Hospital ventilation & infection prevention

Peter Hoffman
Consultant Clinical Scientist
Antimicrobial Resistance and Healthcare Infections Reference Unit
In the beginning ……

The importance of ingress of contaminated air from clinical areas into theatres:


Powerful extracts in the theatre (to get rid of steam from boiling water “sterilisers”). Contaminated air was being drawn into a theatre from adjacent clinical areas. When this inward flow was reversed “This was followed by an immediate reduction in the bacteria in the air and by a striking fall in the incidence of wound infections from 37 out of 427 clean operations to 5 out of 532”.

There are other, similar papers from that era.
But it’s not just air from outside theatres that’s contaminated

Skin cells are constantly being shed.

They are small (5 – 15 micron) particles, some of which will carry microcolonies (1 – 1,000 cells) of those bacteria that live on that person’s skin.

The more people in a space and the more they move, the greater the concentration of these contaminated skin scales (“squames”).
1,000 litres of air in an empty room
1,000 litres of air – person walking by sampler
Contamination from the air supply?

Outdoor air is usually reasonably clean, but unreliably so.

Air to operating theatres is filtered to remove most contamination.

The air supplied is low contamination (HEPA filters not required) - not sterile; it is the most minor of the contamination sources.
Infection prevention & theatre ventilation

1 – Preventing ingress of airborne contamination via the supplied air
   ➢ Filtration

2 – Excluding ingress of airborne contamination from surrounding areas
   ➢ Controlling airflow direction between rooms

3 – Diluting airborne contamination generated in the theatre and preparation room
   ➢ High air supply rates

➢ All this is to stop airborne contamination from settling out in “the wound”
Probably the majority of airborne bacteria that end-up in a surgical wound, do so via exposed instruments.
Theatre suite ventilation

- **S** = Supply ventilation
- **E** = Extract ventilation
- □ = Pressure (pascals) relative to outside suite (zero)
- ○ = Air change rate
Ventilation of operating theatres

For infection control, validation (commissioning) should show:

- Correct air supply engineering, correct filters in place, air cannot bypass filtration (visual inspection of filters)

- Turbulent airflow in theatre with no stagnant areas

- Correct ventilation rates: 25 air changes per hour in theatre and prep
  - i.e. air of 25 time the volume of the room supplied every hour

- Correct airflow between rooms: robust airflow in the right direction, precise pressure is less important
Settle plates for theatre sampling?

Settle plates sample microbes settling out from a theoretical cylinder of air above the plate.

- Large heavy particles will settle-out quickly – sampled at high efficiency
- Small light particles will settle-out slowly – sampled at low efficiency

The relationship to actual microbial numbers in the air will depend on the size distribution of those particles.

There are no pass/fail criteria for settle plates used in theatres

There can be local traditions of using settle plates; their interpretation is subjective.
Airborne isolation

There are a minority of infections where transmission can be by very small airborne particles.

These particles are so light that they behave much as the gas in which they are suspended – they are effectively solutions in the air: “aerosols”

Examples of infections where transmission via the air plays a significant role:

- TB – particularly smear positive or MDR + any TB in the context of immunocompromised patients.
- Varicella-zoster, measles
- Viral haemorrhagic fevers?? (probably not)
Airborne isolation

Isolation of these patients should achieve:

- Dilution of infectious particles in the room for the safety of staff and visitors in the room (in addition to respiratory protection)
- Prevent transfer of contaminated air to nearby rooms
- Safe exhaust of air to outside

All these should be achieved in a negative pressure room
Negative pressure room

A room from which much more air is extracted than supplied. This produces:

- High dilution in the room air – *for the safety of staff and visitors in the room*
- Air passes into the room from adjacent rooms to make-up for the loss of air – *this means that the room leaks inwards and does not pass out to adjacent rooms*
- Air should be exhausted outside away from air intakes, windows or people – *it will be safely exhausted to infinite dilution*

- The room cannot have opening windows – these would negate any air control scheme.
- The door must be kept closed
- The room should have its own toilet and shower

An anteroom is useful.
How to achieve negative pressure?

Mechanical ventilation – expensive but good.

Extract fan in wall or window – cheap but noisy (need patient’s cooperation for successful isolation), controls can be wrongly adjusted (to intake rather than extract) or switched off when should be on.

Whirly bird (wind-driven extracts) – will vary according to windspeed & need regular mechanical maintenance. Useful as backup rather than primary means to achieve negative pressure.
How much negative pressure?

It does not matter, as long as smoke shows good flow from outside to inside.
Air change rate

The greater the air change rate, the faster the dilution of airborne infectious particles – for the safety of staff and visitors in the room.

In patient isolation rooms, there should be at least 6 air changes per hour, preferably around 12. More than this and the patient may not be comfortable.

➢ If the patient is uncomfortable, they may not cooperate with their isolation.

In procedure rooms, such as bronchoscopy, there can be much higher air change rates.
Air change rates and dilution

One air change removes 63% of airborne contamination (assuming good mixing). The timing of this process starts when the patient leaves the room (when dispersion stops).

<table>
<thead>
<tr>
<th>Air changes</th>
<th>Contamination remaining (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>1</td>
<td>36.8</td>
</tr>
<tr>
<td>2</td>
<td>13.5</td>
</tr>
<tr>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>0.67</td>
</tr>
<tr>
<td>10</td>
<td>0.0046</td>
</tr>
</tbody>
</table>

If a bronchoscopy room has 30 air changes per hour, this means one air change every 2 minutes, 5 air changes (>99% removal) in 10 minutes.
Protective isolation

The majority of susceptible patients can be protected from infection by procedures – handwashing, equipment decontamination etc.

A very small minority of highly neutropenic patients (mainly bone marrow transplant) need protection against breathing-in fungal spores – these originate from outside the hospital.
Protective isolation – the positive pressure room

Air is supplied to rooms via high efficiency particulate air (HEPA) filters.

More air is supplied than extracted, so clean air leaks out of their rooms preventing ingress of unfiltered air.

The rate of air supply is irrelevant – it is not trying to dilute anything inside the room.

- It cannot have opening windows
- The door must be kept closed; a lobby is useful.
- It must have its own toilet/shower

*Positive pressure ventilation without HEPA filtration is irrelevant.*
This is not ventilation

This takes in air, cools it and returns it to the same room.

The air does pass through internal filters, but these are not fine enough to remove microbes.

This is a good way of cooling rooms but does nothing about controlling the level of microbial contamination or the airflow between rooms.