



# The surgical microenvironment: What impacts its safety level?

**Vasco de Vasconcelos**

**Warsaw University of Technology**

HumanIC project has received funding from the European Union's Horizon Europe research and innovation program under the Marie Skłodowska-Curie (HORIZON-MSCA-2022-DN-01, project no 101119726)

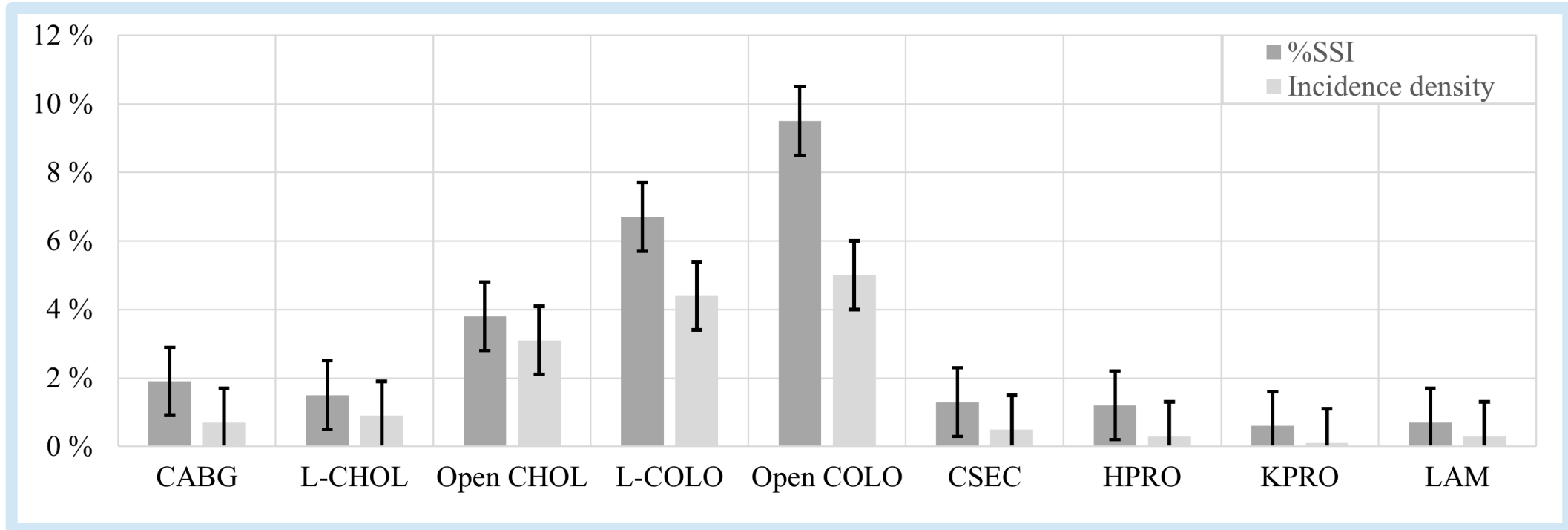


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# 0 Surgical Site Infections



Procedure-specific percentage and incidence density of in-hospital surgical site infections (SSI) in EU/EEA hospitals, 2018–2020



L: Laparoscopic, COLO: Colon; CSEC: Caesarean section, HPRO: Hip Prosthesis, KPRO: Knee Prosthesis, LAM: Laminectomy.

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# 1 Literature Review

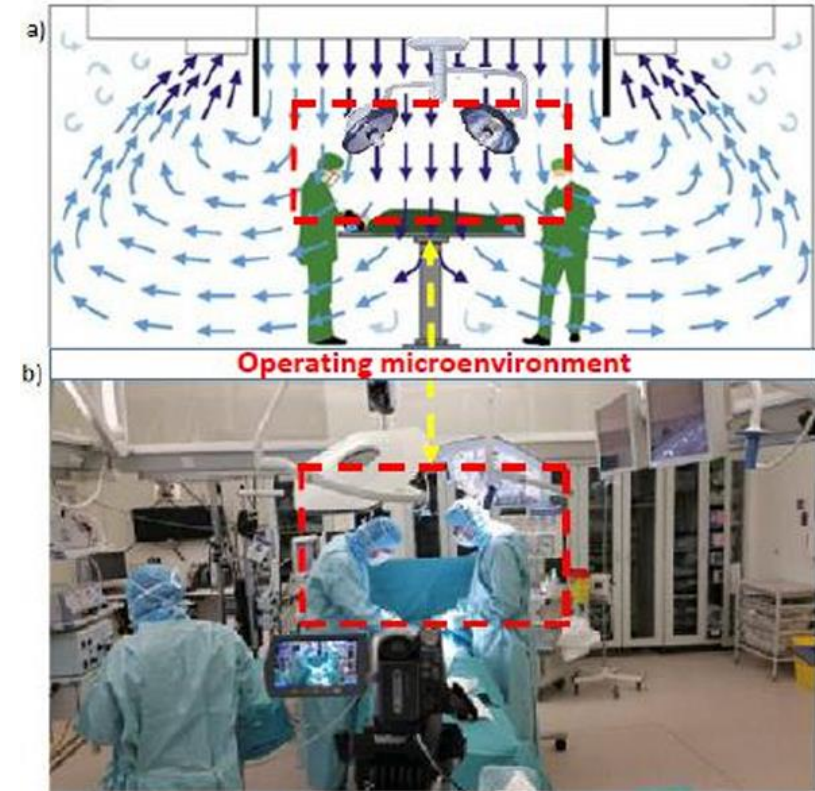


## A Ventilation System



### Scrub suit: shirt and trousers with cuffs

- Critical zone immediately surrounding the surgical site and bounded by the patient, the surgical team, and the surgical lights. Air quality in this zone is critical for preventing SSIs caused by airborne microorganism contamination, while maintaining appropriate thermal conditions is essential to prevent intraoperative hypothermia, both of which are associated with adverse postoperative outcomes.

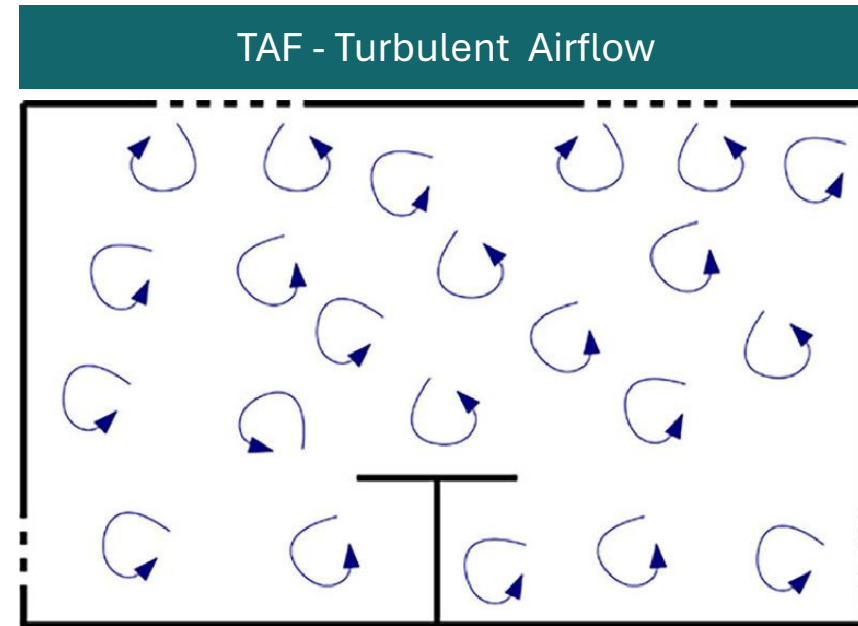
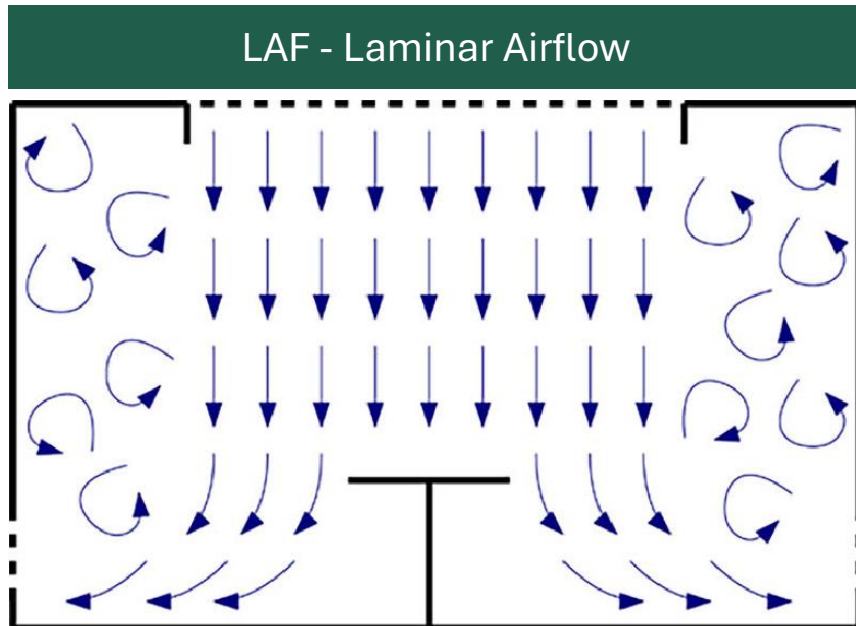


Aganovic, A., 2019. Airflow distribution for minimizing human exposure to airborne contaminants in healthcare facilities. NTNU: Trondheim, Norway.

# 1 Literature Review



## A Ventilation System



Hofer, V., Hartmann, A., Rotheudt, H., Zielke, B. and Kriegel, M., 2022. Disturbance of a laminar air flow caused by differently shaped surgical lights. *International Journal of Ventilation*, 21(3), pp.213-228.

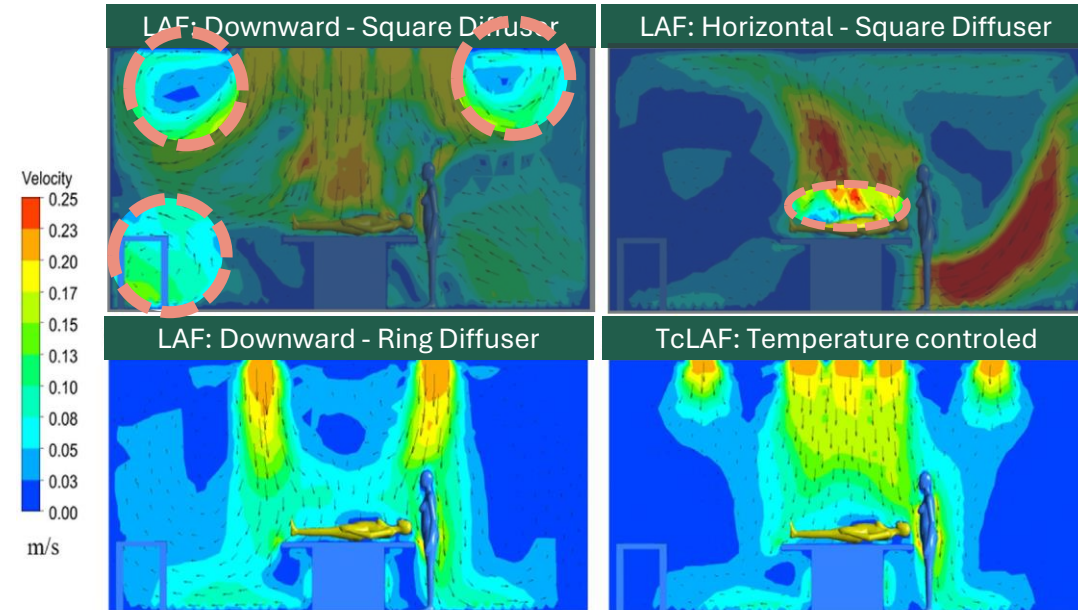
# 1 Literature Review



## A Ventilation System Room Layout

Ventilation system		Room geometry		Supply diffuser characteristics		Exhaust grill characteristics	
		Height [m]	Floor area [m <sup>2</sup> ]	Quantity	Area (per inlet) [m <sup>2</sup> ]	Quantity	Area (per outlet) [m <sup>2</sup> ]
TAF	No. of mentions	7	7	6	5	7	4
	% of mentions	58.33	58.33	50	41.67	58.33	33.33
	mean	<b>3.10 ± 0.18</b>	<b>51.53 ± 13.53</b>	<b>8.33 ± 7.84</b>	<b>0.26 ± 0.13</b>	<b>5.14 ± 2.61</b>	<b>0.17 ± 0.18</b>
LAF	No. of mentions	11	10	11	10	9	6
	% of mentions	91.67	83.33	91.67	83.33	75.00	50.00
	mean	<b>2.94 ± 0.26</b>	<b>39.72 ± 15.75</b>	<b>1.09 ± 0.30</b>	<b>6.11 ± 2.69</b>	<b>6.11 ± 2.32</b>	<b>0.25 ± 0.24</b>

\* The data presented in this table is currently under further development



Liu, Z., Yin, D., Hu, L., He, J. and Cao, G., 2022. Bacteria-carrying particles diffusion in the operating room due to the interaction between human thermal plume and ventilation systems: An experimental-numerical simulation study. Energy and Buildings, 270, p.112277.

# 1 Literature Review



## A Ventilation System

### Environmental control parameters

$$\dot{V}_{total|in} = ACH \cdot V_{room} = \sum_{i=1}^{n|in} \dot{V}|_{in_i} \quad \dot{V}|_i = 3600 \cdot \bar{v}|_i \cdot A|_i \quad , \quad i = in, out$$

Ventilation system		Supply characteristics					Exhaust characteristics			Differential Pressure	
		Kinematic properties			Hygrometric properties		Kinematic properties		Hygrometric properties		
		Volumetric Airflow Rate	Air Change Rate	Mean Air Velocity	Turbulence Intensity	Mean Air Dry Bulb Temperature	Relative Humidity	Volumetric Airflow Rate	Mean Air Dry Bulb Temperature		Relative Humidity
		$V_{total in} [m^3/(h)]$	ACH [ $h^{-1}$ ]	$v _{in} [m/s]$ (on each diffuser)	$TI _{in}$	$T_{db,ha} _{in} [^{\circ}C]$	$\phi_{ha} _{in} [%]$	$V_{total out} [m^3/(h)]$	$T_{db,ha} _{out} [^{\circ}C]$		$\phi_{ha} _{out} [%]$
TAF	No. of mentions	6	8	4	0	4	1	1	1	0	6
	% of mentions	50	66.67	33.33	0	33.33	8.33	8.33	8.33	0	50
	mean	4593.91 ± 3004.24	27.17 ± 15.42	1.02 ± 1.08	---	21.76 ± 2.74	72.39	3481.75	24.00	---	4593.91 ± 3004.24
LAF	No. of mentions	8	8	9	0	8	1	1	0	0	2
	% of mentions	66.67	66.67	75.00	0	66.67	8.33	8.33	0	0	16.67
	mean	5079.64 ± 2647.75	42.37 ± 14.23	0.27 ± 0.11	---	19.45 ± 2.34	72.40	8067.20	---	---	6.25 ± 5.30

\* The data presented in this table is currently under further development

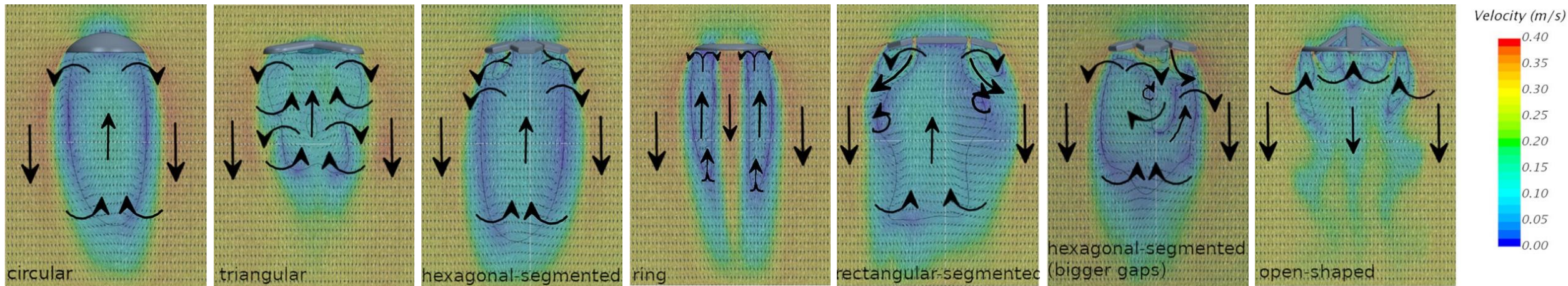


# 1 Literature Review



## Ventilation System

### Surfaces



Hofer, V., Hartmann, A., Rotheudt, H., Zielke, B. and Kriegel, M., 2022. Disturbance of a laminar air flow caused by differently shaped surgical lights. *International Journal of Ventilation*, 21(3), pp.213-228.

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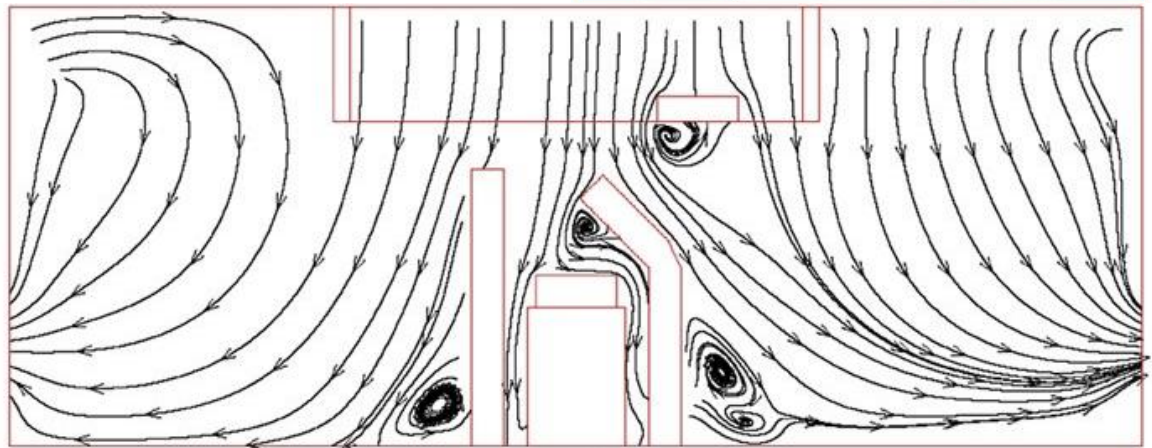
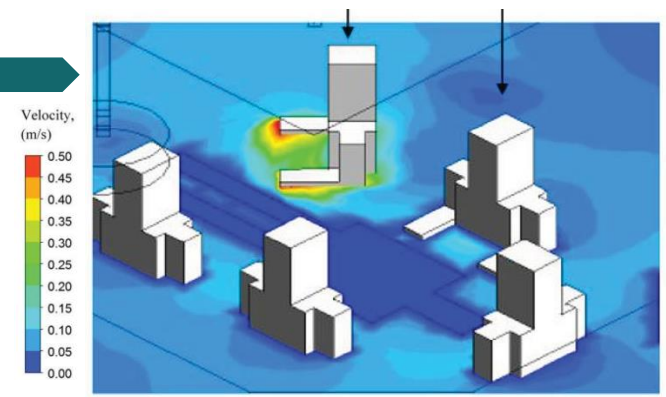
# 1 Literature Review



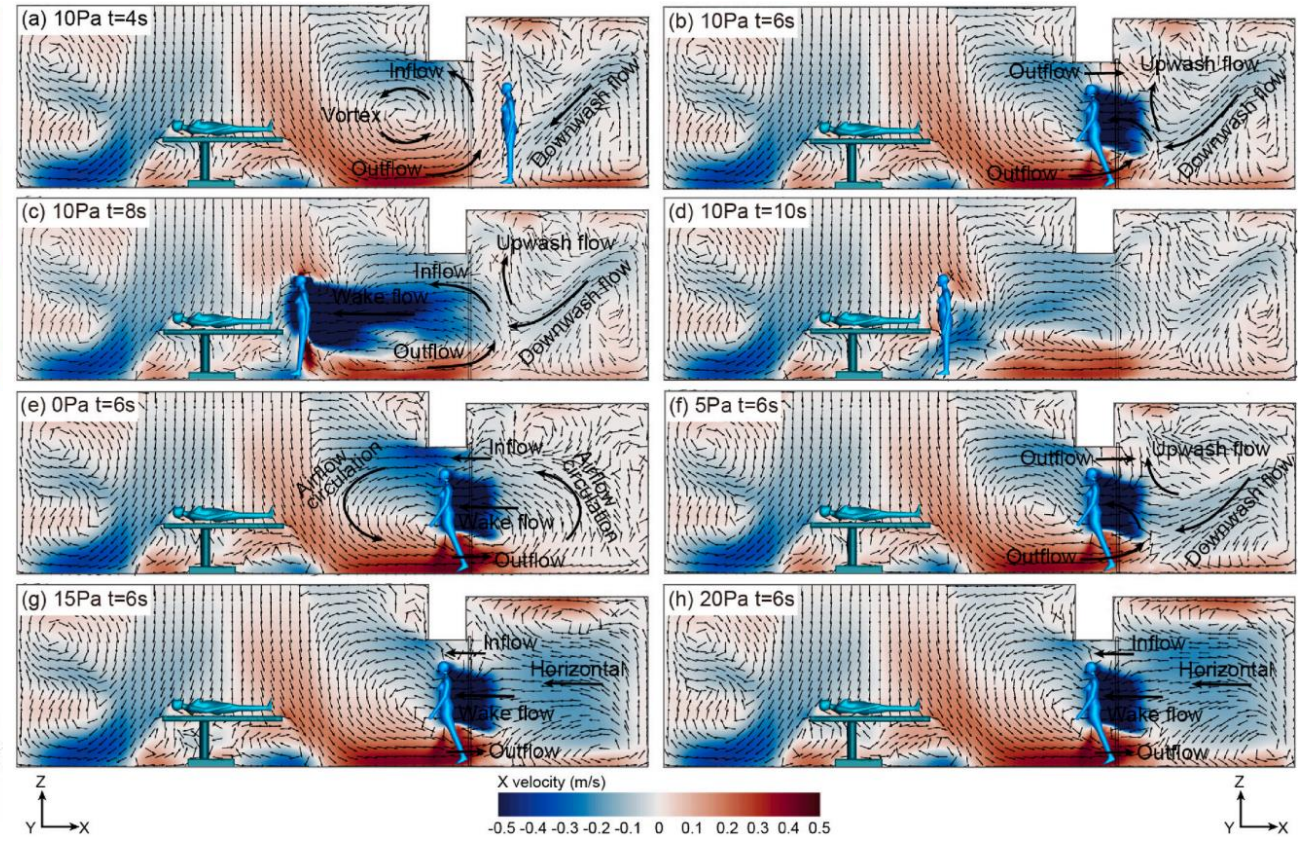
## A Ventilation System

### Human behaviour

Kamar, H.M., Wong, K.Y. and Kamsah, N., 2020. The effects of medical staff turning movements on airflow distribution and particle concentration in an operating room. *Journal of Building Performance Simulation*, 13(6), pp.684-706.



Chow, T.T. and Wang, J., 2012. Dynamic simulation on impact of surgeon bending movement on bacteria-carrying particles distribution in operating theatre. *Building and environment*, 57, pp.68-80.



Liu, H., Liu, Z., He, J., Hu, C. and Rong, R., 2024. Interfacial exchange of airflow and bacteria-carrying particles induced by door opening and foot traffic in an operating room. *Building and Environment*, 262, p.111812.





Bogdan, A., Sudol-Szopińska, I. and Szopiński, T., 2011. Assessment of textiles for use in operating theatres with respect to the thermal comfort of surgeons. *Fibres & Textiles in Eastern Europe*, 19(2), pp.65-9.

### Scrub suit: shirt and trousers with cuffs

- Microbial concentration is lower in cotton–polyester scrubs than in cotton scrubs.
- Microbial concentration is reduced when the shirt is tucked into the trousers, which in turn are tucked into the footwear and are combined with scuffs.

### Surgical mask

- Despite reducing microbial concentration directly in front of the mouth, surgical masks merely redirect exhaled airflow and respiratory airborne particles, and do not reduce overall microbial counts in the operating room, making it unclear if they reduce surgical site infection rates.

### Body exhaust gown

- Contradicting results regarding the effectiveness of the body exhaust system have shown better performance in reducing surgical site infection and microbial concentration next to the wound than standard head coverings.

### Head covering: skull cap, or bouffant hat, or hood

- No clear result regarding the effectiveness of head covering in containing microbial fallout from the hair, scalp, and ears.
- In LAF-equipped rooms, the use of head covering gear reduces microbial concentration.

### Gloves

- Surgical Site Infections are reduced with the wearing of gloves.
- No clear result regarding whether double-gloving has better performance in reducing surgical site infection than single-gloving.
- Multiple layers reduce the perforation in the inner glove.

### Gown

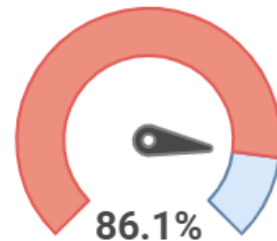
- No clear result regarding whether reusable gowns have better performance in reducing surgical site infection than single-use gowns.

# 1 Literature Review

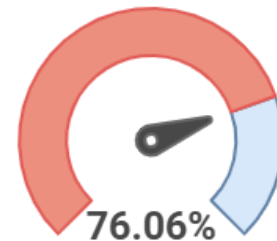


## B Clothing System Thermal comfort

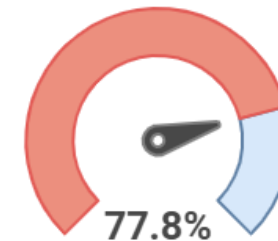
### Confort assessment within the surgery team



Surgeons Perceive Thermal Environment as Uncomfortable



Surgeons Prefer Cooler Operating Room Conditions



Respondents Perceive Garments as Damp or Wet

Made with Napkin

Survey conducted by:

Ćwiklińska, D., Bogdan, A. and Szyłak-Szydłowski, M., 2022. Survey on factors influencing surgeons' sensation in Polish operating theatres. *Building and Environment*, 214, p.108929.



# 1 Literature Review



## B Clothing System Thermal comfort

Components	Usage	Fabric material:	Fabric structure	Weight	Penetration	Thermal insulation, $I_{cl}$ [clo]
Scrub suit	Reusable	69 % cotton, 30 % polyester, 1 % carbon fibre	Plain weave with 47 threads/cm warp and 26 threads/cm weft	150 g/m <sup>2</sup>	Microbial penetration - dry $\leq$ 300 CFU	n. r.
	Single-use	Inner layer: 70 % viscose, 30 % polyester	n. r.	30 g/m <sup>2</sup>	Microbial penetration - dry $\leq$ 100 CFU	n. r.
		Outer layer: Spunbond Meltblown Spunbond Polypropylene	Tri-laminate non-woven fabric with top layer of spunbond polypropylene, a middle layer of meltblown polypropylene and a bottom layer of spunbond polypropylene	35 g/m <sup>2</sup>		
	Reusable	98 % olefin, 2 % carbon fibre	n. r.	125 g/m <sup>2</sup>	n. r.	n. r.
Reusable	n. r. % polyester, n. r. % coal fibre	n. r.	n. r.	n. r.	n. r.	parallel - 0.794 clo; series - 0.994 clo
Gown	Reusable	Front and sleeves: liquid-proof fabric of higher resistance; Remainder of gown: n.r. % polyester, n.r. % carbon fibre	n. r.	300 g	n. r.	parallel - 0.974 clo; series - 1.303 clo
	Reusable	Front and sleeves: PTFE (polytetrafluoroethylene); Remainder of gown: n.r. % polyester, n.r. % carbon fibre	Front and sleeves: laminated membrane; Remainder of gown: n. r.	n. r.	n. r.	parallel - 1.032 clo; series - 1.406 clo
	Single-use	n.r. % cotton, n. r. % of other material	n. r.	n. r.	n. r. (not complied with Standard No. EN 13795:2011 due to lack of resistance to microbial penetration)	parallel - 1.071 clo; series - 1.490 clo
Surgical mask	Reusable	100 % Cotton	Three-layer knit with 45 threads per inch	111.5 g/m <sup>2</sup>	98.9 % for particles with 100 nm of diameter	n. r.
	Single-use	n.r. % polypropylene	non-woven	53.9 g/m <sup>2</sup>	98.5 % for particles with 100 nm of diameter	n. r.
Head covering: hood	Reusable	98 % olefin, 2 % carbon fibre	n. r.	125 g/m <sup>2</sup>	n. r.	n. r.
Footwear: knee-length boots	Reusable	98 % olefin, 2 % carbon fibre	n. r.	125 g/m <sup>2</sup>	n. r.	n. r.

\* The data presented in this table is currently under further development



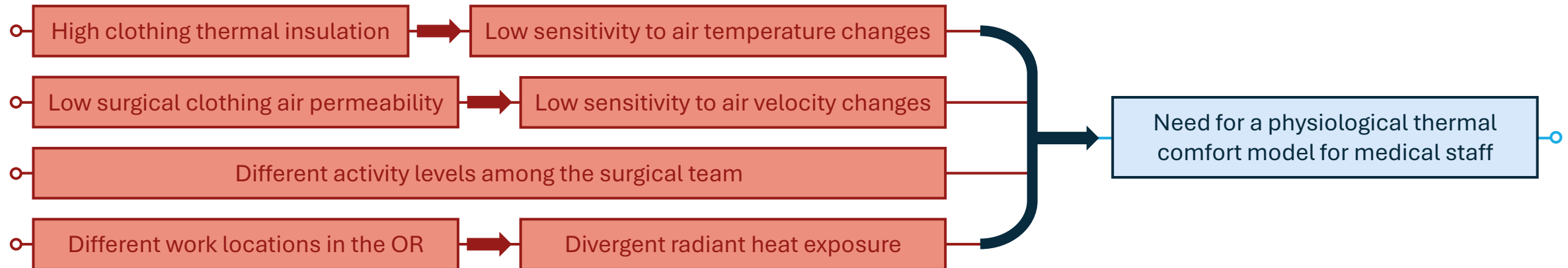
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# Literature Review



## B Clothing System

### Thermal comfort

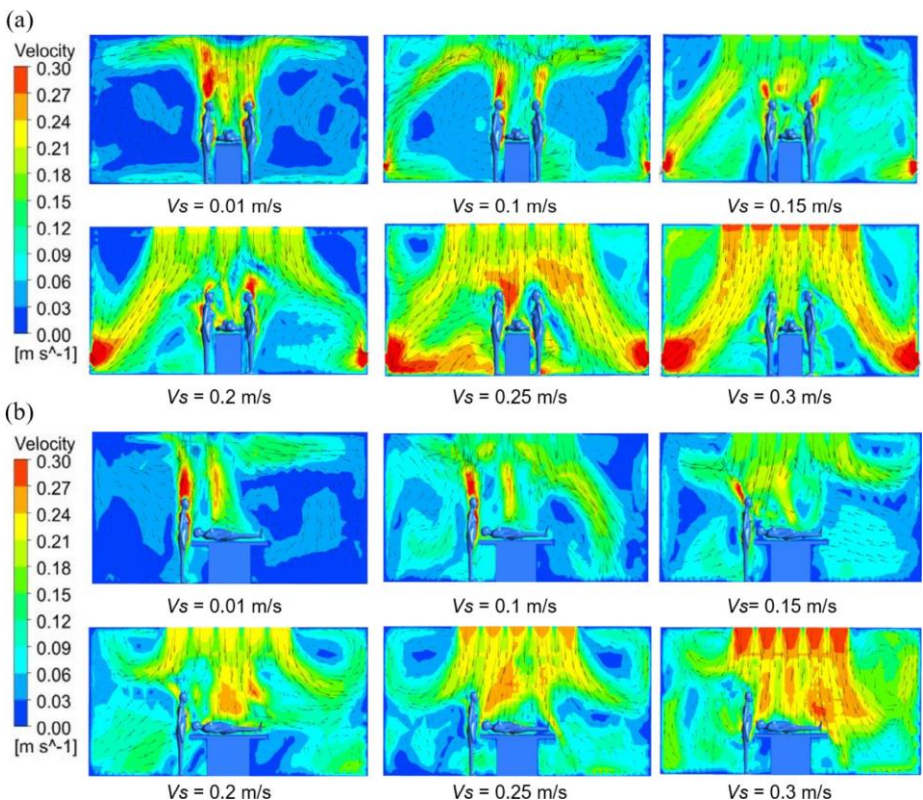


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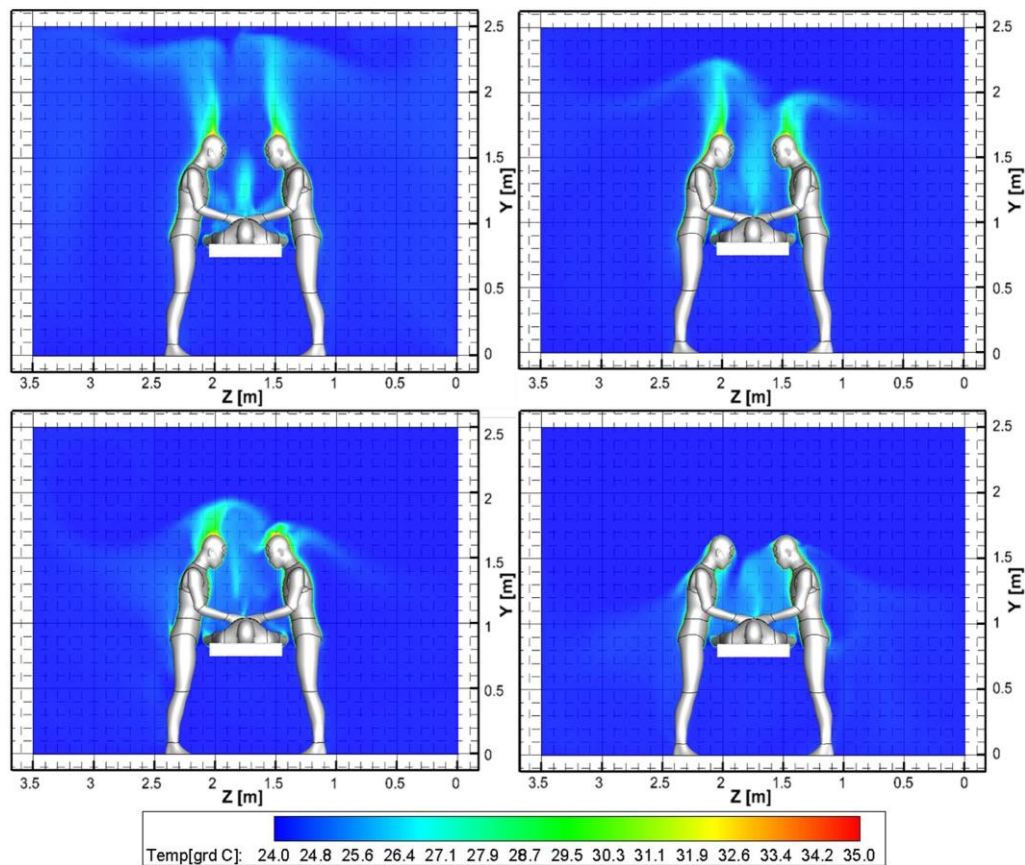


## B Clothing System

### Convective flows



Liu, Z., Yin, D., Niu, Y., Cao, G., Liu, H. and Wang, L., 2022. Effect of human thermal plume and ventilation interaction on bacteria-carrying particles diffusion in operating room microenvironment. *Energy and Buildings*, 254, p.111573.



Tacutu, L., Bode, F., Năstase, I., Croitoru, C. and Dogeanu, A., 2022. Experimental and numerical study on the thermal plumes of a standing and lying human in an operating room. *Science and Technology for the Built Environment*, 28(1), pp.2-20.





# Thank you!

*The presentation will be made public on the:*  
**Future hospitals - Open Resource Training Platform**

**Contact:** [vasco.vasconcelos@pw.edu.pl](mailto:vasco.vasconcelos@pw.edu.pl)

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## Vasco de Vasconcelos

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