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# Ventilation and indoor air quality in health care facilities – practices and challenges

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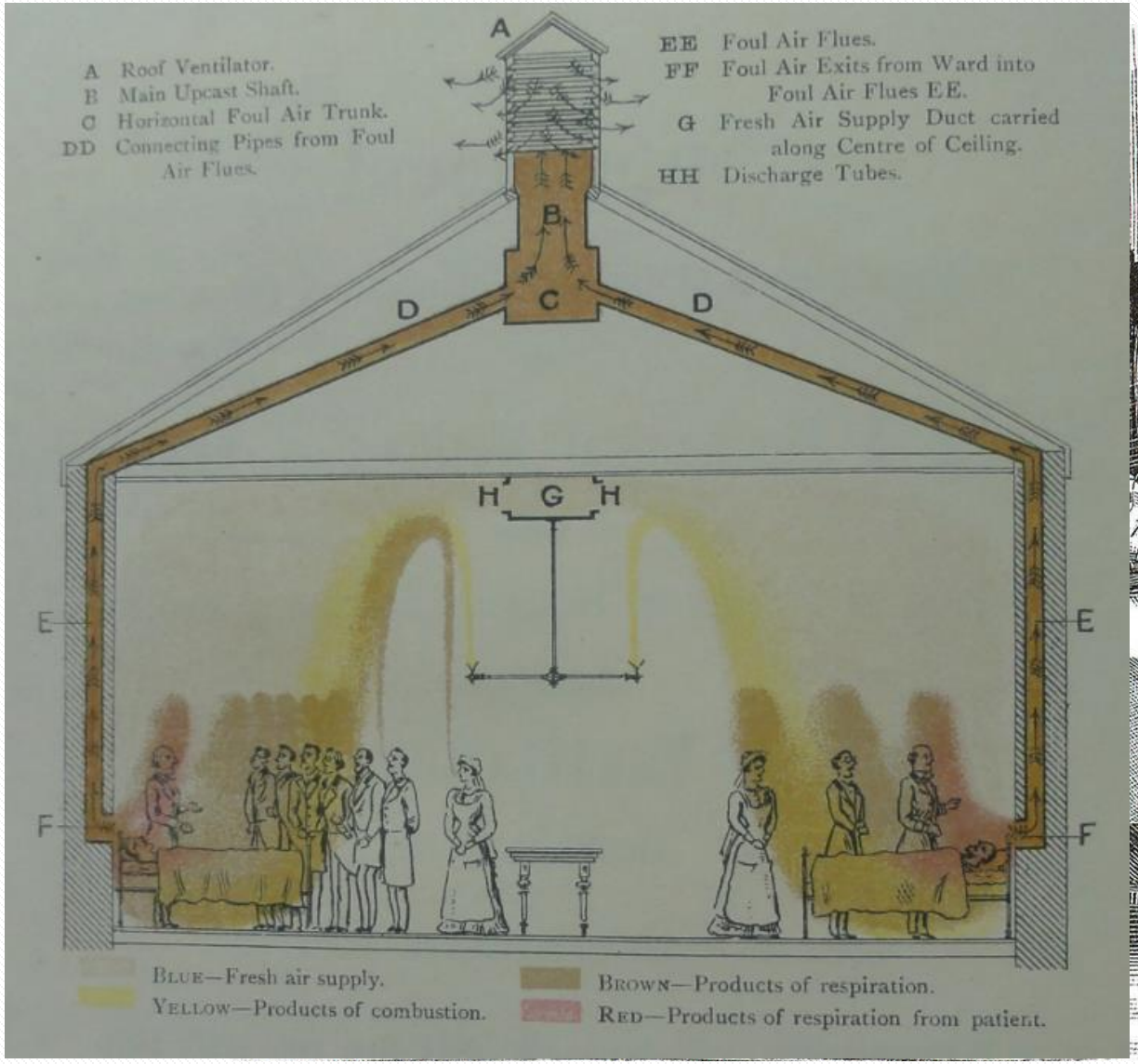
**Session no.: 28.05.2019**

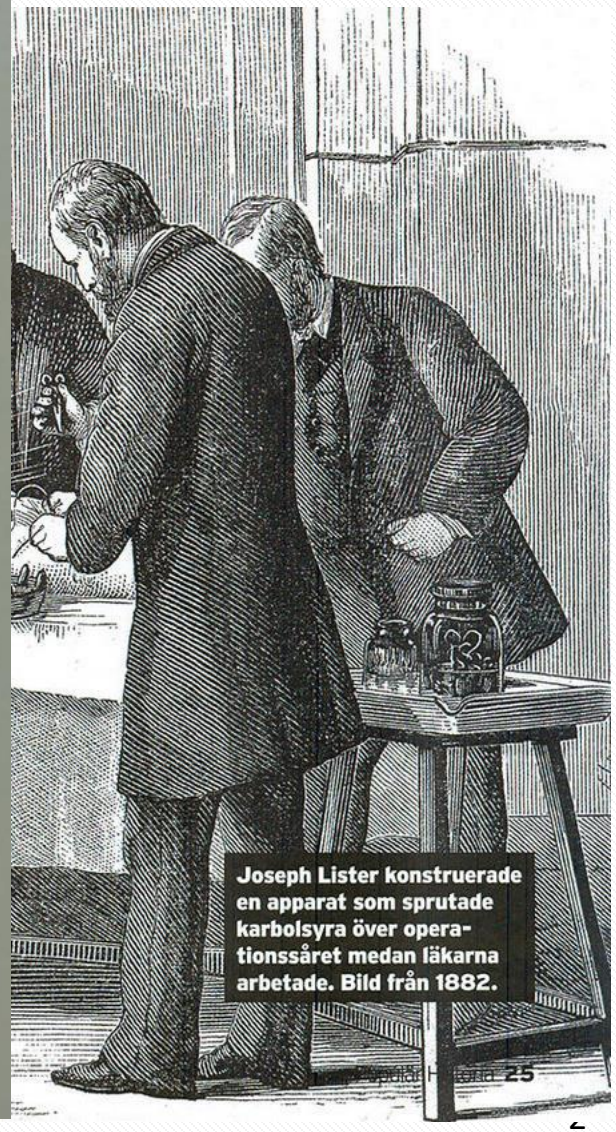
# New challenge or not?

1882 Joseph Lister –

Phenol (fenol, karbolsyre)

1899 Robert Boyle & Son



# Background

- Hospital-acquired infections are a major challenge to patient safety: 4.5 per 100 admissions and almost 5% deaths resulted from or were associated with a hospital-acquired infection.
- High mortality rate in operating rooms- 313 million surgical procedures are performed worldwide each year and at least 4.2 million people worldwide die within 30 days of surgery annually (the 3rd highest cause of mortality in the world).
- Very high energy consumption for indoor environment control in operating rooms (50-100 times of ventilation rate comparing residential and commercial buildings).
- Very high indoor air quality requirements (10-100 colony forming units CFU/$m^3$, while 1000-5000 CFU/$m^3$ in residential buildings).

# Ventilation and indoor air quality in health care facilities – practices and challenges

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Parameter requirements for an LAF-equipped OR environment in eight current European standards (Aganovic, 2019)

| Country | Supply Velocity (m/s) | Pressure difference (Pa) | Humidity (%) | Temperature (°C) | LAF diffuser size ($m^2$) | Maximum bacterial load ($CFU/m^3$) |
|---|---|---|---|---|---|---|
| Austria [ÖNORM H 6020] | 0.22-0.45 | - | 35-45 | 20-24 | ≥ 8 $m^2$ | - |
| France [NF S 90-351] | 0.25-0.35 | 15 ± 5 | - | 19-26 | - | 10 |
| Germany [DIN 1946] | ≥ 0,23 | - | 30-50 | 19-26 | ≥ 3.2 × 3.2 $m^2$ | 4-10* |
| Netherlands [CBZ] | - | - | - | 18-22 | - | - |
| Norway [Aune K.S 2014] | 0.25-0.28 | 5-10 | - | - | - | - |
| Switzerland [SWKI VA 105-01] | 0.23-0.25 | - | 30 | 19-26 | ≥ 9 $m^2$ | 10 |
| UK [HTM 03-01:2007] | 0.38 m/s | 25 | 35-60 | 18-25 | ≥ 2.8 × 2.8 $m^2$ | 10 |
| USA [ASHRAE Standard 170-2013] | - * | 4 | 20-60 | 20-24 | ≥ 3.0 × 3.0 $m^2$ | - |

* supply airflow requirements are based on minimum total ACH > 20

# Clinical studies reporting incidences of deep SSIs after total arthroplasty surgeries for LAF *vs* MV systems in ORs (Aganovic, 2019)

| Country (Study period) | LAF | | MV | |
|---|---|---|---|---|
| | Total | SSI (%) | Total | SSI (%) |
| UK [Kakwani et al. 2007] (2000-04) | 212 | 0 (0.0) | 223 | 9 (4.0) |
| Germany [Brandt et al. 2008] (2000-04) | 23650 | 247 (1.0) | 14369 | 121 (0.8) |
| Norway [Dale et al. 2009] (1987-2008) | 45620 | 324 (0.7) | 48338 | 260 (0.5) |
| Denmark [Pedersen et al. 2010] (1995-2008) | 72423 | 517 (0.7) | 8333 | 80 (0.9) |
| USA [Namba et al. 2012] (2000-04) | 8478 | 46 (0.5) | 109 | 22 013 (0.4) |
| South Korea [Kim et al. 2012] (2000-04) | 2037 | 37 (1.8) | 1149 | 16 (1.3) |
| Germany [Breier et al. 2011] (2004-09) | 43986 | 449 (1.0) | 17780 | 113 (0.6) |


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# Challenges

- Whether surgical facilities affect laminar airflow?
- Does thermal plumes from a patient affect laminar airflow?
- Whether mixing ventilation is better than laminar airflow?
- Can we get 10 CFU/m level in ORs with mixing ventilation?


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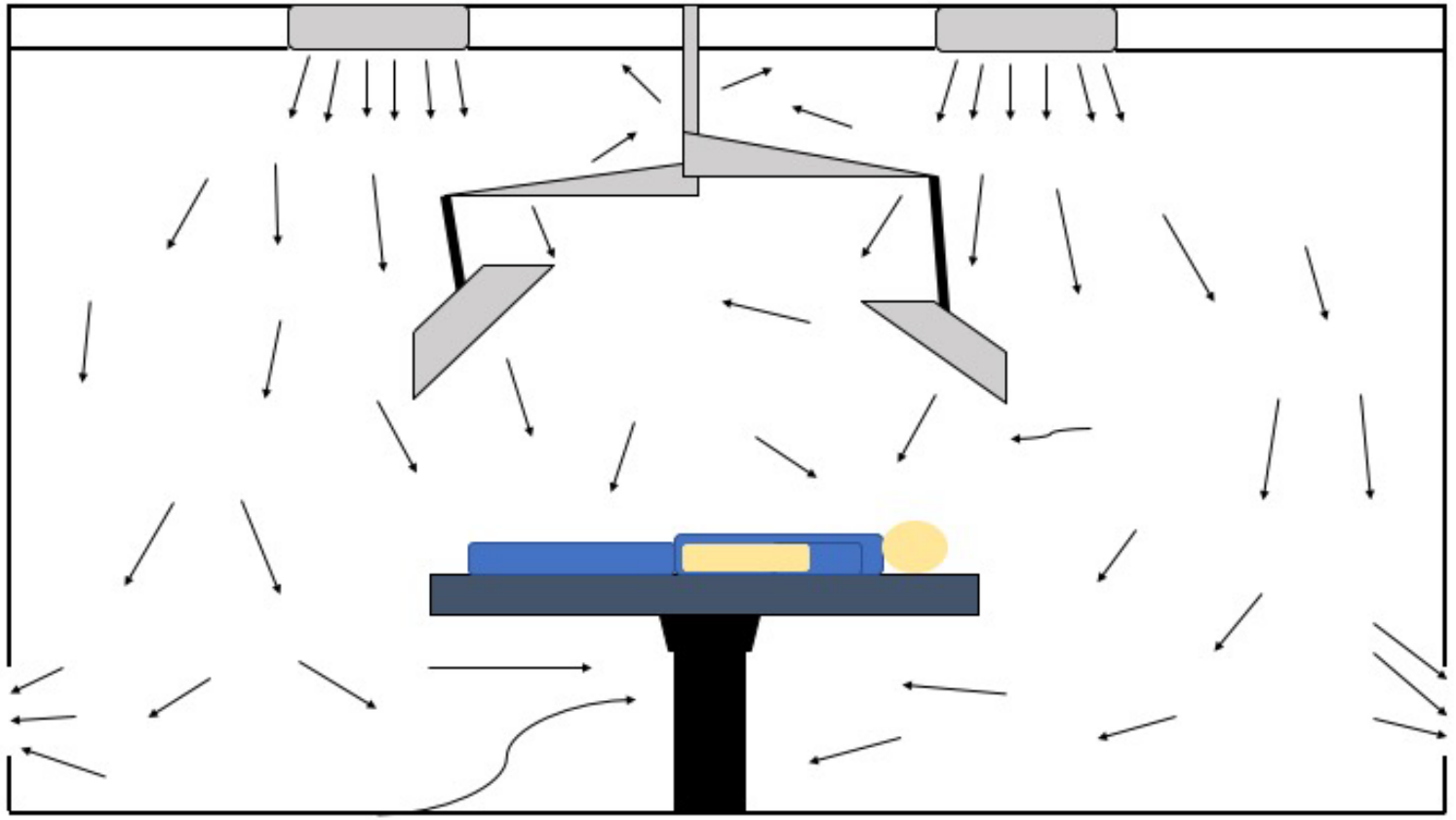
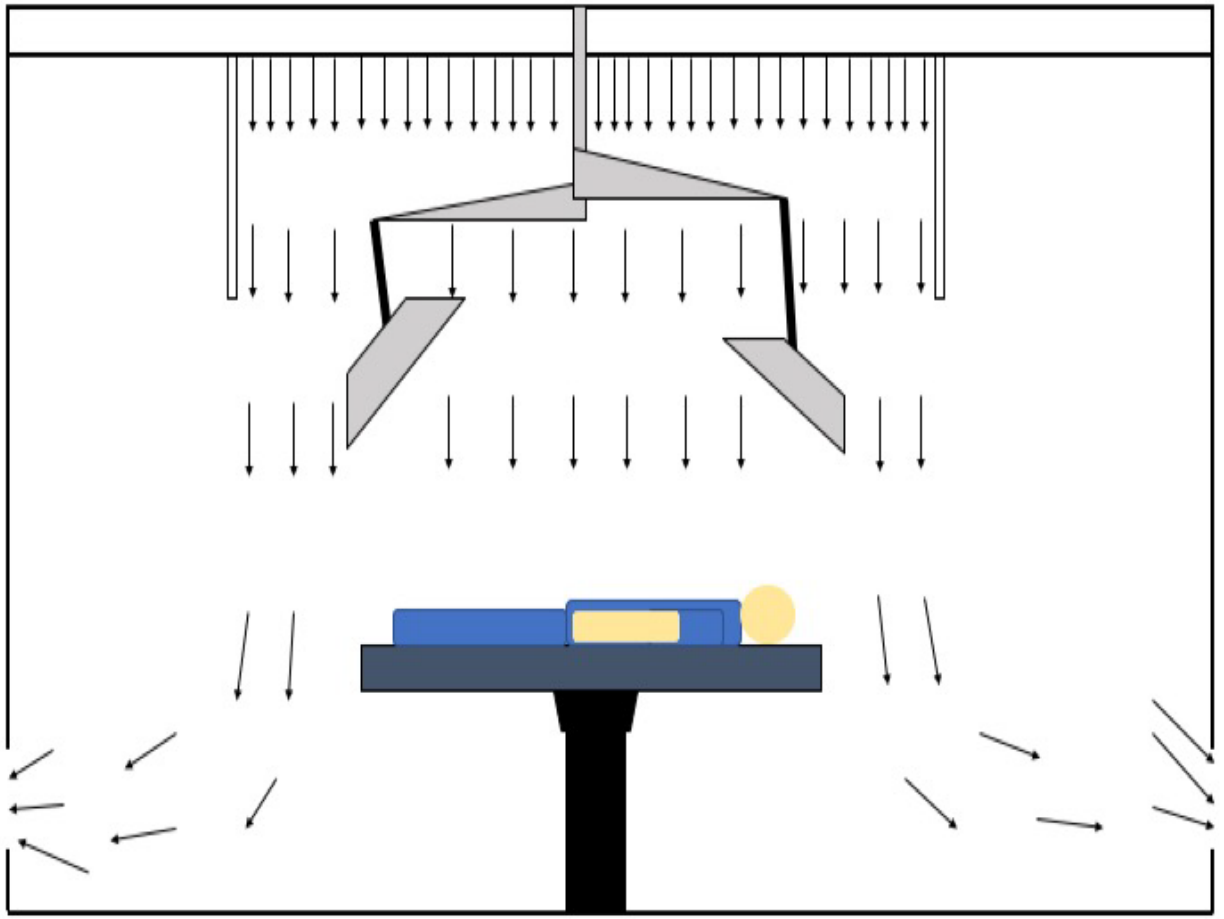
# Mixing ventilation in an OR



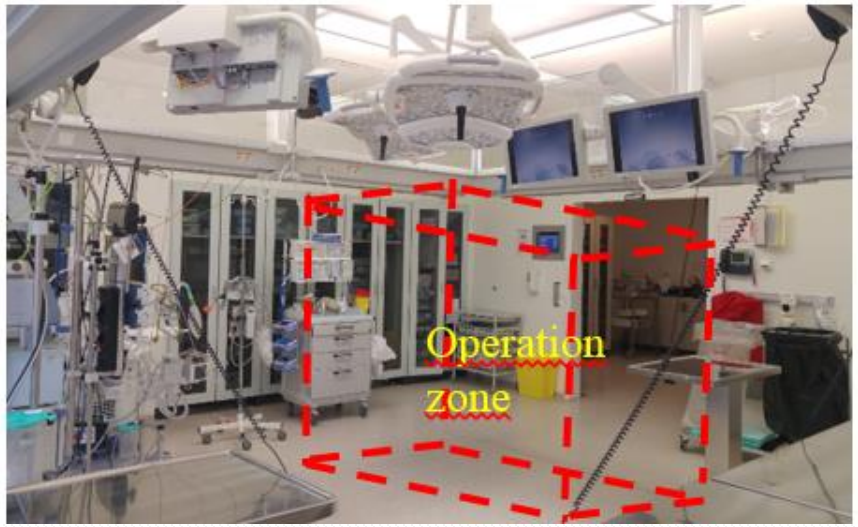
- Mixing ventilation (Nilsson, 2003; Nilssen, 2018)

# Laminar airflow system in an OR



- Laminar airflow systems (Nilsson, 2003; Nilssen, 2018)

# Case 1 Field measurements at St. Olavs Hospital




A photo of the OR at St. Olavs hospital


Locations of measurement instruments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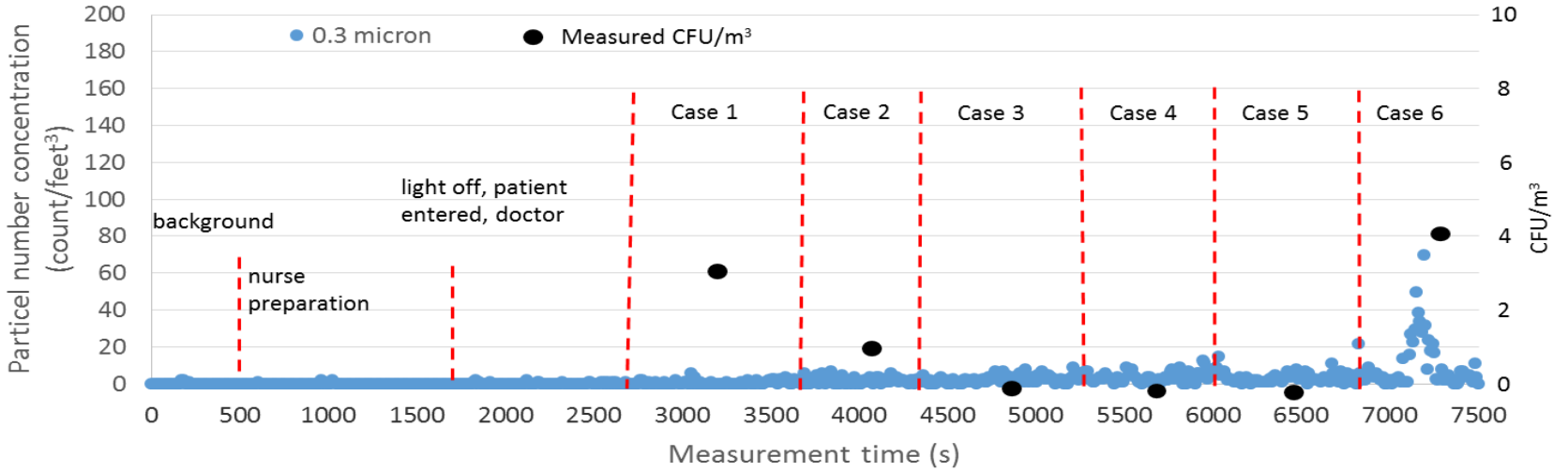
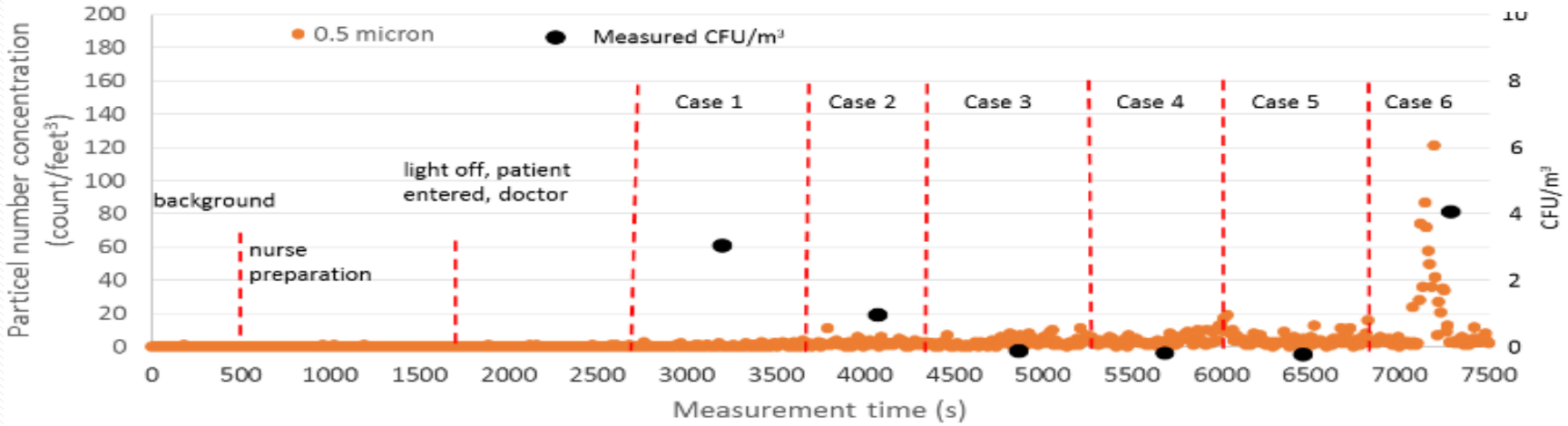
# Measurement conditions

*Table 1 measurement conditions*

| | Persons inside the operating room | | Door opening | Measured parameters | Light position | |
|---|---|---|---|---|---|---|
| | nonsterile | sterile | | | Angle | Height from the floor |
| Case 1 | 4 | 3 | 2 | PM, bacteria | 45° | 1.93±0.01 m |
| Case 2 | 4 | 3 | 3 | PM, bacteria | 45° | 1.75±0.01 m |
| Case 3 | 3 | 3 | 2 | PM, fungus | 45° | 1.75±0.01 m |
| Case 4 | 3 | 3 | 0 | PM, bacteria | horizontal | 1.75±0.01 m |
| Case 5 | 3 | 3 | 0 | PM, fungus | horizontal | 1.75±0.01 m |
| Case 6 | 3 | 3 | 2 | PM, bacteria | 45° | 1.75±0.01 m |

# Measurement results




- *The measured fine particle concentration and CFU, I) 0.3-0.5 micron, II) 0.5-1.0 micron,*



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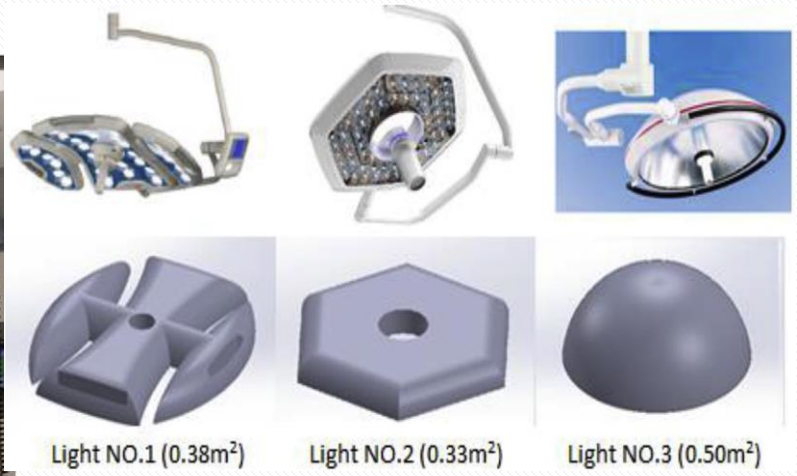
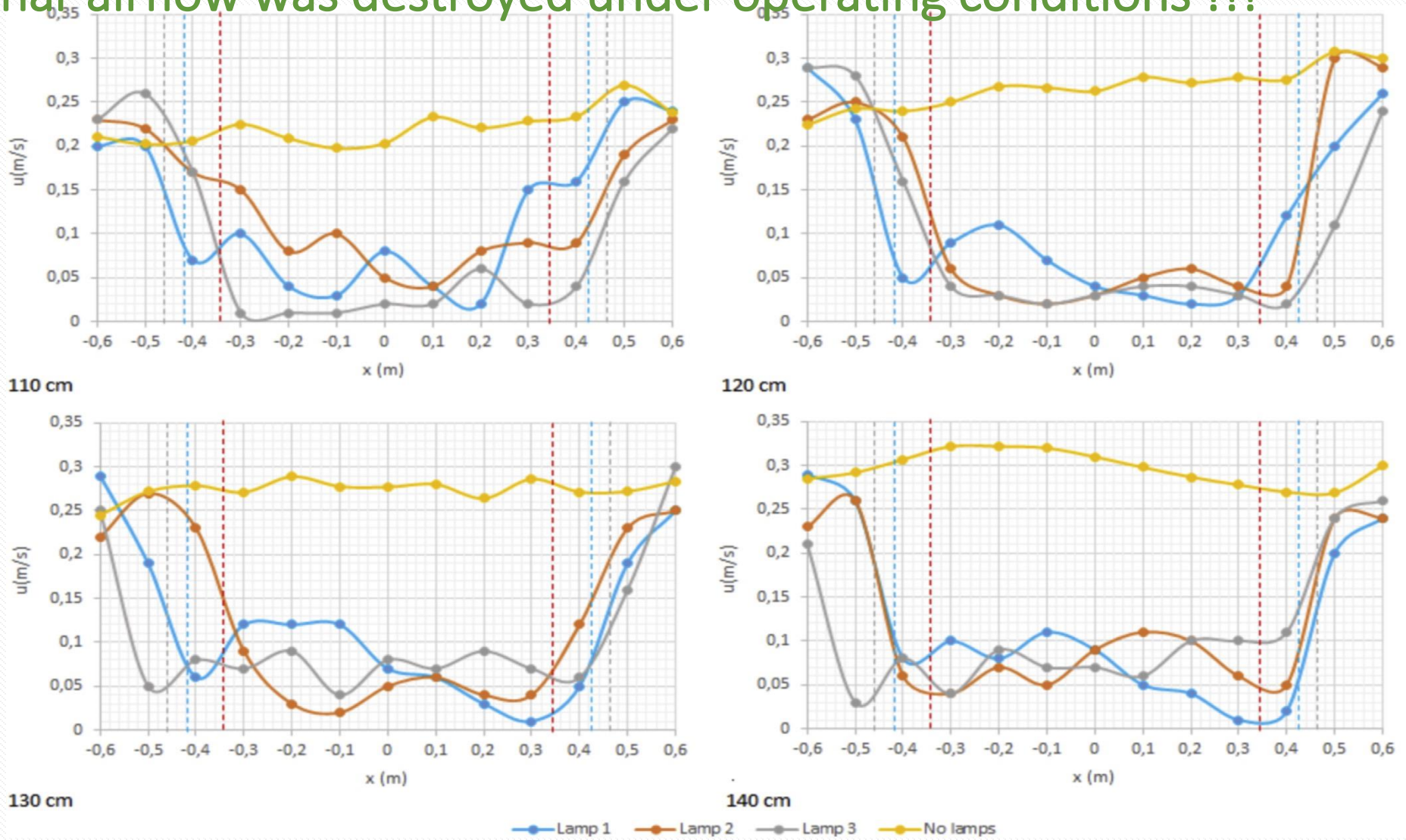
# Case 2 Whether surgical facilities affect laminar airflow?



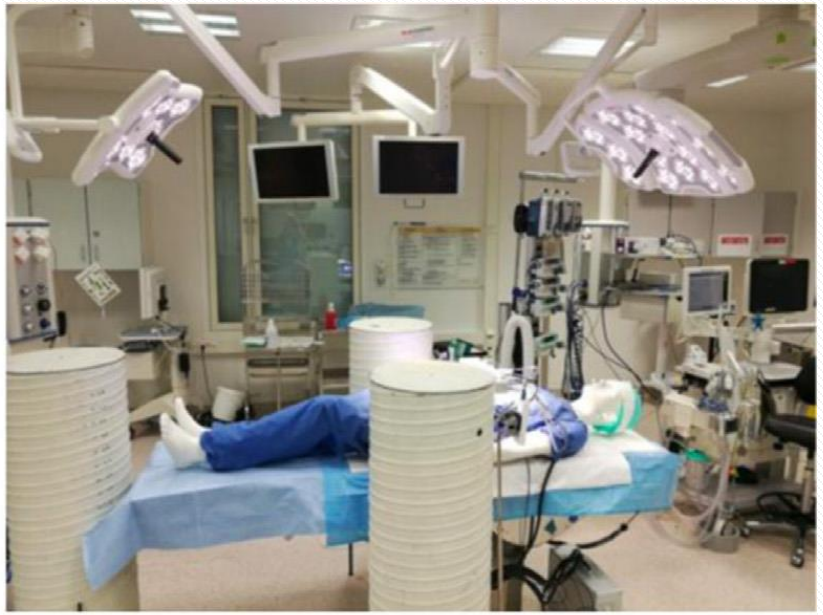

Impact of surgical lights on the velocity distribution and airborne contamination level in an operating room with laminar airflow system
Building and Environment, Volume 126, December 2017, Pages 42-53

# Laminar airflow was destroyed under operating conditions !!!



# Case 3 Measurements with thermal manikin in an OR with MV and LAF

a)



b)

- a) LAF, b) MV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# Summary of measurement conditions for 4 cases and 2 scenarios

| Scenario | Case | Ventilation mode | Operating lamps |
|---|---|---|---|
| S1 | Case 1 | LAF | Away from measurement zone |
| | Case 2 | MV | Away from measurement zone |
| S2 | Case 3 | LAF | 2 lamps 1.9 m from floor |
| | Case 4 | MV | 2 lamps 1.9 m from floor |

*LAF*, laminar airflow; *MV*, mixing ventilation.


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**Ventilation and indoor air quality in health care facilities – practices and challenges**

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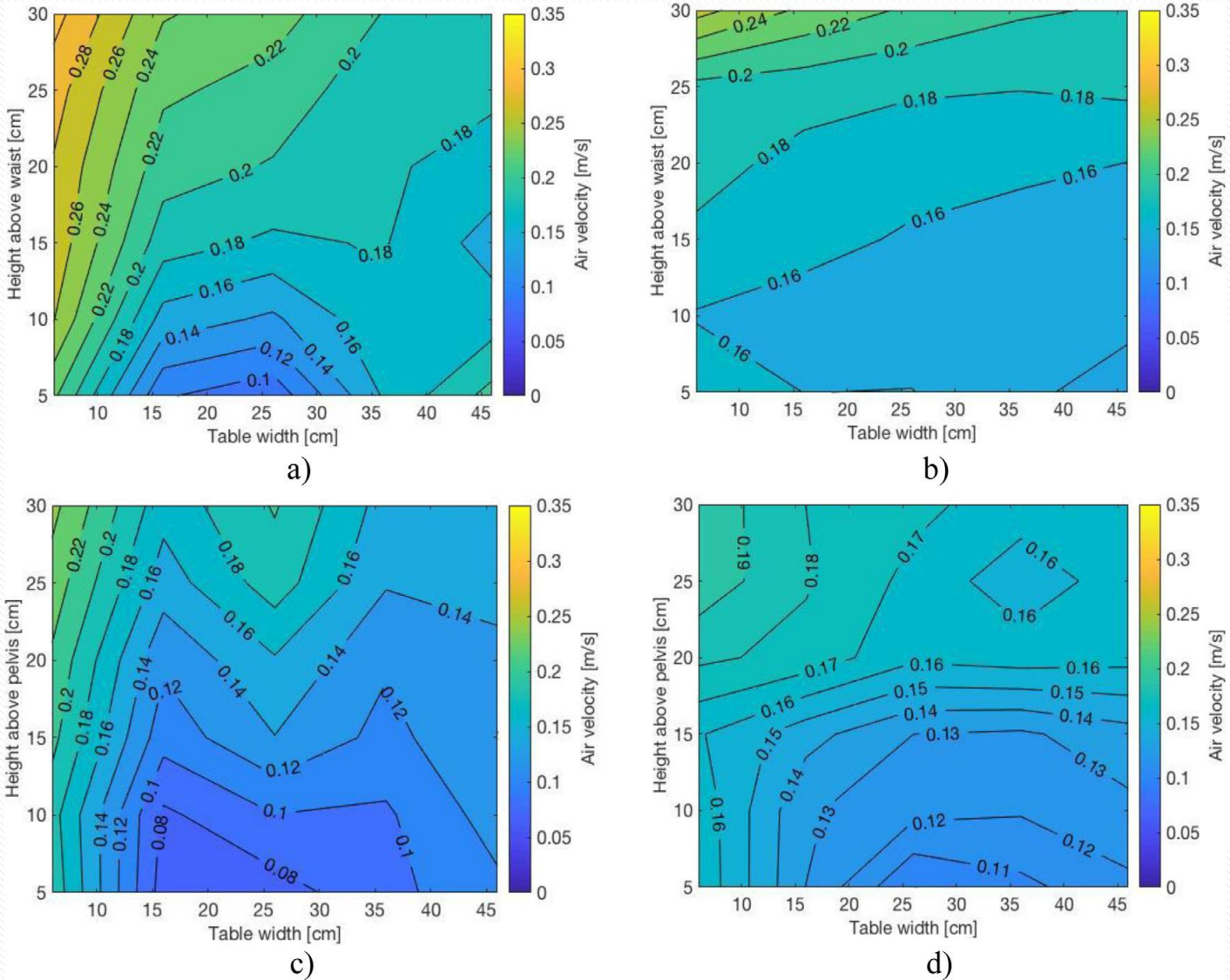


# Velocity distribution over a simulated patient in scenario 1

Velocity contours above a lying patient surrounded by 3 surgical staff (scenario 1), including cases 1 and 2. (a) Above-the-waist position with an LAF system, (b) above-the-waist position with an MV system, (c) above-the-pelvis position with an LAF system, and (d) above-the-pelvis position with an MV system.


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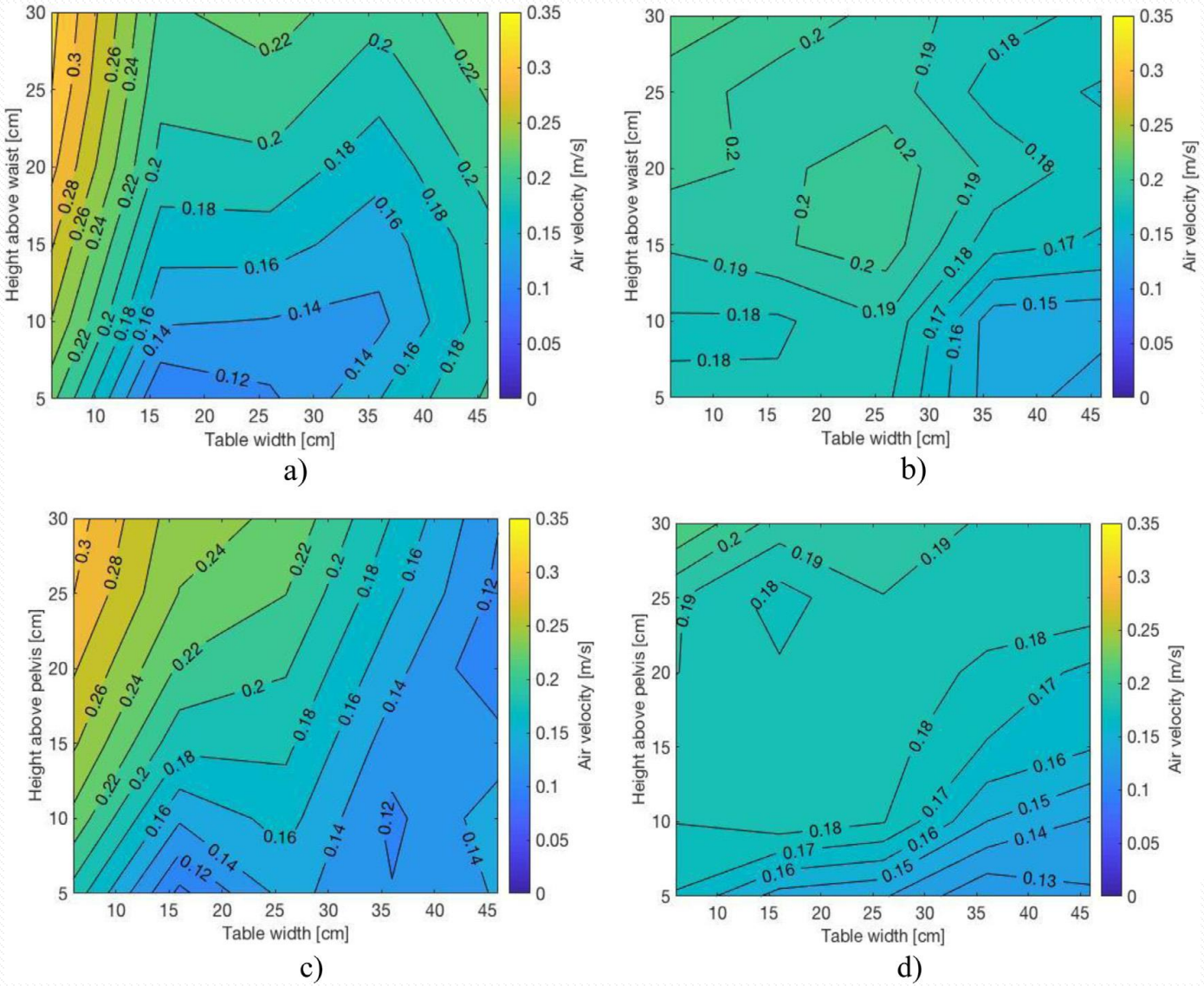


# Velocity distribution over a simulated patient in scenario 2

Velocity contours above a lying patient surrounded by 3 surgical staff (scenario 1), including cases 3 and 4. (a) Above-the-waist position with an LAF system, (b) above-the-waist position with an MV system, (c) above-the-pelvis position with an LAF system, and (d) above-the-pelvis position with an MV system.

- Mock up surgery at St. Olavs hospital

# Case 4 Measurements of CFU in an OR with MV

**Control measure:**

**Movements and activity level**

A predefined movement and action plan for each member of the staff

**Number of people present**

5 staff members and 1 patient

**Door openings**

**Talking**

All staff members say the alphabet out loud every 7th minute

**Operation length**

2 hours


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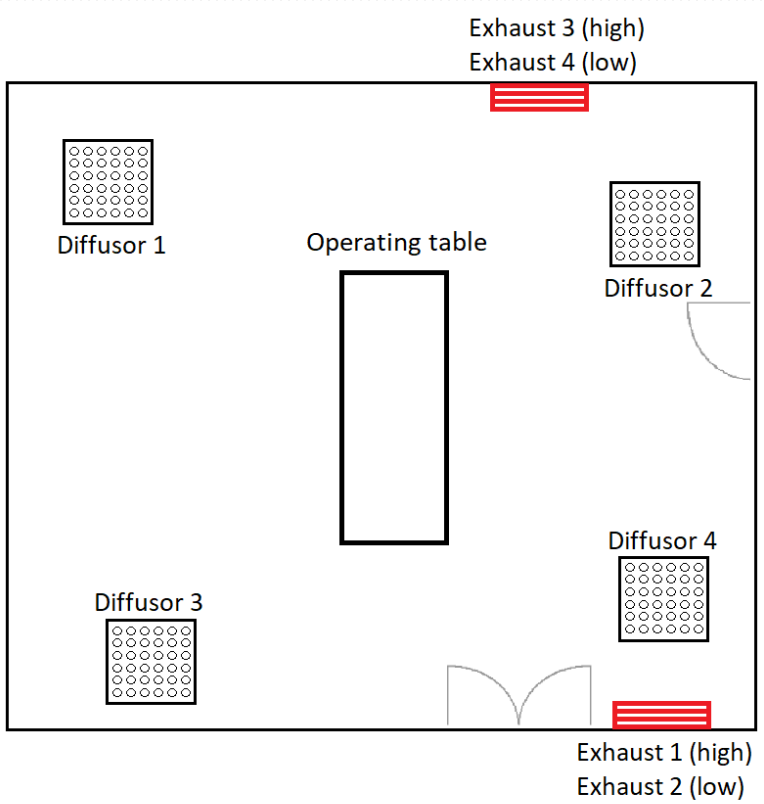
# Ventilation in an OR with MV

- Mixing ventilated operating room, located at the emergency, hearth and lung centre at St.Olavs hospital, Trondheim, Norway
- 22,5 air changes per hour
- 5 Pa overpressure in relation to surrounding rooms
- Four ceiling mounted radial diffusers
- Two exhaust locations in the room →One high and one low mounted exhaust grill at each location
- 23°C setpoint for room temperature
- CFU/m$^3$ measurements of empty room, showed 0CFU/m$^3$





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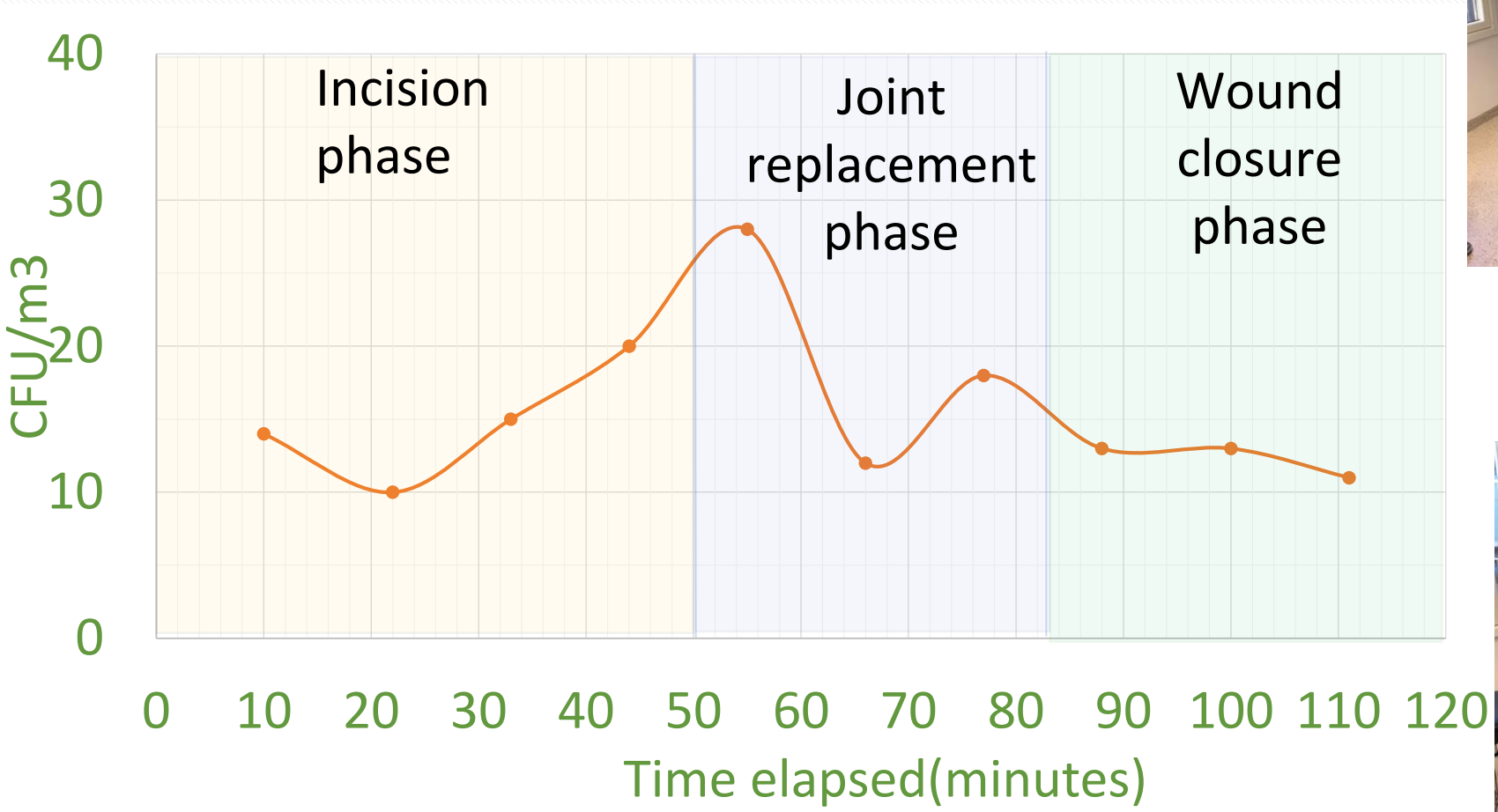
# Results of measured CFU




a) Clothing worn by Surgeons and sterile nurse

b) Clothing worn by distribution and anaesthetic nurse

c) Clothing worn by patient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# Conclusions

- In operating theatres, **many factors**, including the use of operating lamps, the number of staff, supply airflow rate may **influence the local indoor air quality** inoperating rooms with MV and LAF.
- These **internal heat sources** in an OR with LAF, like facilities and human bodies, will generate various forms of thermal plumes, which **have great potential to hinder** clean airflow to the surgical site.
- Under certain operating conditions, **mixing ventilation may distribute clean air effectively** to the operating microenvironment.
- **Lower CFU level** may be achieved in ORs with Mixing ventilation when using proper surgical clothing with lower activity intensity.


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# End of the presentation

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