What’s in the air and how to keep it away?

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ESCMID Post-graduate technical workgroup
Infection Prevention and Control; Let’s get Practical
## Disclosure of speaker’s interests

### (Potential) conflict of interest

| None |

### Potentially relevant company relationships in connection with event

| None |

- Sponsorship or research funding
- Fee or other (financial) payment
- Shareholder
- Other relationship, i.e. …
Content

• History
• Transmission
• Prevention and isolation rooms
History of quarantine

• Isolation; separation of individuals who are contagious
  – Isolation is one of the oldest known methods to prevent transmission
  – Live-long isolation of Lepra patients

• Quarantine; same procedure for individuals suspected to be(come) contagious;
  – Quarantine; 500 BC
    • Hippocratus indicated that it takes 40 days for an acute illness to reveal
    • After 40 days the disease was chronic (and therefore no plaque)
History of quarantine

• 1377; quarantine;
  – Law of rector Harbour of Ragusa (Dubrovnik); trentina= 30
  – 40 days for travellers; quaranta=40

  – Economic advantage; black death was destroy of trade

  – Population of Ragusa was not allowed to visit travellers in quarantine for 30-40 days

→ Venezia 1432; Lazaretto’s; quarantine station on an island
→ spread of quarantine laws over Europe (Pisa, Marseille)
History of quarantine

– 16th century; Fracastoro argued; “little particles can spread disease”

first use of the Latin word fomes (tinder) in Contagione et Contagiosis Morbis (1546)

→ “I call fomites such things as clothes, linen, etc., which although not themselves corrupt, can nevertheless foster the essential seeds of the contagion and thus cause infection.”

→ In 1546 he proposed that epidemic diseases are caused by transferable tiny particles or "spores" that could transmit infection by direct or indirect contact or even without contact over long distances. In his writing, the "spores" of diseases may refer to chemicals rather than to any living entities.

• His theory remained influential for nearly three centuries, before being superseded by a fully developed germ theory.
Mass grave Lazaretto Vecchio, 500 death per day (plaque)

1348-1359; 30% of European population
History of quarantine

- 16th century; certificate “free of disease”
- 19th century; cholera epidemics;
  - 1834; proposal for international standardization of quarantine measures
  - 1893; agreement USA/Europe; notifiable diseases; cholera, yellow fever, plaque
- 20th century tbc; “great white plague”
  - 1880-1930 sanatoria; = transmission prevention
  - Base for Public health;
    - lazaretto became health center
    - 1907; International organisation for public health; in 2 years 20 countries → WHO
      - 1926; smallpox and typhus added
- 21th century;
  - 2003; SARS; quarantine 10 days
History of quarantine
Content

- History
- Transmission
- Prevention and isolation rooms
HOW DOES IT SPREAD?

- by air
- by splash accident
- blood-borne
- fecal-oral
- by using no hand desinfection

cross-infection
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)
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
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
THE FUTURE: MORE CHALLENGES

• In 2050: 25% of the population > 65 years

• chronic diseases
  – frequent and longer hospital visits
  – higher risk on hospital acquired infections

• Increase of multiresistant pathogens
  (MRSA, VRE,CPE)

• Pandemics: influenza

• Increase of exotic diseases (travelling, mobility)
• **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, suctioning, 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 → long distances
Droplet suspension. Illustration of the mechanics of suspension of droplet nuclei produced by an infected patient due to the effects of air friction and gravity.
EVERYONE KNOWS:
WHEN ONE CHICKEN FALLS ILL...
ALL OTHERS....
# TRANSMISSION AND ISOLATION

## Impact on Hospital Design

<table>
<thead>
<tr>
<th>Transmission</th>
<th>Isolation</th>
<th>Measures</th>
<th>Example m.o.</th>
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</thead>
<tbody>
<tr>
<td>Contact; Direct/indirect</td>
<td>Single room</td>
<td>Gloves/gowns</td>
<td>clostridium, ESBL, HSV</td>
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<tr>
<td>Droplet</td>
<td>Single room</td>
<td>Mask</td>
<td>pneumococci, streptococci, bordetella, meningococci</td>
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<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>
(A) Airflow visualisation in the microenvironment around two life-size mannequins. The source mannequin is exhaling through the nose. Smoke visualization of exhalation flow from nose of the right mannequin penetrating into the breathing zone of the left mannequin, which are 0.4 m apart.

(B) Demonstration of cross-infection in a simulation ward

DISSEMINATED VARICELLA
Content

• History
• Transmission
• Prevention and isolation rooms
Isolation rooms

• Definition;
  – A room with controlled air flow
  – A room with an anteroom
  – And/or a room with controlled air quality
TO PROTECT: technical program of requirements of isolation rooms

Goals;
1. to protect your patient from acquiring nosocomial infections
2. To protect your personnel from acquiring infections

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

→ Isolation rooms; whereto does the air flow?
SINGLE ROOMS AND MORE...

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.
# AIR CHANGES PER HOUR (ACH)

## 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>
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<th>99% efficiency</th>
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<th>99.9% efficiency</th>
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<td>50</td>
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<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:

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Guidelines for Environmental Infection Control in Health-Care Facilities CDC 2003
Droplet generation. A flash photo of a human sneeze, showing the expulsion of droplets that may be laden with infectious pathogens. Sneezing can produce as many as 40,000 droplets of 0.5–12 μm. These particles can be expelled at a velocity of 100 m/s.


*Journal of Hospital Infection, Volume 64, Issue 2, 2006, 100–114*
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 (< 2 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.
Most doctors think they are not vulnerable!?
TRANSMISSION BY AEROSOLS

it is not just air and rooms....

Risk of Infection with M. tuberculosis:
Moderate exposure (13 infectious quanta per hour)
New policy; mandatory isolation of

- pts (suspected for) tbc
- Pts (suspected for) HIV and abnormal thoracic X ray
- Discontinued; after 3 negative smears
- Tb epidemiologist/coordinator
- 6-mntly mandatory screening HCWs

Number of tuberculosis exposure episodes per month. The arrow indicates when the new expanded respiratory isolation policy was introduced.
Six-month tuberculin skin test (TST) conversion rates for health care workers at Grady Memorial Hospital. The number of health care workers with a positive test result divided by the total number of health care workers tested during that time is shown above each bar.
Trends in tuberculosis cases and health care worker tuberculin skin test conversions and major infection control interventions. 1Intervention is ongoing.
A bit of history again...

'Der Zauberberg’
Thomas Mann 1924

Berghotel Sanatorium Schatzalp
Davos
FIGURE 2. Example of airborne infection isolation (AII) room with anteroom and neutral anteroom*.

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.
The immunocompromised risk for aspergillus....
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: exogeneous source → high-efficiency particulate air (HEPA) filtration
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]  
Rahme 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 Buchner et al. [24] and Sherertz 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 Sherertz 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]  
2001 guidelines for the design and construction of hospital and health care facilities [52]  
Siegler et al. [53] contributed a book section  
Studies by Buckner et al. [24] and Sherertz et al. [35] were considered in the present review  
Arnow et al. [54], Breton et al. [55], Guarro et al. [56], Burton et al. [57], Kyriakides et al. [58],  
McWhinney et al. [48], and Rahme [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  
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**NOTE.** HEPA: high efficiency particulate air.  
<sup>a</sup> B: Strong or moderate evidence for efficacy, but only limited clinical benefit; generally recommended.  
<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.
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.
FIGURE 2. Example of airborne infection isolation (AII) room with anteroom and neutral anteroom*

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- 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
Indication for isolation; what to do when all rooms are occupied?

<table>
<thead>
<tr>
<th>Isolatie-indicatie</th>
<th>Mortaliteit</th>
<th>Morbiditeit</th>
<th>Pers/Politiek</th>
<th>Pers/politiek x2</th>
<th>Richtlijnen</th>
<th>Transmissiekans</th>
<th>Transmissiekans x2</th>
<th>Totaal</th>
<th>Opmerking</th>
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</table>
KEEP IN MIND THE RISKS...
Ventilation Requirements isolation rooms; CDC Guideline Preventing Health-Care-Associated Pneumonia 2003-4

- Protected environment (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.

QUESTIONS ON DEBATE

• Q1: HEPA in the patient room
  or
  HEPA in the patient room AND the corridor?
  consider: 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?

• All answers with thanks to Peter Hofmann HPA
"When I return:
put me in a closet
rather than in the ward"

from Bacon 1920,
Emerging Inf Dis 2001:7
QUESTIONS ON DEBATE

• Q1: HEPA in the patient room

   or

   HEPA in the patient room AND the corridor?

consider: where does the air come from?
   where is the air inlet situated?

→ In case of demolition near by or large renovations
All air through central HEPA filtration (Q1); supplies both rooms and corridors;
whole ward at slight positive pressure to surrounds
QUESTIONS ON DEBATE

• Q2:
  >12 ACH needed and comfortable?

• Q2b:
  – fresh air HEPA filtered or
  – Recirculation over HEPA filter

Q2: The only infection where aerosol spread is the main hazard is TB and some viruses. Here air change rates (Q2) may be important.

Q2b: 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)
QUESTIONS ON DEBATE

• Q3: Airflow in HEPA filtered rooms:
  – 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).
QUESTIONS ON DEBATE

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

Having a lobby 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)
Q4: Universal protection: risk for infectious particles?

**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
• 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

• Q5: Control of air flow pattern: in terms of pressure (\(>2.5\text{Pa}\)) or flow?

Safety is achieved by having a wide margin between the rates of air supply and extraction (Q5).
Design and people...
THINK BEFORE DESIGN
THINK BEFORE DECIDE
IT’S ALL IN THE AIR