Reduction of airborne bacteria in clean areas and in operating room

- **WHY?**
  - Increased number of operations susceptible to infection of airborne bacteria e.g., hip joint operations
  - Increased frequency of bacteria resistant to antibiotics

- **HOW?**
  - Technical measures:
  - Ventilation and clothing systems
Viable particle or colony forming unit (CFU) of Staphylococcus
Airborne bacteria in the operating room

Aberdeen Royal Infirmary 1889

Lister’s spray with carbolic acid into the air
From the Archives of Surgery 1938

1938 North Carolina, M.D. Deryl Hart

concludes in his paper *Pathogenic bacteria in the air of operating rooms – their widespread distribution and the method of control* that

1. The greatest cause of infection in clean incisions in the modern, well run operating room is the pathogenic bacteria floating in the air, universally present in the occupied room

2. Air condition with forced ventilation is effective in reducing the amount of contamination of the air

3. Large, heavy masks should be worn over the nose and mouth by all occupants at all times
The number of airborne CFUs in the operating room

The combination of

- **The ventilation system**
  - Mainly depending on the air volume flow

- **The total source strength**
  - The clothing systems used
  - The number of people
  - The activity level
Evaluation of clothing systems
Test Chamber

- Changing area
- Body-box
- HEPA filter
- Exhaust fan
- Measuring probes
Unidirectional vertical airflow
The Source Strength

\[ c = \frac{q_s}{Q} \]

Where:

\[ C = \text{concentration, particles (number/m}^3\text{), bacteria-carrying particles (CFU/m}^3\text{)} \]

\[ q_s = \text{source strength, outward particle flow (number/s), bacteria-carrying particle (CFU/s)} \]

\[ Q = \text{total air flow (m}^3\text{/s)} \]
Compared clothing systems
Compared clothing systems
Tested woven polyester fabrics

- **Integrity® (US)**
  - 95 g/m²
  - 3/1 twill

- **Selguard® (Japan)**
  - 120 g/m²
  - Plain

- **XR 50 (Taiwan)**
  - 115 g/m²
  - 3/2 twill

- 1 mm
# Results - Source Strength Test Chamber

<table>
<thead>
<tr>
<th>Clothing system; polyester (50%) and cotton (50%)</th>
<th>Contaminant</th>
<th>Number per second from one (1) person</th>
<th>1 wash</th>
<th>25 washes</th>
<th>Approx. 50 washes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Food industry polyester (65%) and cotton (35%)</strong></td>
<td>Particles ≥0.5 µm</td>
<td>99,885</td>
<td></td>
<td></td>
<td>49,531</td>
</tr>
<tr>
<td></td>
<td>Particles ≥5 µm</td>
<td>2,790</td>
<td></td>
<td></td>
<td>1,780</td>
</tr>
<tr>
<td></td>
<td>Particles ≥25 µm</td>
<td>738</td>
<td></td>
<td></td>
<td>506</td>
</tr>
<tr>
<td></td>
<td>CFU</td>
<td>11.8</td>
<td></td>
<td></td>
<td>13.8</td>
</tr>
<tr>
<td><strong>Surgical clothing system</strong>; polyester (50%) and cotton (50%)</td>
<td>Particles ≥0.5 µm</td>
<td>4,060</td>
<td>13,875</td>
<td>12,207</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Particles ≥5 µm</td>
<td>270</td>
<td>535</td>
<td>698</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CFU</td>
<td>1.7</td>
<td>4.2</td>
<td>9.0</td>
<td></td>
</tr>
</tbody>
</table>
# Results - Source Strength

## Test Chamber

<table>
<thead>
<tr>
<th>Clothing system</th>
<th>Contaminant</th>
<th>Number per second from one (1) person</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1 wash</td>
</tr>
<tr>
<td>High quality cleanroom clothing system; polyester (99%) and carbon fiber (1%)</td>
<td>Particles ≥0.5 µm</td>
<td>585</td>
</tr>
<tr>
<td></td>
<td>Particles ≥5 µm</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>CFU</td>
<td>0.38</td>
</tr>
<tr>
<td>Operating room clothing of cleanroom quality in combination with undergarments</td>
<td>Particles ≥0.5 µm</td>
<td>146</td>
</tr>
<tr>
<td></td>
<td>Particles ≥5 µm</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>CFU</td>
<td>0.2</td>
</tr>
</tbody>
</table>
Four compared clothing systems
Mixed material  Blouse and trousers
69% cotton, 30% polyester and 1% carbon fiber
Disposable head-cover  Private socks and shoes
Blouse and trousers  69% cotton, 30% polyester and 1% carbon fiber; Disposable head-cover Private shoes
Surgical clothing: Ordinary
Blouse and trousers, 50% cotton and 50% polyester
Disposable head-cover
Private socks and shoes
Blouse and trousers, 50% cotton and 50% polyester
Disposable head-cover
Clean air suit; Head-cover, blouse and trousers 99% polyester (microfiber) and 1% carbon fiber

Private socks and shoes
Head-cover, blouse and trousers 99% polyester (microfiber) and 1% carbon fiber
Cleanroom quality; Head-cover, coverall and long boots, 99% polyester and 1% carbon fiber
Underwear (blouse and trousers) in 100% polyester (microfiber)
Cleanroom quality; Head-cover, coverall and long boots, 99% polyester and 1% carbon fiber
Underwear 100% polyester (microfiber)
Summary of Results from Operation rooms

Mixed material

Ordinary clothing

Clean Air Suit

Cleanroom quality with undergarments
Pore size matters

Mixed material

Polyester 99%, carbon fiber 1%
**Some Source Strength calculations**

- Indications based on data from ongoing operations; Supply air 0.54 m$^3$/s

<table>
<thead>
<tr>
<th>Clothing system</th>
<th>Mean Value Concentration during operation (CFU/m$^3$)</th>
<th>Total Source Strength (CFU/s)</th>
<th>Average number of people</th>
<th>Operating room Source Strength per person (CFU/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixed material</td>
<td>58.9</td>
<td>31.8</td>
<td>5</td>
<td>6.4</td>
</tr>
<tr>
<td>Ordinary</td>
<td>24</td>
<td>13.0</td>
<td>7</td>
<td>1.9</td>
</tr>
<tr>
<td>Microfiber</td>
<td>13.2</td>
<td>7.1</td>
<td>8</td>
<td>0.9</td>
</tr>
<tr>
<td>Cleanroom quality</td>
<td>2.5</td>
<td>1.4</td>
<td>7</td>
<td>0.2</td>
</tr>
</tbody>
</table>
The capability of ventilation systems

- **2000 m³/h~0.56 m³/s** could reduce a total source strength of 5.6 CFU/s to a concentration of 10 CFU/m³

- **5 000 m³/h~1.4 m³/s** could reduce a total source strength of 14 CFU/s to a concentration of 10 CFU/m³

- **10 000 m³/h~2.8 m³/s** could reduce a total source strength of 28 CFU/s to a concentration of 10 CFU/m³
The concentration of airborne biocontamination in operating rooms and in clean areas depends upon:

- Supply air filter quality
- Air flow (m$^3$/h)
- Number of people and their degree of activity
- Clothing system
- Measuring technique
Clothing systems for operating room and clean areas

- A question of comfort?
- Routines and working discipline?
- A question of patient safety?
- Time for upgrading?
Thank you for your attention!