OF THE INTENSIVE CARE UNIT

- SINGLE ROOMS AND ISOLATION ROOMS
  - Isolation room: 25% (Trondheim), one out of 8 (CvZ), or to be established (Guideline ICU)

- CONTAINMENT / COHORTING
  - 8-12 beds per unit: best from a functional perspective
    - Guidelines for intensive care unit design Crit Care med. 23(3),1995,582-588

Trondheim ICU design

Supporting rooms

Workplace for 1 bed

Workstation for 8 beds

Supporting rooms
Any evidence of impact design on HAI? Most of these on single rooms versus multiple rooms

<table>
<thead>
<tr>
<th>Design strategies or environmental interventions</th>
<th>Single-bed rooms</th>
<th>Access to daylight</th>
<th>Appropriate lighting</th>
<th>Views of nature</th>
<th>Family zone in patient rooms</th>
<th>Carpeting</th>
<th>Noise-reducing finishes</th>
<th>Ceiling lifts</th>
<th>Nursing floor layout</th>
<th>Decentralized supplies</th>
<th>Acuity-adaptable rooms</th>
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<tbody>
<tr>
<td>Health care outcomes</td>
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<td>Reduced medical errors</td>
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<td>Reduced patient falls</td>
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<td>Reduced length of stay</td>
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<td>Improved patient privacy and confidentiality</td>
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<td>Improved social support</td>
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<td>Increased patient satisfaction</td>
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*Indicates that a relationship between the specific design factor and health care outcome was indicated, directly or indirectly by empirical studies reviewed in this report.

**Indicates that there is especially strong evidence (converging findings from multiple rigorous studies) indicating that a design intervention improves a health care outcome.

AJIC 2010 Bartley
THE ENVIRONMENT:
A CLOUD OF BACTERIA

<table>
<thead>
<tr>
<th>Table I</th>
<th>Results of surface swabbing</th>
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<tbody>
<tr>
<td></td>
<td>Total before cleaning</td>
</tr>
<tr>
<td>No. of rooms sampled</td>
<td>24&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>No. of swabs</td>
<td>359</td>
</tr>
<tr>
<td>Number yielding MRSA</td>
<td>264 (73.5)</td>
</tr>
<tr>
<td>From direct plating</td>
<td>185 (70.1)</td>
</tr>
<tr>
<td>++ Growth</td>
<td>75 (40.5)</td>
</tr>
<tr>
<td>+ Growth</td>
<td>110 (59.5)</td>
</tr>
<tr>
<td>From enrichment only</td>
<td>79 (29.9)</td>
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</tbody>
</table>

Matched denotes rooms in which adjacent sites were sampled before and after intervention. The number in parenthesis denotes the percentage.

- \( \text{H}_2\text{O}_2 \): Hydrogen peroxide vapour decontamination.
- <sup>a</sup>: Eighteen single isolation rooms, two four-bed bays, four bathrooms.
- <sup>b</sup>: Eight single isolation rooms, two four-bed bays.
- <sup>c</sup>: Four single isolation rooms, two bathrooms.
- <sup>d</sup>: Four single isolation rooms, two bathrooms.

ADVANTAGE OF A SINGLE ROOM:

- NO NEIGHBOUR, NO “NOT YET IDENTIFIED INFECTIOUS” NEIGHBOUR
- POSSIBILITY OF A CLEAN ENVIRONMENT
CONTAMINATION OF THE ENVIRONMENT

- Desinfection after discharge
- Risk in multi-person rooms and patients not (yet) known to be infectious

Figure 1  Detection rate of multi-resistant Gram-positive and Gram-negative bacteria on different environmental items. (■) Gram-positive pathogens; (□) Gram-negative pathogens.

Lemmen JHI 2004
STAPHYLOCOCCI: DISPERSION STUDIES BY SOLLBERG

![Graph showing spread of Staphylococcus aureus colonies over time and air contamination.](image-url)
CONTAMINATION OF THE ENVIRONMENT

No need to say:

- carpet and furniture and furnishing:
- aggressive desinfection methods must be daily feasible

Needs creative solutions of implementing a healing environment

No upholstery, soft furniture, wool or cotton fabrics other than bed linen
Of all the recent changes in hospital interior design, perhaps the most dramatic have taken place in the patient room. Patient rooms have been transformed from cold, strictly utilitarian spaces into clean, safe, therapeutic environments with the comforts of home and the aesthetics and amenities of a fine hotel.
### TABLE 2
Factors Associated With Noncompliance With Handwashing

<table>
<thead>
<tr>
<th>Factor</th>
<th>No. of Handwashing Indications</th>
<th>Compliance ( )</th>
<th>OR (CI&lt;sub&gt;95&lt;/sub&gt;) on Univariate Analysis*</th>
<th>OR (CI&lt;sub&gt;95&lt;/sub&gt;) on Multivariate Analysis*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Professional category</td>
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</tr>
<tr>
<td>Nurse</td>
<td>484</td>
<td>156 (32.2)</td>
<td>1.02 (0.67–1.60)</td>
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</tr>
<tr>
<td>Physician</td>
<td>916</td>
<td>290 (31.7)</td>
<td>1.00†</td>
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</tr>
<tr>
<td>Time of day</td>
<td></td>
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<tr>
<td>Morning</td>
<td>924</td>
<td>302 (32.7)</td>
<td>1.03 (0.80–1.30)</td>
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<tr>
<td>Afternoon</td>
<td>476</td>
<td>144 (30.3)</td>
<td>1.00†</td>
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<tr>
<td>No. of patients</td>
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<tr>
<td>1</td>
<td>272</td>
<td>110 (40.4)</td>
<td>1.65 (1.21–2.24)</td>
<td>1.71 (1.26–2.31)</td>
</tr>
<tr>
<td>2</td>
<td>553</td>
<td>174 (31.5)</td>
<td>1.11 (0.87–1.43)</td>
<td>1.13 (0.9–1.46)</td>
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<tr>
<td>3 or more</td>
<td>575</td>
<td>162 (28.2)</td>
<td>1.00†</td>
<td>1.00†</td>
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<tr>
<td>No. of indications</td>
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<tr>
<td>1 to 2</td>
<td>903</td>
<td>275 (30.5)</td>
<td>0.64 (0.43–0.94)</td>
<td>0.63 (0.44–0.90)</td>
</tr>
<tr>
<td>3 to 4</td>
<td>328</td>
<td>96 (29.2)</td>
<td>0.57 (0.42–0.79)</td>
<td>0.54 (0.40–0.72)</td>
</tr>
<tr>
<td>5 or more</td>
<td>169</td>
<td>75 (44.4)</td>
<td>1.00†</td>
<td>1.00†</td>
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<tr>
<td>Indication type</td>
<td></td>
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<tr>
<td>Clean low risk</td>
<td>258</td>
<td>65 (25.2)</td>
<td>0.61 (0.45–0.84)</td>
<td>0.55 (0.39–0.75)</td>
</tr>
<tr>
<td>Dirty high risk</td>
<td>1,142</td>
<td>381 (33.4)</td>
<td>1.00†</td>
<td>1.00†</td>
</tr>
<tr>
<td>Total</td>
<td>1,400</td>
<td>446 (31.9)</td>
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</tbody>
</table>

OR = odds ratio; CI<sub>95</sub> = 95% confidence interval.

*OR and CI<sub>95</sub> are given for noncompliance with handwashing.

†Reference category.

‡Level of risk for contamination is ranked according to previous recommendations. 

Kuzu: ICHE 2005; 26; 312-5
CONTACT TRANSMISSION AND HAND HYGIENE

- Consider carefully the location for hand alcohol dispensers.
Evidence for single rooms...

Fig. 4 Forest plot of comparison – Studies comparing single- vs. multi-bedrooms, outcome colonization with (multi-)drug resistant pathogens or infection with any pathogen
EBM; the single room

Fig. 6 Forest plot of comparison – Studies comparing single- vs. multi-bedrooms, outcome bacteremia
Table 3. Predictors of Methicillin-Resistant *Staphylococcus aureus* (MRSA) and Vancomycin-Resistant Enterococci (VRE) Acquisition*

<table>
<thead>
<tr>
<th>Model</th>
<th>Odds Ratio (95% Confidence Interval)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>MRSA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prior occupant MRSA positive</td>
<td>1.4 (1.0-1.8)</td>
<td>.04</td>
</tr>
<tr>
<td>Age, in decades</td>
<td>1.1 (1.0-1.2)</td>
<td>.02</td>
</tr>
<tr>
<td>Pre-ICU LOS†</td>
<td>1.2 (1.1-1.4)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Leukemia</td>
<td>0.4 (0.2-0.9)</td>
<td>.02</td>
</tr>
<tr>
<td>VRE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prior occupant VRE positive</td>
<td>1.4 (1.0-1.9)</td>
<td>.02</td>
</tr>
<tr>
<td>Age, in decades</td>
<td>1.2 (1.1-1.3)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Pre-ICU LOS†</td>
<td>1.4 (1.3-1.6)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>1.3 (1.0-1.7)</td>
<td>.03</td>
</tr>
</tbody>
</table>

Abbreviations: ICU, intensive care unit; LOS, length of stay.

*No interactions found.
†By 10-day intervals.
### Diversity index:  = D/N*100

N isolates of a species in a defined environment  
D distinguishable genotypes

Association between survival time and simple diversity index: 
correlation coefficient=0.821 (P=0.024)

<table>
<thead>
<tr>
<th>Micro-organisms</th>
<th>Median survival time (days)</th>
<th>Number of isolates</th>
<th>Number of indistinguishable genotypes</th>
<th>Simple diversity index</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Staphylococcus aureus</td>
<td>12.0</td>
<td>456</td>
<td>340</td>
<td>74.6</td>
<td>70.3-78.5</td>
</tr>
<tr>
<td>Enterococcus faecium</td>
<td>60.0</td>
<td>60</td>
<td>37</td>
<td>61.7</td>
<td>48.2-73.9</td>
</tr>
<tr>
<td>Enterococcus faecalis</td>
<td>31.0</td>
<td>169</td>
<td>83</td>
<td>49.1</td>
<td>41.6-57.2</td>
</tr>
<tr>
<td>Enterobacter spp.</td>
<td>17.5</td>
<td>105</td>
<td>90</td>
<td>85.7</td>
<td>77.5-91.8</td>
</tr>
<tr>
<td>Klebsiella pneumoniae</td>
<td>7.5</td>
<td>80</td>
<td>69</td>
<td>86.2</td>
<td>76.7-92.9</td>
</tr>
<tr>
<td>Escherichia coli</td>
<td>2.0</td>
<td>157</td>
<td>141</td>
<td>89.8</td>
<td>84.0-94.1</td>
</tr>
<tr>
<td>Acinetobacter spp.</td>
<td>9.0</td>
<td>30</td>
<td>21</td>
<td>70.0</td>
<td>50.5-91.8</td>
</tr>
<tr>
<td>Pseudomonas aeruginosa</td>
<td>1.5</td>
<td>134</td>
<td>111</td>
<td>82.8</td>
<td>75.4-88.8</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>1191</td>
<td>892</td>
<td>77.9</td>
<td></td>
</tr>
</tbody>
</table>

*a According to Table I.  
*b Without duplicates.

### OUTBREAKS: sources

<table>
<thead>
<tr>
<th>Source</th>
<th>Total no. of outbreaks&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Outbreaks including some kind of closure</th>
<th>Closure rate</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient</td>
<td>395</td>
<td>66</td>
<td>16.7%</td>
<td>0.03</td>
</tr>
<tr>
<td>Environment</td>
<td>194</td>
<td>24</td>
<td>12.4%</td>
<td>NS</td>
</tr>
<tr>
<td>Medical devices</td>
<td>172</td>
<td>12</td>
<td>7.0%</td>
<td>0.04</td>
</tr>
<tr>
<td>Personnel</td>
<td>154</td>
<td>17</td>
<td>11.0%</td>
<td>NS</td>
</tr>
<tr>
<td>Drugs</td>
<td>73</td>
<td>3</td>
<td>4.1%</td>
<td>0.03</td>
</tr>
<tr>
<td>Food</td>
<td>50</td>
<td>1</td>
<td>2.0%</td>
<td>0.03</td>
</tr>
<tr>
<td>Equipment for patient care</td>
<td>35</td>
<td>5</td>
<td>14.3%</td>
<td>NS</td>
</tr>
<tr>
<td>Source not known</td>
<td>518</td>
<td>80</td>
<td>13.8%</td>
<td>NS</td>
</tr>
<tr>
<td>Total</td>
<td>1561</td>
<td>194</td>
<td>12.4%</td>
<td>—</td>
</tr>
</tbody>
</table>

<sup>a</sup> Multiple answers possible.

NS, not significant.


Closure of ward most likely in case of the patient or environment being the source!
OUTBREAKS: sources and solutions

TABLE 1
Distribution of Outbreaks According to the Most Frequent Species and Characteristics per 100 Outbreaks (Only Species With at Least 20 Outbreaks)

<table>
<thead>
<tr>
<th>Species</th>
<th>No. of Outbreaks</th>
<th>Average No. of Patients</th>
<th>Average No. of Patients Who Died</th>
<th>Average No. of Staff Involved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Staphylococcus aureus</td>
<td>151 (14.8)</td>
<td>56.8</td>
<td>3.1</td>
<td>6.3</td>
</tr>
<tr>
<td>Pseudomonas aeruginosa</td>
<td>91 (8.9)</td>
<td>20.3</td>
<td>1.8</td>
<td>0.1</td>
</tr>
<tr>
<td>Klebsiella pneumoniae</td>
<td>73 (7.1)</td>
<td>23.1</td>
<td>3.0</td>
<td>0.1</td>
</tr>
<tr>
<td>Serratia marcescens</td>
<td>67 (6.6)</td>
<td>8.4</td>
<td>1.5</td>
<td>0.9</td>
</tr>
<tr>
<td>Hepatitis B virus</td>
<td>60 (5.9)</td>
<td>18.3</td>
<td>0.8</td>
<td>1.5</td>
</tr>
<tr>
<td>Hepatitis C virus</td>
<td>42 (4.1)</td>
<td>10.4</td>
<td>0.1</td>
<td>0.3</td>
</tr>
<tr>
<td>Legionella pneumophila</td>
<td>38 (3.7)</td>
<td>15.3</td>
<td>3.1</td>
<td>3.9</td>
</tr>
<tr>
<td>Enterobacter cloacae</td>
<td>34 (3.3)</td>
<td>19.0</td>
<td>1.1</td>
<td>0.4</td>
</tr>
<tr>
<td>Escherichia coli</td>
<td>27 (2.6)</td>
<td>4.1</td>
<td>2.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Acinetobacter baumannii</td>
<td>24 (2.3)</td>
<td>26.3</td>
<td>1.1</td>
<td>0.2</td>
</tr>
<tr>
<td>Hepatitis A virus</td>
<td>22 (2.2)</td>
<td>13.6</td>
<td>0.1</td>
<td>7.6</td>
</tr>
<tr>
<td>Burkholderia cepacia</td>
<td>21 (2.1)</td>
<td>32.0</td>
<td>4.6</td>
<td>0.1</td>
</tr>
<tr>
<td>Mycobacterium tuberculosis</td>
<td>21 (2.1)</td>
<td>18.7</td>
<td>10.9</td>
<td>6.6</td>
</tr>
<tr>
<td>Candida albicans</td>
<td>20 (2.0)</td>
<td>40.9</td>
<td>3.2</td>
<td>1.3</td>
</tr>
</tbody>
</table>

TABLE 4
Measures Taken to Stop the Outbreak (Various Measures Were Taken in Most Outbreaks)

<table>
<thead>
<tr>
<th>Type of Measure</th>
<th>No. of Outbreaks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient screening/surveillance</td>
<td>552 (54.0)</td>
</tr>
</tbody>
</table>
EVERYONE KNOWS:
WHEN ONE CHICKEN FALLS ILL...
ALL OTHERS.....
CONCLUSIONS design ICU ward

1. Single rooms
   → increase compliance to prevention measures
   → prevention of transmission from “the yet known and not yet known infectious” patient
   → patients and environment are both sources of pathogens

2. Containment by small self-supporting independent units

3. Separate in function and people (routing)
"When I return: put me in a closet rather than in the ward"

from Bacon 1920, Emerging Inf Dis 2001:7
Outline

- Introduction design hospital
- Design of the (ICU) ward
- Isolation rooms
- Construction or renovation measures
Isolation rooms

- To protect contamination of outdoor/corridor by contaminated air from the isolation room;
  not filtered air, room at negative pressure

- To protect contamination of room-air from outside the isolation room;
  HEPA filtered air and room at positive pressure
isolation room; just a special one...

- Air is important; flow direction and air quality
Isolation rooms;
TO PROTECT YOUR PATIENT:
technical program of requirements

not only single rooms, but more is important to protect your patient from acquiring nosocomial infections

- consider: AIR
  - air changes per hour (ACH)
  - where does it come from, and where does it go

- Isolation rooms; where does the air flow
- Is extra quality needed?
consider: AIR: where does it come from and where does it go?

AIA 2001

- exhaust outlets > 25 feet from air intake systems
- bottom of outdoor air intake = 6 feet above ground or 3 feet above roof level
- exhaust outlet of contaminated air = above roof level: minimize recirculation

*Height of air recirculation zone may be variable. Air should be exhausted above this zone to prevent re-entrainment.
ISOLATION ROOM

- Technical requirements;

  1. well-sealed windows, doors, and intake and exhaust ports
  2. ceilings smooth and free of fissures, open joints, and crevices
  3. sealing walls above and below the ceiling
  4. monitoring for leakage and making any necessary repairs
  5. maintain, monitor and document airflow permanently
  6. self-closing devices on all room exit doors
  7. a HEPA filter in the exhaust duct if return air is recirculated or do not recirculate
  8. Choose the flow directions and air quality depending on your aim of protection
ISOLATION ROOM; aim; prevention of contamination of outdoor air

FIGURE 2. Example of airborne infection isolation (All) room with anteroom and neutral anteroom*
ISOLATION ROOM; aim; prevention of contamination of patient room and outdoor air

Source: Used with permission from Andrew J. Streifel, M.P.H., University of Minnesota.

Note: Top diagram indicates airflow patterns when patient with only airborne infectious disease occupies room. Middle and bottom diagrams indicate recommended airflow patterns when room is occupied by immunocompromised patient with airborne infectious disease. Stacked black boxes represent patient beds. Long open boxes with cross-hatches represent supply air. Open boxes with single, diagonal slashes represent air exhaust registers. Arrows indicate directions of airflow.

*All isolation room with anteroom engineering features include:
- pressure differential of 2.5 Pa (0.01-in. water gauge);
- airflow differential >125 cfm supply versus exhaust;
- sealed room with approximately 0.5-sq. ft. leakage;
- clean to dirty airflow;
- monitoring;
- ≥12 air exchanges/hr (ACH) new or renovation, 6 ACH existing; and
- anteroom airflow patterns.
Infectious particles in the anteroom

NON - HEPA filtered air in the patient room

HEPA in the anteroom?

Effect of ACH?

Infectious particles in the anteroom
NEUTROPENIA AND FUNGAL INFECTIONS PREVENTION BY HOSPITAL DESIGN

- High environmental Aspergillus spore counts → major risk for infection after inhalation of the spores
  - hospital construction, renovation and demolition

- Prevention: exogenous source
  → high-efficiency particulate air (HEPA) filtration
### HEPA YES OR NO: SYSTEMATIC REVIEW

Table 5. Different guidelines of the Centers for Disease Control and Prevention (CDC) that recommend the installation of high-efficiency particulate air (HEPA) filters, categories of use, and the content of references included in the guidelines.

<table>
<thead>
<tr>
<th>CDC guidelines</th>
<th>Category of HEPA filter use</th>
<th>References in guidelines and their content</th>
</tr>
</thead>
</table>
| Guidelines for the prevention of opportunistic infections in recipients of hematopoietic stem cell transplants [10] | BIII<sup>a</sup>            | Guidelines for prevention of nosocomial pneumonia [9]  
Rhame et al. [34] were considered in the present review  
Opal et al. [44] conducted a study during hospital renovation                                                                 |
| Guidelines for preventing nosocomial pneumonia [9]                              | IB<sup>b</sup>              | Studies by Buckner et al. [24] and Sheirz et al. [35] were considered in the present review  
Murray et al. [45] and Streifel et al. [46] focused on technical data regarding the use of ventilation for controlling microbes  
Opal et al. [44] and Barnes et al. [47] conducted studies during hospital renovation  
Neither McWhinney et al. [48] nor Rogers [49] showed a reduction in mortality or fungal infection as a result of use of HEPA filtration |
Studies by Sheirz et al. [35] and Oren et al. [37] were considered in the present review  
Thio et al. [50] conducted an investigation of an outbreak of invasive aspergillosis  
Rice et al. [51] focused on technical data regarding the use of ventilation for controlling microbes  
2001 guidelines for the prevention of nosocomial pneumonia [9]  
Siegler et al. [53] contributed a book section  
Studies by Buckner et al. [24] and Sheirz et al. [35] were considered in the present review  
Aronow et al. [54], Breton et al. [56], Guarro et al. [56], Burton et al. [57], Kyriakides et al. [58],  
McWhinney et al. [48], and Rhame [59] did not show a reduction in mortality or fungal infection resulting from the use of HEPA filtration  
Weems et al. [60], Barnes et al. [47], and Overberger et al. [61] conducted studies during hospital renovation  
Murray et al. [45] and Streifel et al. [46] focused on technical data regarding the use of ventilation for controlling microbes |
| Guidelines for environmental infection control in healthcare facilities [12]    | IB<sup>b</sup> and IC<sup>c</sup> | 2001 guidelines for the design and construction of hospital and healthcare facilities [52]  
Siegler et al. [53] contributed a book section  
Studies by Buckner et al. [24] and Sheirz et al. [35] were considered in the present review  
Aronow et al. [54], Breton et al. [56], Guarro et al. [56], Burton et al. [57], Kyriakides et al. [58],  
McWhinney et al. [48], and Rhame [59] did not show a reduction in mortality or fungal infection resulting from the use of HEPA filtration  
Weems et al. [60], Barnes et al. [47], and Overberger et al. [61] conducted studies during hospital renovation  
Murray et al. [45] and Streifel et al. [46] focused on technical data regarding the use of ventilation for controlling microbes |

**NOTE.** HEPA, high-efficiency particulate air.

<sup>a</sup> B: Strong or moderate evidence for efficacy, but only limited clinical benefit; generally recommended. III: Evidence from opinions of respected authorities based on clinical experience, descriptive studies, or reports of expert committees.

<sup>b</sup> IB: Strongly recommended for implementation and supported by certain experimental, clinical, or epidemiological studies and a strong theoretical rationale.

<sup>c</sup> IC: Required by state or federal regulation, or representing an established association standard.
### Table 3. Results of meta-analyses of studies with death as the outcome.

<table>
<thead>
<tr>
<th>Authors, year of publication [reference]</th>
<th>Patients in rooms with HEPA/LAF ventilation, no.</th>
<th>Patients in rooms with no ventilation system, no.</th>
<th>Total patients, no.</th>
<th>RR (95% CI)</th>
<th>With HEPA/LAF ventilation</th>
<th>Without ventilation</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Who died</td>
<td>Who survived</td>
<td>Who died</td>
<td>Who survived</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yates et al., 1973 [26]</td>
<td>11</td>
<td>24</td>
<td>17</td>
<td>35</td>
<td>87</td>
<td>0.96 (0.51–1.78)</td>
<td>31</td>
</tr>
<tr>
<td>Levine et al., 1973 [27]</td>
<td>1</td>
<td>21</td>
<td>9</td>
<td>29</td>
<td>60</td>
<td>0.19 (0.03–1.42)</td>
<td>5</td>
</tr>
<tr>
<td>Buckner et al., 1978 [24]</td>
<td>23</td>
<td>6</td>
<td>25</td>
<td>2</td>
<td>56</td>
<td>0.86 (0.69–1.06)</td>
<td>79</td>
</tr>
<tr>
<td>Storb et al., 1983 [25]</td>
<td>5</td>
<td>34</td>
<td>28</td>
<td>63</td>
<td>130</td>
<td>0.42 (0.17–1.00)</td>
<td>13</td>
</tr>
<tr>
<td>Petersen et al., 1987 [29]</td>
<td>13</td>
<td>36</td>
<td>12</td>
<td>38</td>
<td>99</td>
<td>1.11 (0.56–2.18)</td>
<td>27</td>
</tr>
<tr>
<td>Petersen et al., 1988 [28]</td>
<td>13</td>
<td>128</td>
<td>15</td>
<td>186</td>
<td>342</td>
<td>1.24 (0.61–2.51)</td>
<td>9</td>
</tr>
<tr>
<td>All</td>
<td>66</td>
<td>249</td>
<td>106</td>
<td>353</td>
<td>774</td>
<td>0.86 (0.65–1.14)</td>
<td>21</td>
</tr>
<tr>
<td>RCTs with death as the outcome</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>With HEPA/LAF ventilation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Without ventilation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-RCTs with death as the outcome</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>With HEPA/LAF ventilation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Without ventilation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Note.** CI, confidence interval; HEPA, high-efficiency particulate air; LAF, laminar airflow; non-RCT, nonrandomized controlled trial; RCT, randomized controlled trial; RR, relative risk.

* Pooled RR determined by the DerSimonian and Laird method.
HEPA YES OR NO: SYSTEMATIC REVIEW

Forrest plot of relative risks (RRs) and 95% confidence intervals for mortality (A) in 6 RCTs of air filtration for fungal infection (B) in 4 RCTs of air filtration.

Eckmanns JID 2006; 193:1408–18
Infection Control and Ventilation Requirements
Isolation rooms; CDC Guideline 2003

- Minimize exposures to activities that might cause aerosolization of fungal spores IB

- Minimize the length of time outside their rooms IB

- Ventilation engineering specifications and dust-controlling processes IB, IC
  - central or point-of-use HEPA filters for supply air IB, IC (AIA: 5.1, 5.2, 7.2.D)
  - well-sealed windows, doors, and intake and exhaust ports
  - ceilings smooth and free of fissures, open joints, and crevices
  - sealing walls above and below the ceiling
  - monitoring for leakage and making any necessary repairs IB, IC (AIA: 7.2.D3)
Infection Control and Ventilation Requirements
Isolation rooms; CDC Guideline 2003 cont’nd

- ventilate the room to maintain >12 ACH IC (AIA: 7.2.D)
- air enters from one side, flows across the bed, exits from the opposite side IC (AIA: 7.31.D1)
- positive room air pressure (>2.5 Pa) in relation to corridor IB, IC (AIA: Table 7.2)
- maintain, monitor and document airflow permanently IC (AIA: 7.2.D6)
- self-closing devices on all room exit doors IC (AIA: 7.2.D4)
- do not use laminar air flow systems in newly constructed PE rooms II

- Take measures to protect those who also have an airborne infectious disease
  - ensure patient’s room maintain positive pressure
  - anteroom + independent exhaust of contaminated air to the outside, or a HEPA filter in the exhaust duct if return air is recirculated IC (AIA: 7.2.D1, A7.2.D)
Ventilation Requirements

isolation rooms; CDC Guideline Preventing Health-Care-Associated Pneumonia 2003-4

- PE for allogeneic HSCT recipients

  New specialized-care units: minimize accumulation of fungal spores via
  1) HEPA filtration of incoming air
  2) directed room airflow
  3) positive air pressure in patient's room in relation to the corridor
  4) well-sealed room
  5) high (>12) air changes per hour (IB, IC)

  Do not use LAF routinely in PE (IB)

- Units for autologous HSCT and solid-organ transplant recipients

  No recommendation can be made for constructing PE for recipients of autologous HSCTs or solid-organ-transplants (Unresolved issue)
ISOLATION ROOM; monitoring

- Rooms should be monitored continuously by the pressure differential between the room and its neutral-pressure surround.
- The value of such pressure is relatively unimportant as long as the direction of airflow it signifies is clearly indicated.
- Remote building management.

Hospital and community acquired infection and the built environment design and testing of infection control rooms J.T. Walker, *, P. Hoffman, A.M. Bennett, M.C. Vos, M. Thomas, N. Tomlinson. JHI (2007) 65(S2) 43–49
## Design Parameters

<table>
<thead>
<tr>
<th>Function of Space</th>
<th>Pressure Relationship to Adjacent Areas (n)</th>
<th>Minimum Outdoor ach</th>
<th>Minimum Total ach</th>
<th>All Room Air Exhausted Directly to Outdoors (j)</th>
<th>Air Recirculated by Means of Room Units (a)</th>
<th>Design Relative Humidity (k), %</th>
<th>Design Temperature (l), °F/°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toilet room</td>
<td>Negative</td>
<td>NR</td>
<td>10</td>
<td>Yes</td>
<td>No</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Newborn nursery suite</td>
<td>NR</td>
<td>2</td>
<td>6</td>
<td>NR</td>
<td>No</td>
<td>30–60</td>
<td>72–78/22–26</td>
</tr>
<tr>
<td>Protective environment room (t)</td>
<td>Positive</td>
<td>2</td>
<td>12</td>
<td>NR</td>
<td>No</td>
<td>max 60</td>
<td>70–75/21–24</td>
</tr>
<tr>
<td>All room (u)</td>
<td>Negative</td>
<td>2</td>
<td>12</td>
<td>Yes</td>
<td>No</td>
<td>max 60</td>
<td>70–75/21–24</td>
</tr>
<tr>
<td>Combination All/PE room</td>
<td>Positive</td>
<td>2</td>
<td>12</td>
<td>Yes</td>
<td>No</td>
<td>Max 60</td>
<td>70-75/21-24</td>
</tr>
<tr>
<td>All anteroom (u)</td>
<td>(e)</td>
<td>NR</td>
<td>10</td>
<td>Yes</td>
<td>No</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>PE anteroom (t)</td>
<td>(e)</td>
<td>NR</td>
<td>10</td>
<td>NR</td>
<td>No</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Combination All/PE anteroom</td>
<td>(e)</td>
<td>NR</td>
<td>10</td>
<td>Yes</td>
<td>No</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Labor/delivery/recovery/postpartum (LDRP) (s)</td>
<td>NR</td>
<td>2</td>
<td>6</td>
<td>NR</td>
<td>NR</td>
<td>max 60</td>
<td>70–75/21–24</td>
</tr>
</tbody>
</table>
7.2 Additional Room-Specific Requirements

7.2.1 Airborne Infection Isolation (AII) Rooms. Ventilation for AII rooms shall meet the following requirements whenever an infectious patient occupies the room:

a. Each AII room shall comply with requirements of Tables 6.4, 6.7.2, and 7.1. AII rooms shall have a permanently installed device and/or mechanism to constantly monitor the differential air pressure between the room (when occupied by patients with a suspected airborne infectious disease) and the corridor, whether or not there is an anteroom. A local visual means shall be provided to indicate whenever negative differential pressure is not maintained.

b. All air from the AII room shall be exhausted directly to the outdoors.

Exception: All rooms that are retrofitted from standard patient rooms from which it is impractical to exhaust directly outdoors may be provided with recirculated air from the room's exhaust on the condition that the air first passes through a HEPA filter.

c. All exhaust air from the AII rooms, associated anterooms, and associated toilet rooms shall be discharged directly to the outdoors without mixing with exhaust air from any other non-AII room or exhaust system.

d. Exhaust air grilles or registers in the patient room shall be located directly above the patient bed on the ceiling or on the wall near the head of the bed unless it can be demonstrated that such a location is not practical.

e. The room envelope shall be sealed to limit leakage airflow at 0.01 in. wc (2.5 Pa) differential pressure across the envelope.

f. Differential pressure between AII rooms and adjacent spaces that are not AII rooms shall be a minimum of −0.01 in. wc (−2.5 Pa). Spaces such as the toilet room and the anteroom (if present) that are directly associated with the AII room and open directly into the AII room are not required to be designed with a minimum pressure difference from the AII room but are still required to maintain the pressure relationships to adjacent areas specified in Table 7.1.

g. When an anteroom is provided, the pressure relationships shall be as follows: (1) the AII room shall be at a negative pressure with respect to the anteroom, and (2) the anteroom shall be at a negative pressure with respect to the corridor.

7.2.2 Protective Environment (PE) Rooms. Ventilation for PE rooms shall meet the following requirements:

a. The room envelope shall be sealed to limit leakage airflow at 0.01 in. wc (2.5 Pa) differential pressure across the envelope.

b. Each PE room shall comply with the requirements of Tables 6.4, 6.7.2, and 7.1. PE rooms shall have a permanently installed device and/or mechanism to constantly monitor the differential air pressure between the room and the corridor when occupied by patients requiring a protective environment regardless of whether there is an anteroom. A local visual means shall be provided to indicate whenever positive differential pressure is not maintained.

c. Air distribution patterns within the protective environment room shall conform to the following:
1. Supply air diffusers shall be above the patient bed unless it can be demonstrated that such a location is not practical. Diffuser design shall limit air velocity at the patient bed to reduce patient discomfort. (See ASHRAE Standard 55 [2010a] in Informative Appendix B.)

2. Return/exhaust grilles or registers shall be located near the patient room door.

d. Differential pressure between PE rooms and adjacent spaces that are not PE rooms shall be a minimum of +0.01 in. wc (+2.5 Pa). Spaces such as the toilet room and the anteroom (if present) that are directly associated with the PE room and open directly into the PE room are not required to be designed with a minimum pressure difference from the PE room but are still required to maintain the pressure relationships to adjacent areas specified in Table 7.1.

e. PE rooms retrofitted from standard patient rooms may be ventilated with recirculated air, provided that air first passes through a HEPA filter and the room complies with parts “a” through “d” of Section 7.2.2.

f. When an anteroom is provided, the pressure relationships shall be as follows: (1) the PE room shall be at a positive pressure with respect to the anteroom and (2) the anteroom shall be at a positive pressure with respect to the corridor.

7.2.3 Combination Airborne Infectious Isolation/Protective Environment (AII/PE) Rooms. Ventilation for AII/PE rooms shall meet the following requirements:

a. Supply air diffusers shall be located above the patient bed.

b. Exhaust grilles or registers shall be located near the patient room door.

c. The pressure relationship to adjacent areas for the required anteroom shall be one of the following:
   1. The anteroom shall be at a positive pressure with respect to both the AII/PE room and the corridor or common space.
   2. The anteroom shall be at a negative pressure with respect to both the AII/PE room and the corridor or common space.

d. AII/PE rooms shall have two permanently installed devices and/or mechanisms to constantly monitor the differential air pressure. One device and/or mechanism shall monitor the pressure differential between the AII/PE room and the anteroom. The second device and/or mechanism shall monitor the pressure differential between the anteroom and the corridor or common space. For each device and/or mechanism, a local visual means shall be provided to indicate whenever differential pressure is not maintained.
Outline

- Introduction design hospital
- Design of the (ICU) ward
- Isolation rooms
- Construction or renovation measures
## Table 1. Selected events of nosocomial infection associated with the dispersal of microorganisms during construction

<table>
<thead>
<tr>
<th>Year, author</th>
<th>Organism</th>
<th>Population</th>
<th>Epidemiologic factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airborne</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1976 Aisner et al&lt;sup&gt;1&lt;/sup&gt;</td>
<td>Aspergillus spp</td>
<td>Acute leukemia</td>
<td>Fireproofing insulation</td>
</tr>
<tr>
<td>1982 Lento et al&lt;sup&gt;2&lt;/sup&gt;</td>
<td>Aspergillus spp</td>
<td>BMT; renal</td>
<td>Road construction; window air conditioners</td>
</tr>
<tr>
<td>1985 Krasinski et al&lt;sup&gt;3&lt;/sup&gt;</td>
<td>Rhizopus; Aspergillus</td>
<td>Neonatal</td>
<td>False ceiling</td>
</tr>
<tr>
<td>1987 Streifel et al&lt;sup&gt;4&lt;/sup&gt;</td>
<td>Penicillium spp</td>
<td>BMT</td>
<td>Rotted wood cabinet</td>
</tr>
<tr>
<td>1987 Weems et al&lt;sup&gt;5&lt;/sup&gt;</td>
<td>Rhizopus; Mucor sp;</td>
<td>Hematologic BMT</td>
<td>Construction activity</td>
</tr>
<tr>
<td>1990 Fox et al&lt;sup&gt;6&lt;/sup&gt;</td>
<td>Penicillium sp; Cladosporium sp</td>
<td>OR</td>
<td>Ventilation duct fiberglass insulation</td>
</tr>
<tr>
<td>1991 Arnow et al&lt;sup&gt;7&lt;/sup&gt;</td>
<td>Aspergillus sp</td>
<td>Cancer-melanoma</td>
<td>Tiles; humidified cell incubators; air filters</td>
</tr>
<tr>
<td>1993 Flynn et al&lt;sup&gt;8&lt;/sup&gt;</td>
<td>Aspergillus terreus</td>
<td>ICU</td>
<td>ICU renovation; elevators</td>
</tr>
<tr>
<td>1994 Gerson et al&lt;sup&gt;9&lt;/sup&gt;</td>
<td>Aspergillus sp</td>
<td>General</td>
<td>Carpeting</td>
</tr>
<tr>
<td>1995 Alvarez et al&lt;sup&gt;10&lt;/sup&gt;</td>
<td>Scoedosporium prolificans (inflata)</td>
<td>Neutropenic hematology</td>
<td>Construction, presumed environmental</td>
</tr>
<tr>
<td>1996 Pittet et al&lt;sup&gt;11&lt;/sup&gt;</td>
<td>Aspergillus sp</td>
<td>COPD</td>
<td>Air filter replacement</td>
</tr>
<tr>
<td>Waterborne</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1976 Haley et al&lt;sup&gt;12&lt;/sup&gt;</td>
<td>Legionella spp</td>
<td>Immunosuppressed</td>
<td>Soil; water</td>
</tr>
<tr>
<td>1980 Dondero et al&lt;sup&gt;13&lt;/sup&gt;</td>
<td>Legionella spp</td>
<td>Adults, employees</td>
<td>Cooling towers</td>
</tr>
<tr>
<td>1980 Crane et al&lt;sup&gt;14&lt;/sup&gt;</td>
<td>Pseudomonas paucimobilis</td>
<td>ICU</td>
<td>Potable water used to fill flush water bottles</td>
</tr>
<tr>
<td>1985 Claesson et al&lt;sup&gt;15&lt;/sup&gt;</td>
<td>Group A Streptococcus</td>
<td>Maternity</td>
<td>Shower head</td>
</tr>
<tr>
<td>1993 Sniadeck et al&lt;sup&gt;16&lt;/sup&gt;</td>
<td>Mycobacterium xenopi</td>
<td>Endoscopy-pseudo</td>
<td>Potable water; scopes</td>
</tr>
<tr>
<td>1997 Dearborn et al&lt;sup&gt;17&lt;/sup&gt;</td>
<td>Stachybotrys atra</td>
<td>Infants</td>
<td>Water-damaged homes</td>
</tr>
<tr>
<td>1997 Fridkin et al&lt;sup&gt;18&lt;/sup&gt;</td>
<td>Acrocinium kiliense</td>
<td>Ambulatory surgery</td>
<td>Vent system humidifier</td>
</tr>
</tbody>
</table>

*BMT, Bone marrow transplant; OR, operating room; ICU, intensive care unit; COPD, chronic obstructive pulmonary disease.*

### Table 3
Recommendations from international guidelines for infection control and prevention measures during building works and specific recommendations for healthcare facilities managing HSCT recipients in the setting of building works

<table>
<thead>
<tr>
<th>Intervention</th>
<th>Generic health facility building guidelines</th>
<th>Guidelines targeted to reducing infection risk in high-risk patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia 2012</td>
<td>☑</td>
<td>☑</td>
</tr>
<tr>
<td>United Kingdom 2013</td>
<td>☑</td>
<td>☑</td>
</tr>
<tr>
<td>Canada 2010</td>
<td>☑</td>
<td>☑</td>
</tr>
<tr>
<td>CDC 2003</td>
<td>☑</td>
<td>☑</td>
</tr>
<tr>
<td>HICPAC 2007</td>
<td>☑</td>
<td>☑</td>
</tr>
<tr>
<td>Ireland 2002</td>
<td>☑</td>
<td>☑</td>
</tr>
<tr>
<td>Tomblyn 2009</td>
<td>☑</td>
<td>☑</td>
</tr>
<tr>
<td>Yokoe 2009</td>
<td>☑</td>
<td>☑</td>
</tr>
</tbody>
</table>

- Keep at-risk patient areas positively pressurised compared with outside/maintain negative pressure in the construction area
- Install and maintain filters properly
- Seal clinical areas from outside air effectively
- Carry out surveillance for active cases
- N95 masks for high-risk patients when outside of their protective environment
- HEPA filter the air of high-risk patient rooms during construction
- Minimum air exchanges for high-risk patient rooms >12 per hour

CDC, Centers for Disease Control and Prevention; HEPA, high-efficiency particulate air; HICPAC, Healthcare Infection Control Practices Advisory Committee; HSCT, haemopoietic stem cell transplants.

Consensus guidelines for implementation of quality processes to prevent invasive fungal disease and enhanced surveillance measures during hospital building works, 2014 Internal Medicine Journal 44
Responsibilities of IP during renovation/construction

Prevent;

- patients with reduced resistance are exposed to pathogenic opportunists

- These are microorganisms that spread in a number of ways (building material, water) and can cause construction-related nosocomial infections
Responsibilities of IP during renovation/construction

Written guideline for:

- Project manager and the contractor, on or directly adjacent to the construction site itself
- Employees with patient-related activities

With:

Preventive measures for:

- Fungi (Aspergillus), Nocardia
- Legionella spp

Mortality:

- Nosocomial aspergillosis: 65% - 100%
- Nosocomial legionellosis: 24% - 80%
Responsibilities of IP during renovation/construction

At the initiative phase

- Presence at multidisciplinary consultations
- Review design drawings (draft + final)
- Assessing prevention measures
- Separating hospital traffic (patients, employees, visitors) from construction traffic (goods and personnel)

During the construction process

- Notification of project managers if there are changes
- Delivery of the renovated/built environment
Our old hospital…
TASKS AND RESPONSIBILITIES

Project manager, supervisor and contractor:
- make an inventory of which prevention measures under his / her leadership should be taken by the implementers of the construction project

Cleaning service:
- When what and how

Medical and nursing officer:
- Relocating patients and providing additional protective measures

Infection Prevention:
- Knowledge of the construction project through the project manager
- Check adequate infection prevention measures
- Drawing up programs of requirements with regard to infection prevention in the area of the location, layout and inventory of the relevant patient-related spaces
- Risk assessment on indication
PREVENTION MEASURES BY PROJECT MANAGER
BEFORE STARTING CONSTRUCTION

- Dust-tight shielding from ceiling to floor: including above lowered ceiling cracks
- Plastic foil only for a few days in view of vulnerability
- Close parts of ventilation system
- Close off suction opening of hospital ventilation system on construction site
- Change airflow / pressure in the system when needed
- No chutes inside unless chute segments and the debris container are properly sealed
- Cover connections of medical gases and vacuum lines
- For immunocompromised patients: create mobile unit under-pressure
PREVENTION MEASURES BY PROJECT MANAGER DURING AND AFTER CONSTRUCTION

Measures during construction (renovation)

- Avoid dust formation during construction work as much as possible: eg "wet" drilling or direct dust extraction

After construction (renovation)

- Deliver clean and dust-free, even above suspended ceilings
- Check ventilation system: replace all filters, if necessary
- Special air treatment systems; operating rooms, isolation rooms and procedure rooms check and clean before use
- Flush cold and hot water pipes
- When disconnecting and connecting (hot) water pipes, flush and check on Legionella presence (have a control plan!)
- Hygienic check before opening
# Infection Control Risk Assessment

## Matrix of Precautions for Construction & Renovation

### Step One:
Using the following table, identify the **Type of Construction Project Activity (Type A-D)**

<table>
<thead>
<tr>
<th>TYPE</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A</strong></td>
<td>Inspection and Non-Invasive Activities.</td>
</tr>
<tr>
<td></td>
<td>Includes, but is not limited to:</td>
</tr>
<tr>
<td></td>
<td>- removal of ceiling tiles for visual inspection only, e.g., limited to 1 tile per 50 square feet</td>
</tr>
<tr>
<td></td>
<td>- painting (but not sanding)</td>
</tr>
<tr>
<td></td>
<td>- wallcovering, electrical trim work, minor plumbing, and activities which do not generate dust or require cutting of walls or access to ceilings other than for visual inspection.</td>
</tr>
<tr>
<td><strong>B</strong></td>
<td>Small scale, short duration activities which create minimal dust</td>
</tr>
<tr>
<td></td>
<td>Includes, but is not limited to:</td>
</tr>
<tr>
<td></td>
<td>- installation of telephone and computer cabling</td>
</tr>
<tr>
<td></td>
<td>- access to chase spaces</td>
</tr>
<tr>
<td></td>
<td>- cutting of walls or ceiling where dust migration can be controlled.</td>
</tr>
<tr>
<td><strong>C</strong></td>
<td>Work that generates a moderate to high level of dust or requires demolition or removal of any fixed building components or assemblies</td>
</tr>
<tr>
<td></td>
<td>Includes, but is not limited to:</td>
</tr>
<tr>
<td></td>
<td>- sanding of walls for painting or wall covering</td>
</tr>
<tr>
<td></td>
<td>- removal of floorcoverings, ceiling tiles and casework</td>
</tr>
<tr>
<td></td>
<td>- new wall construction</td>
</tr>
<tr>
<td></td>
<td>- minor duct work or electrical work above ceilings</td>
</tr>
<tr>
<td></td>
<td>- major cabling activities</td>
</tr>
<tr>
<td></td>
<td>- any activity which cannot be completed within a single workshift.</td>
</tr>
<tr>
<td><strong>D</strong></td>
<td>Major demolition and construction projects</td>
</tr>
<tr>
<td></td>
<td>Includes, but is not limited to:</td>
</tr>
<tr>
<td></td>
<td>- activities which require consecutive work shifts</td>
</tr>
<tr>
<td></td>
<td>- requires heavy demolition or removal of a complete cabling system</td>
</tr>
<tr>
<td></td>
<td>- new construction.</td>
</tr>
<tr>
<td>Low Risk</td>
<td>Medium Risk</td>
</tr>
<tr>
<td>-------------</td>
<td>------------------------------</td>
</tr>
<tr>
<td>Office areas</td>
<td>Cardiology</td>
</tr>
<tr>
<td></td>
<td>Echocardiography</td>
</tr>
<tr>
<td></td>
<td>Endoscopy</td>
</tr>
<tr>
<td></td>
<td>Nuclear Medicine</td>
</tr>
<tr>
<td></td>
<td>Physical Therapy</td>
</tr>
<tr>
<td></td>
<td>Radiology/MRI</td>
</tr>
<tr>
<td></td>
<td>Respiratory Therapy</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
IC Matrix - Class of Precautions: Construction Project by Patient Risk

<table>
<thead>
<tr>
<th>Patient Risk Group</th>
<th>TYPE A</th>
<th>TYPE B</th>
<th>TYPE C</th>
<th>TYPE D</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOW Risk Group</td>
<td>I</td>
<td>II</td>
<td>II</td>
<td>III/IV</td>
</tr>
<tr>
<td>MEDIUM Risk Group</td>
<td>I</td>
<td>II</td>
<td>III</td>
<td>IV</td>
</tr>
<tr>
<td>HIGH Risk Group</td>
<td>I</td>
<td>II</td>
<td>III/IV</td>
<td>IV</td>
</tr>
<tr>
<td>HIGHEST Risk Group</td>
<td>II</td>
<td>III/IV</td>
<td>III/IV</td>
<td>IV</td>
</tr>
</tbody>
</table>

Note: Infection Control approval will be required when the Construction Activity and Risk Level indicate that Class III or Class IV control procedures are necessary.
# Description of Required Infection Control Precautions by Class

<table>
<thead>
<tr>
<th>During Construction Project</th>
<th>Upon Completion of Project</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CLASS I</strong></td>
<td></td>
</tr>
<tr>
<td>1. Execute work by methods to minimize raising dust from construction operations.</td>
<td>1. Clean work area upon completion of task.</td>
</tr>
<tr>
<td>2. Immediately replace a ceiling tile displaced for visual inspection</td>
<td></td>
</tr>
<tr>
<td><strong>CLASS II</strong></td>
<td></td>
</tr>
<tr>
<td>1. Provide active means to prevent airborne dust from dispersing into atmosphere.</td>
<td>1. Wipe work surfaces with cleaner/disinfectant.</td>
</tr>
<tr>
<td>2. Water mist work surfaces to control dust while cutting.</td>
<td>2. Contain construction waste before transport in tightly covered containers.</td>
</tr>
<tr>
<td>3. Seal unused doors with duct tape.</td>
<td>3. Wet mop and/or vacuum with HEPA filtered vacuum before leaving work area.</td>
</tr>
<tr>
<td>4. Block off and seal air vents.</td>
<td>4. Upon completion, restore HVAC system where work was performed.</td>
</tr>
<tr>
<td>5. Place dust mat at entrance and exit of work area</td>
<td></td>
</tr>
<tr>
<td>6. Remove or isolate HVAC system in areas where work is being performed.</td>
<td></td>
</tr>
<tr>
<td><strong>CLASS III</strong></td>
<td></td>
</tr>
<tr>
<td>1. Remove or Isolate HVAC system in area where work is being done to prevent contamination of duct system.</td>
<td>1. Do not remove barriers from work area until completed project is inspected by the owner’s Safety Department and Infection Prevention &amp; Control Department and thoroughly cleaned by the owner’s Environmental Services Department.</td>
</tr>
<tr>
<td>2. Complete all critical barriers i.e., sheetrock, plywood, plastic, to seal area from non-work area or implement control cube method (cut with plastic covering and sealed connection to work site with HEPA vacuum for vacuuming prior to exit) before construction begins.</td>
<td>2. Remove barrier materials carefully to minimize spreading of dirt and debris associated with construction.</td>
</tr>
<tr>
<td>3. Maintain negative air pressure within work site utilizing HEPA equipped air filtration units.</td>
<td>3. Vacuum work area with HEPA filtered vacuums.</td>
</tr>
<tr>
<td>5. Cover transport receptacles or carts. Tape covering unless solid lid.</td>
<td>5. Upon completion, restore HVAC system where work was performed.</td>
</tr>
<tr>
<td><strong>CLASS IV</strong></td>
<td></td>
</tr>
<tr>
<td>1. Isolate HVAC system in area where work is being done to prevent contamination of duct system.</td>
<td>1. Do not remove barriers from work area until completed project is inspected by the owner’s Safety Department and Infection Prevention &amp; Control Department and thoroughly cleaned by the owner’s Environmental Services Dept.</td>
</tr>
<tr>
<td>2. Complete all critical barriers i.e., sheetrock, plywood, plastic, to seal area from non-work area or implement control cube method (cut with plastic covering and sealed connection to work site with HEPA vacuum for vacuuming prior to exit) before construction begins.</td>
<td>2. Remove barrier material carefully to minimize spreading of dirt and debris associated with construction.</td>
</tr>
<tr>
<td>3. Maintain negative air pressure within work site utilizing HEPA equipped air filtration units.</td>
<td>3. Contain construction waste before transport in tightly covered containers.</td>
</tr>
<tr>
<td>4. Seal holes, pipes, conduits, and punctures.</td>
<td>4. Cover transport receptacles or carts. Tape covering unless solid lid.</td>
</tr>
<tr>
<td>5. Construct interroom and require all personnel to pass through this room so they can be vacuumed using a HEPA vacuum cleaner before leaving work site or they can wear cloth or paper coveralls that are removed each time they leave work site.</td>
<td>5. Vacuum work area with HEPA filtered vacuums.</td>
</tr>
<tr>
<td>6. All personnel entering work site are required to wear shoe covers. Shoe covers must be changed each time the worker exits the work area.</td>
<td>6. Wet mop area with cleaner/disinfectant.</td>
</tr>
<tr>
<td>7. Upon completion, restore HVAC system where work was performed.</td>
<td></td>
</tr>
</tbody>
</table>
Step 4. Identify the areas surrounding the project area, assessing potential impact

<table>
<thead>
<tr>
<th>Unit Below</th>
<th>Unit Above</th>
<th>Lateral</th>
<th>Lateral</th>
<th>Behind</th>
<th>Front</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk Group</td>
<td>Risk Group</td>
<td>Risk Group</td>
<td>Risk Group</td>
<td>Risk Group</td>
<td>Risk Group</td>
</tr>
</tbody>
</table>

Step 5. Identify specific site of activity e.g., patient rooms, medication room, etc.

Step 6. Identify issues related to: ventilation, plumbing, electrical in terms of the occurrence of probable outages.

Step 7. Identify containment measures, using prior assessment. What types of barriers? (E.g., solids wall barriers); Will HEPA filtration be required?

(Note: Renovation/construction area shall be isolated from the occupied areas during construction and shall be negative with respect to surrounding areas)

Step 8. Consider potential risk of water damage. Is there a risk due to compromising structural integrity? (e.g., wall, ceiling, roof)

Step 9. Work hours: Can or will the work be done during non-patient care hours?

Step 10. Do plans allow for adequate number of isolation/negative airflow rooms?

Step 11. Do the plans allow for the required number & type of handwashing sinks?

Step 12. Does the infection prevention & control staff agree with the minimum number of sinks for this project? (Verify against FGI Design and Construction Guidelines for types and area)

Step 13. Does the infection prevention & control staff agree with the plans relative to clean and soiled utility rooms?

Step 14. Plan to discuss the following containment issues with the project team. E.g., traffic flow, housekeeping, debris removal (how and when),
# Infection Control Construction Permit

<table>
<thead>
<tr>
<th>Location of Construction</th>
<th>Permit No:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Coordinator:</td>
<td>Project Start Date:</td>
</tr>
<tr>
<td>Contractor Performing Work</td>
<td>Estimated Duration:</td>
</tr>
<tr>
<td>Supervisor:</td>
<td>Permit Expiration Date:</td>
</tr>
<tr>
<td>Telephone:</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>CONSTRUCTION ACTIVITY</th>
<th>YES</th>
<th>NO</th>
<th>INFECTION CONTROL RISK GROUP</th>
</tr>
</thead>
<tbody>
<tr>
<td>TYPE A: Inspection, non-invasive activity</td>
<td>GROUP 1: Low Risk</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TYPE B: Small scale, short duration, moderate to high levels</td>
<td>GROUP 2: Medium Risk</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TYPE C: Activity generates moderate to high levels of dust, requires greater 1 work shift for completion</td>
<td>GROUP 3: Medium/High Risk</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TYPE D: Major duration and construction activities requiring consecutive work shifts</td>
<td>GROUP 4: Highest Risk</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**CLASS I**
1. Execute work by methods to minimize raising dust from construction operations.
2. Immediately replace any ceiling tile displaced for visual inspection.
3. Minor Demolition for Remodeling

**CLASS II**
1. Provides active means to prevent air-borne dust from dispersing into atmosphere.
2. Water mist work surfaces to control dust while cutting.
3. Seal unused doors with dust tape.
4. Block off and seal air vents.
5. Wipe surfaces with cleaner/disinfectant.
7. Wet mop and/or vacuum with HEPA filtered vacuum before leaving work area.
8. Place dust mat at entrance and exit of work area.
9. Isolate HVAC system in areas where work is being performed, restore when work completed.

**CLASS III**
1. Obtain infection control permit before construction begins.
2. Isolate HVAC system in area where work is being done to prevent contamination of duct system.
3. Complete all critical barriers or implement control cube method before construction begins.
4. Maintain negative air pressure within work site utilizing HEPA equipped air filtration units.
5. Do not remove barriers from work area until complete project is checked by Infection Prevention & Control and thoroughly cleaned by Environmental Services.
6. Vacuum work with HEPA filtered vacuums.
7. Wet mop with cleaner/disinfectant.
8. Remove barrier materials carefully to minimize spreading of dust and debris associated with construction.
10. Cover transport receptacles or carts. Tape covering.
11. Upon completion, restore HVAC system where work was performed.

**CLASS IV**
1. Obtain infection control permit before construction begins.
2. Isolate HVAC system in area where work is being done to prevent contamination of duct system.
3. Complete all critical barriers or implement control cube method before construction begins.
4. Maintain negative air pressure within work site utilizing HEPA equipped air filtration units.
5. Seal holes, gaps, conduits and punctures appropriately.
6. Construct antechamber will require all personnel to pass through this room so they can be vacuumed using a HEPA vacuum cleaner before leaving work site or they can wear coveralls that are removed each time they leave the work site.
7. All personnel entering work site are required to wear shoe covers.
8. Do not remove barriers from work area until completed project is checked by Infection Prevention & Control and thoroughly cleaned by Environmental Services.
9. Vacuum work area with HEPA filtered vacuums.
10. Wet mop with disinfectant.
11. Remove barrier materials carefully to minimize spreading of dust and debris associated with construction.
13. Cover transport receptacles or carts. Tape covering.
14. Upon completion, restore HVAC system where work was performed.

**Date**

**Initial**

**Additional Requirements**

**Date**

**Initial**

Exceptions/Additions to this permit are noted by attached memos and

**Permit Request By:**

**Permit Authorized By:**

Adapted with permission V Kennedy, B Barnard, St Luke Episcopal Hospital, Houston TX. Form modified /updated & provided courtesy of Judene Bertley, FCSI Inc Beverly Hills MI 2002. jbertley@ameritech.net

Updated, 2009
QUESTIONS ON DEBATE

Q1: HEPA in the patient room or HEPA in the patient room AND the corridor?
- where does the air come from
- where is the air inlet situated
- ongoing renovation/demolition

Q2: >12 ACH needed and comfortable?
- fresh air HEPA filtered or
- Recirculation over HEPA filter

Q3: Airflow: from one side to the opposite side or LAF?

Q4: Universal protection: risk for infectious particles?
- air flow from patient room to anteroom
- air flow from anteroom to patient room

Q5: Control of air flow pattern: in terms of pressure (>2.5Pa) or flow?

Dust and spores
Due to ongoing demolition
Q1: HEPA AIR IN THE CORRIDOR? the effect of demolition

FIGURE 2. Aspergillus niger and A. flavus colony concentrations at each outdoor location before and after the implosion. During the first 10 minutes after the implosion at 100 m and the first 5 minutes at 200 m, Aspergillus concentrations could not be quantified due to plate overgrowth. Bars for those time periods represent total fungal overgrowth.

FIGURE 1. Map of the implosion site and sampling locations.

Srinivasan et al. Infect Control Hosp Epidemiol 2002;23:520-524
Q1: HEPA AIR IN THE CORRIDOR? 
the effect of demolition

**FIGURE 3.** Particle concentrations and total fungal concentrations (bars) at the 100-m location. Bars for the 5- and 10-minute samples represent fungal overgrowth of the plates. Time of the implosion was 10:03 am. Collection of data on particle mass concentration began 60 minutes before and continued for 120 minutes after the implosion. Collection of data on fungal count began 45 minutes before and continued for 90 minutes after the implosion.

**FIGURE 4.** Particle concentrations and total fungal concentrations (bars) at the 200-m location. The bar for the 5-minute sample represents fungal overgrowth of the plate. Time of the implosion was 10:03 am. Collection of data on particle mass concentration began 60 minutes before and continued for 120 minutes after the implosion. Collection of data on fungal count began 45 minutes before and continued for 90 minutes after the implosion.

Srinivasan et al. *Infect Control Hosp Epidemiol* 2002;23:520-524
QUESTIONS ON DEBATE; answer Q1

- Q1: HEPA in the patient room or HEPA in the patient room AND the corridor?
  
  → in case of ongoing demolition and renovation;
  - All air through central HEPA filtration (Q1); supplies both rooms and corridors; whole ward at slight positive pressure to surrounds

  → No demolition / renovation;
  - All air through central HEPA filtration (Q1); supplies rooms

Thanks to Peter Hofmann HPA Dacie Ward, Hammersmith Hospital, London
1. Airborne Contaminant Removal

Table B.1. Air changes/hour (ACH) and time required for airborne-contaminant removal efficiencies of 99% and 99.9%*

<table>
<thead>
<tr>
<th>ACH+</th>
<th>99% efficiency</th>
<th>99.9% efficiency</th>
</tr>
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<tbody>
<tr>
<td>2</td>
<td>138</td>
<td>207</td>
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<tr>
<td>4</td>
<td>69</td>
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<tr>
<td>50</td>
<td>6</td>
<td>8</td>
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</tbody>
</table>

* This table is revised from Table S3-1 in reference 4 and has been adapted from the formula for the rate of purging airborne contaminants presented in reference 1435.
+ Shaded entries denote frequently cited ACH for patient-care areas.
§ Values were derived from the formula:

Guidelines for Environmental Infection Control in Health-Care Facilities CDC 2003
Q2: TRANSMISSION BY AEROSOLS

Risk of Infection with M. tuberculosis:
Moderate exposure (13 infectious quanta per hour)

Risk of Infection

Room Air Changes per Hour

- None
- Disposable
- Half-face elastomeric
- PAPR- hood
- Full-face elastomeric
- PAPR-full-face
- Respirator

Rooms 1-4
Figure 1. Kaplan-Meier analysis of time from hiring to tuberculin conversion among all participants, stratified by level of air exchange in nonisolation rooms.

The solid line represents clinical personnel at increased-risk hospitals with fewer than two air exchanges per hour (ACH), the dotted line represents clinical personnel at increased-risk hospitals with two or more air exchanges per hour, and the dashed line represents clinical personnel at low-risk hospitals and nonclinical personnel, exposed to all air exchange rates. The latter data were truncated after 20 years because there were too few participants.
QUESTIONS ON DEBATE; answer Q2

Q2: >12 ACH needed and comfortable?
  ▪ fresh air HEPA filtered or
  ▪ Recirculation over HEPA filter

  ▪ The only infection where aerosol spread is the main hazard is TB, more of a risk if TB is MDR. Here air change rates (Q2) may be important.

  ▪ The problem with air recirculation (Q2) is if things go wrong and the filter leaks. This would actively transfer contamination between rooms if one AHU for the unit. If air is fed back in so it takes the same pathway as fresh air, the system relies on one set of filters that need to be monitored. (This should be judged on engineering criteria, but there must be continuous or regular monitoring when a system is critical)

Thanks to Peter Hofmann HPA Dacie Ward, Hammersmith Hospital, London
QUESTIONS ON DEBATE; answer Q3

Q3: Airflow: from one side to the opposite side or LAF?

- If the only air to breath in a room has passed through a filter, provision as laminar airflow is irrelevant – also direction of flow in the room (Q3)

Thanks to Peter Hofmann HPA Dacie Ward, Hammersmith Hospital, London
QUESTIONS ON DEBATE; answer Q4

Q4: Universal protection: risk for infectious particles?

- air flow from patient room to anteroom
- air flow from anteroom to patient room

- Having an anteroom at negative pressure (Q4) to both room and corridor, so no air leaves the lobby except via mechanical extract, would create a barrier between room and common areas. (This is fairly marginal but probably worth doing if building a new unit)

- Having an anteroom at positive pressure needs HEPA filtering of the air exhausted in the lobby
QUESTIONS ON DEBATE; answer Q4

- Assume that stopping rooms leaking will not be high quality assurance but ensure they leak in a safe direction
  - If rooms are to contain airborne infection, they should leak inwards, i.e. be “negative pressure”
  - If rooms are to keep fungal spores away from patients, it needs HEPA (high efficiency particulate air) filters that supply air in excess such that clean air escapes outward via gaps, preventing contaminated air from entering via those gaps. This is “positive pressure” but positive pressure without HEPA filtration is pointless – it will just be supplying fungal spores via the ventilation system.

- A mixture of approaches may be needed according to local requirements (but no switchable rooms – people get it wrong!).
QUESTIONS ON DEBATE; answer Q5

Q5: Control of air flow pattern: in terms of pressure (>2.5Pa) or flow?

- Safety is achieved by having a wide margin between the rates of air supply and extraction (Q5)