Surgical Environment and Operating Room Discipline: Keys to Infection Control

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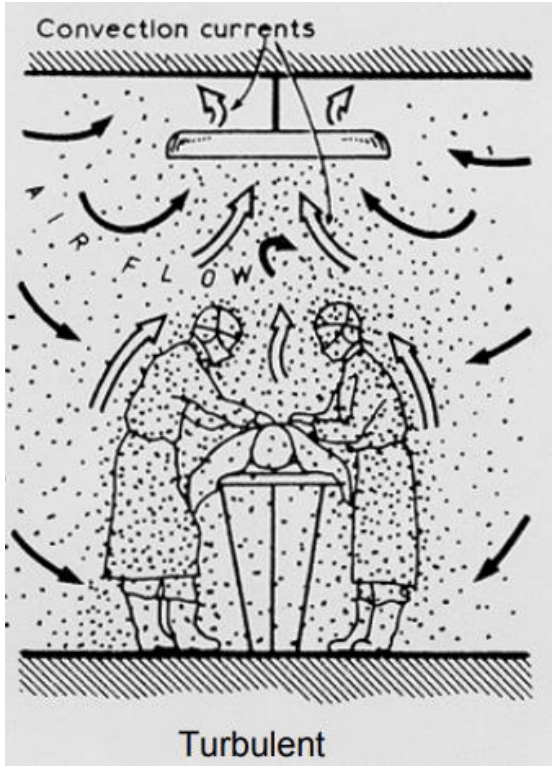
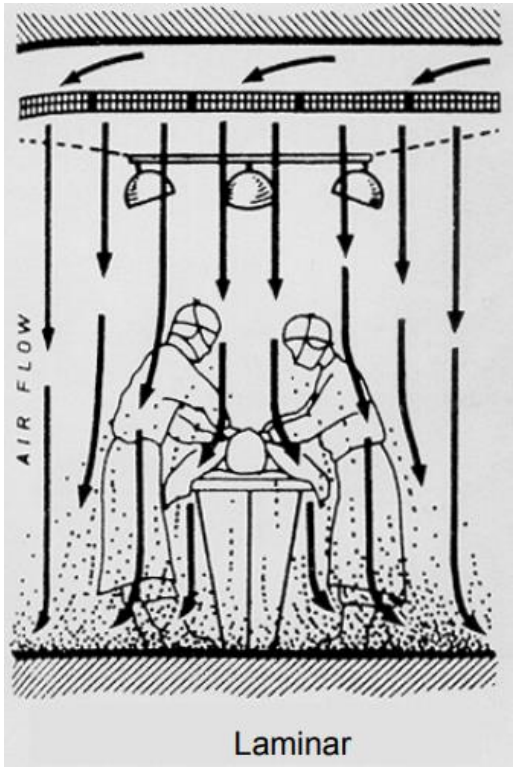
Origins of the airborne risk in OR

- ↘ SSI rates from **8.9% to 1.3%,** following hip replacement in UDAF vs TV
- Strong correlation between SSI rates and the number of airborne bacteria close to the wound site

Body Exhaust Gown



Turbulent



Laminar

Wrightington Clean Air Enclosure (1970)

Charnley J. Br J Surg 1964;51:202e5.; Charnley J, Br J Surg 1969;56(9):641e9.

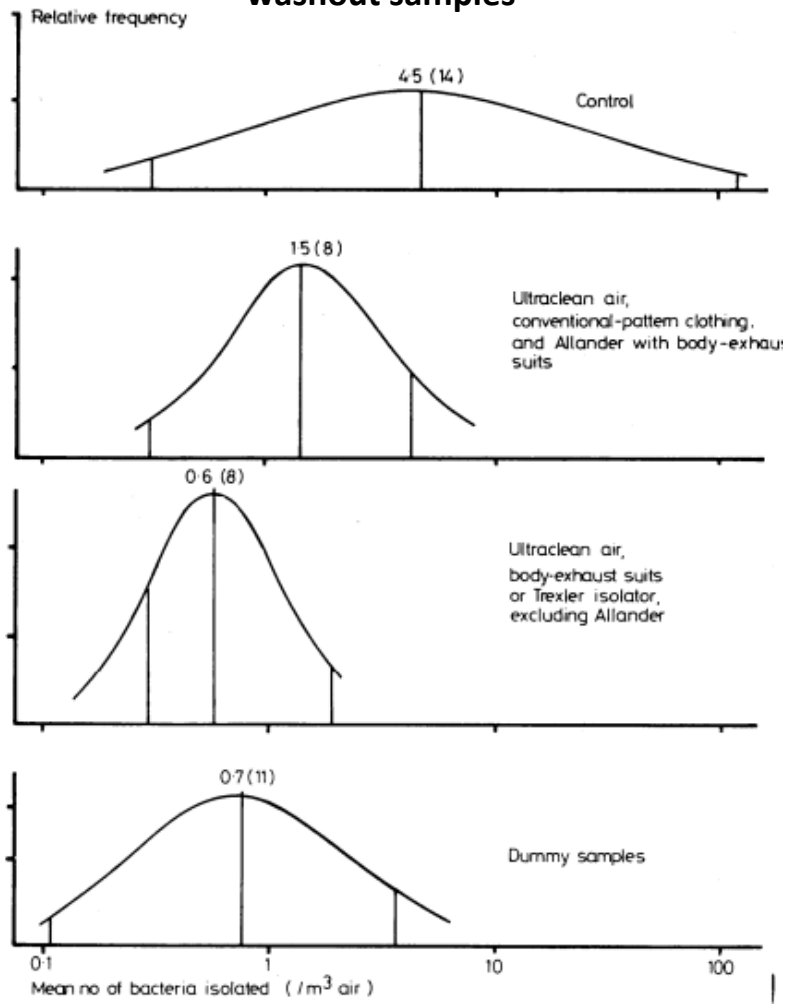
Air contamination in the OR

- RCT involving 19 hospitals: 11 England, 4 Scotland, 4 Sweden
- Sepsis after total hip or knee replacement, conventional/ultraclean air OR
- 8055 procedures: 6781 hips and 1274 knees

Sepsis	Control	Ultraclean-air	Ratio
All	1.5% (63/4133)	0.6% (23/3922)	2.6 (1.6-4.2)
Conventional clothing	2.2% (28/1252)	1.0% (11/1058)	2.2, <0.05
Body-exhaust suits	1.0% (6/832)	0.1% (1/954)	6.9, <0.05
With SAP	0.8% (24/2968)	0.3% (10/2863)	3.5, <0.05
Without SAP	3.4% (39/1161)	1.2% (13/1060)	

- Airborne route of surgical infection, at least in some cases
- Limitations: No control for the SAP, body-exhaust suits; No uniform method for random allocation; Performance of “conventional” systems?

Numbers of bacteria isolated from wound-washout samples



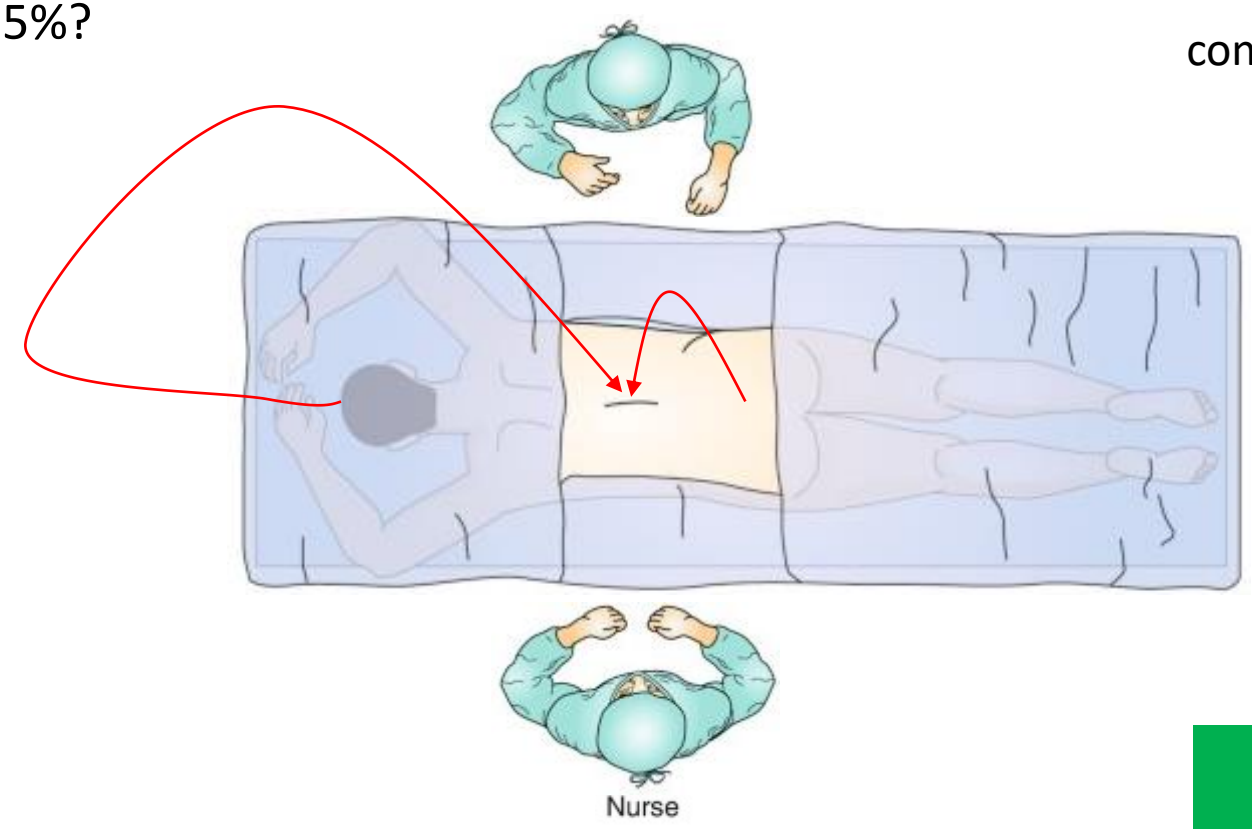
Lidwell OM, J Hosp Infect 1983;4(2):111e31.

Physiopathology of SSI

Intraoperative contaminations

Patient's endogenous flora

≈ 70% to 95%?



Airborne transmission

MO originating from the patient contaminating the wound through the air

Air ventilation system
Aseptic measures

Physiopathology of SSI

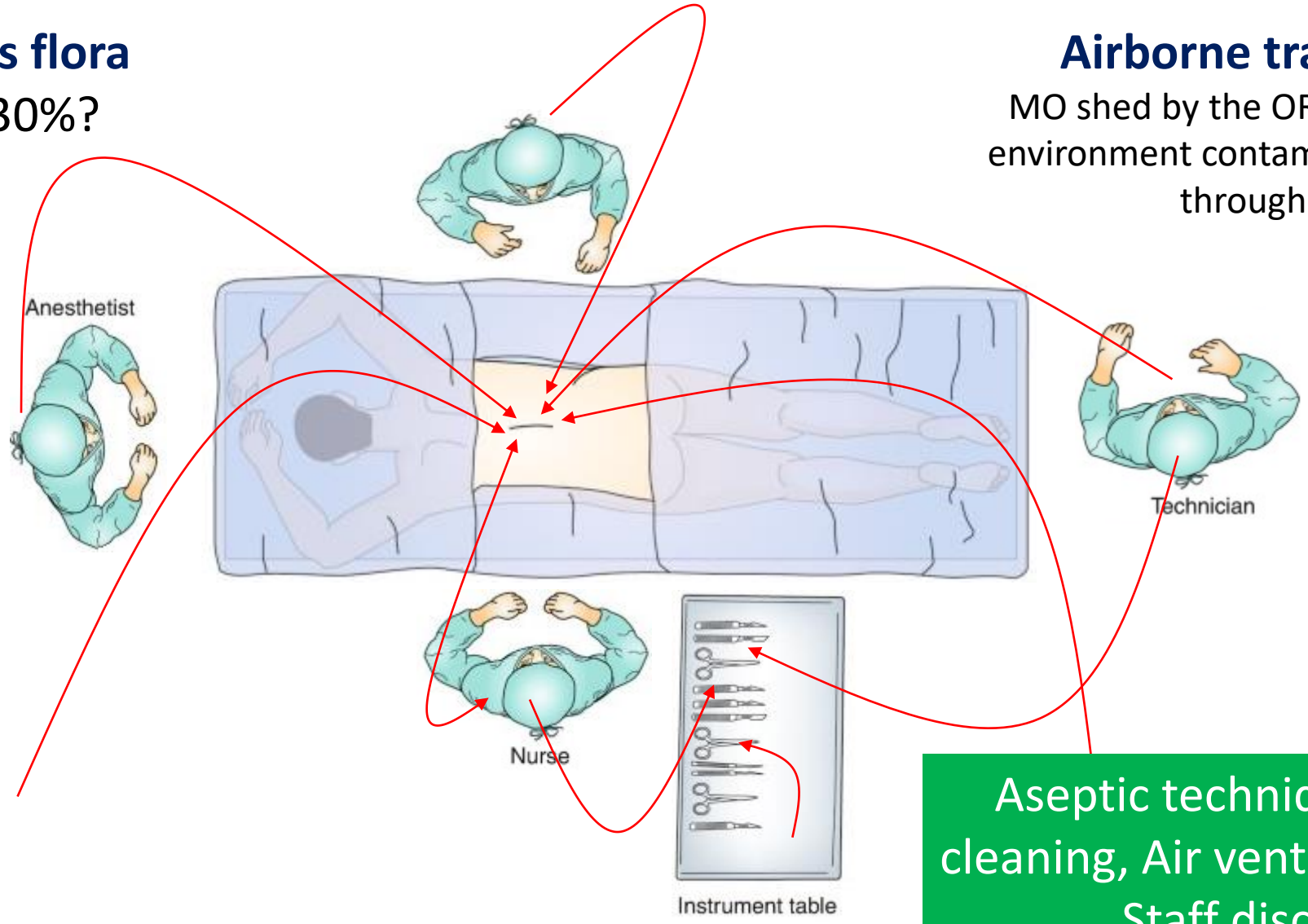
Intraoperative contaminations

Exogenous flora

≈ 5% to 30%?

Airborne transmission

MO shed by the OR personnel or the environment contaminating the wound through the air

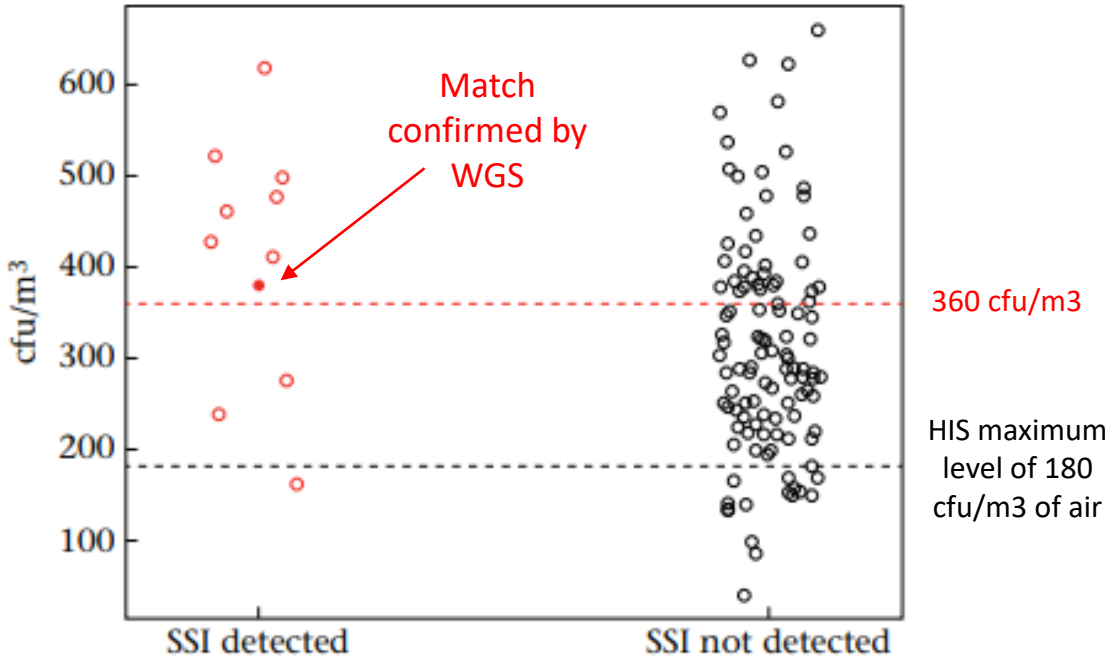


Aseptic technique, Surface cleaning, Air ventilation system, Staff discipline

Air contamination in the OR

- Relationship between intraoperative airborne bacteria and bacteria causing SSI in Ghana
- Active air sampling during 116 clean/clean-contaminated elective procedures, TV + HEPA filter

	Nb procedures	SSI
Thyroidectomy and parathyroidectomy	25	0
Non-cosmetic mammary surgery	26	5, 19%
Excision of lipomas or subcutaneous tissue	3	0
Controlled abdominal surgery	7	4, 57%
Repair of Inguinal hernia	25	1, 4%
Non-cosmetic mammary surgery	18	0
Excision of lipomas or subcutaneous tissue	10	1, 10%



- ASA-score >1, clean-contaminated wounds, airborne bacteria >360 cfu/m3 significantly associated with SSI after adjustment
- Match between air- and SSI-isolates in 1/ 11 case

M.A. Stauning et al. / Journal of Hospital Infection 104 (2020) 309e320

Effect of LAF on SSI

- 12 observational cohort studies comparing laminar airflow with conventional ventilation in the operating room

	Laminar airflow	Conventional ventilation	Odds ratio (95% CI)
	Events	Events	Events
Total hip arthroplasty	1544	671	1.29 (0.98–1.71)
Total knee arthroplasty	322	416	1.08 (0.77–1.52)
Abdominal and open vascular surgery	948	469	0.75 (0.43–1.33)

- No LAF system differentiation or definition based on technical specifications,
- No or limited documentation of surgical clothing worn, and validation on the ceiling LAF systems

World Health Organization

Bischoff Lancet ID 2017

Effect of LAF on SSI

	Reference	Type	Outcome	Summary
1	Lytsy JHI 2019	Position paper	-	LAF should be used for TJA
2	DGKH, 2019	Position paper	-	LAF reduce particulate and bacterial load
3	Cao AJIC 2019	Experimental, 2 OT	Airflow distribution	LAF greatly affected by **thermal plumes**
4	Knudsen JHI 2021	17 OTs and 51 TJA	Airborne Bacteria	LAF > TV
5	Marsault JHI 2021	Experimental, 2 OT	Airborne Bacteria	LAF > TV
6	Aganovic, JHI 2021	Syst. Review, 12 studies	Airborne Bacteria	LAF > TV
7	Langvatn JHI 2020	Arthroplasty Register	**Revision for SSI**	LAF > TV
8	Bao ICHE 2020	Meta-analysis, 14 studies	**SSI**	LAF or TV not associated with SSI
9	Wang JAMAopen	Retrospective cohort	**PJI**	LAF not associated with reduced PJI
10	Lu R Coll Surg Engl 2021	Meta-analysis, 14 studies	**SSI**	LAF or TV not associated with SSI

Many confounding factors; including staff discipline
Significant misreporting rate associated with the surgeon reported ventilation data

Are we oversimplifing the problem?

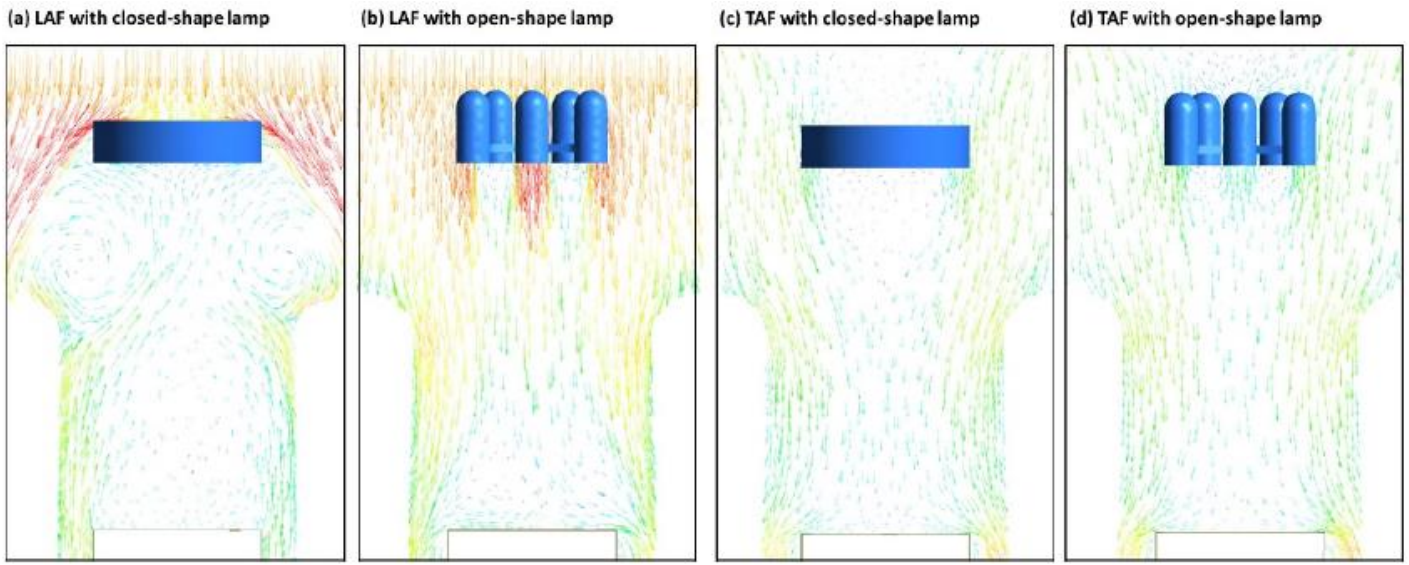
- **OR ventilation effectiveness depends on:**
  - Location, type, and number of supply diffusers
  - Supply air change rates and temperature
  - Locations and strengths of heat sources, including the surgical lights
  - Size and location of equipment in the room that can obstruct the flow path of the air and contaminants
  - Size and locations of room returns
  - Human activities: frequency of opening and closing OR doors

J.L.A. Lans et al. / Journal of Hospital Infection 122 (2022) 115e125

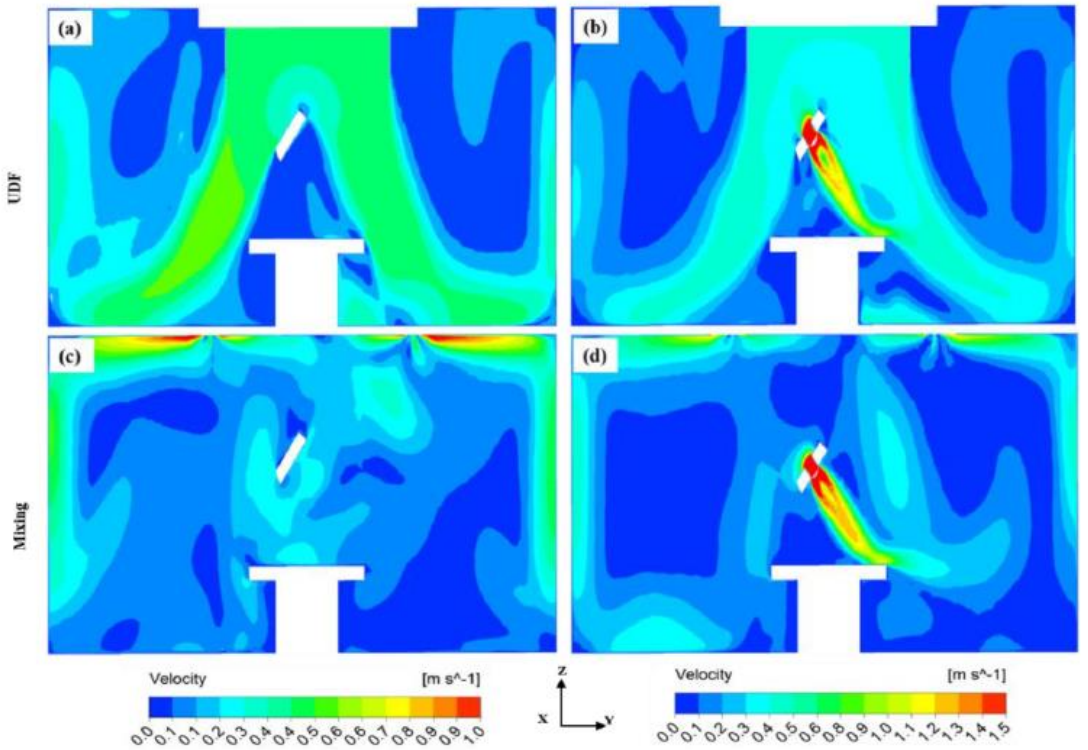
Are we oversimplifing the problem?

Influence of surgical lamp design

Velocity vector plot



Velocity contours



Particle/m2/h	LAF	Mixing
Closed-shaped	338	249
45° inclination	310	554
Fan-mounted	<1	183
45° inclination	98	112

Design and inclination of the surgical lamp may influence the velocity area below the lamp and the air contamination

Kong Wang, PhD 2020
PARASTOO SADEGHIAN, PhD 2020

Are we oversimplifing the problem?

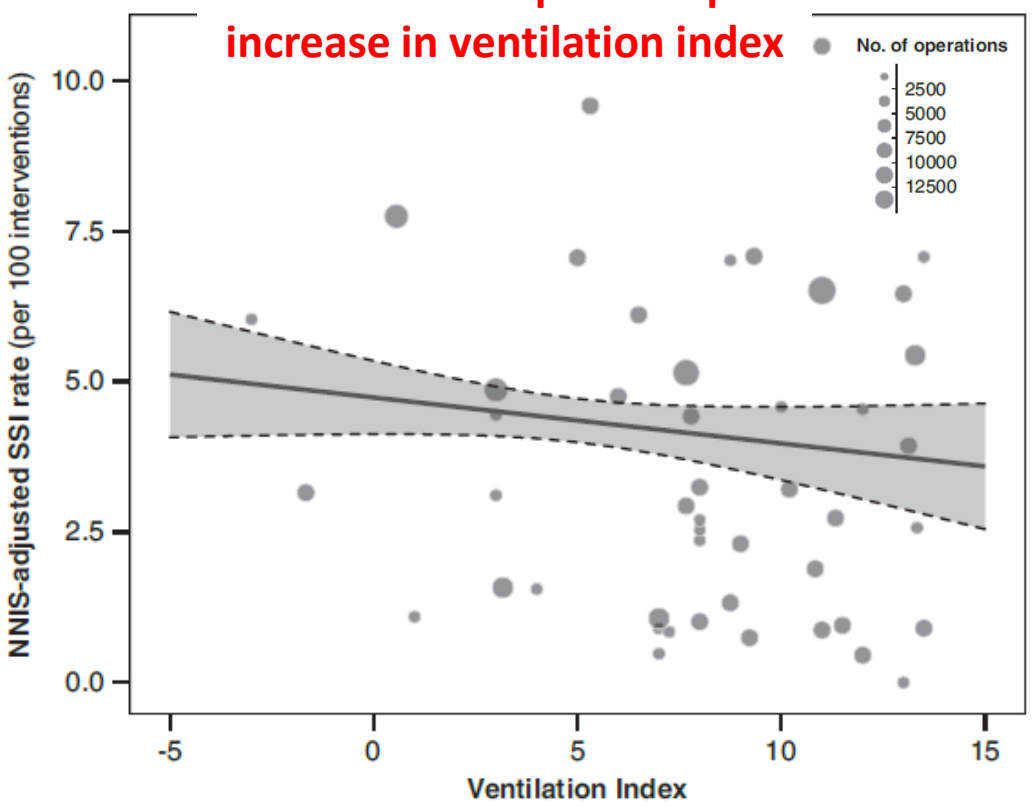
Ventilation quality of 168 Swiss ORs using a ventilation index

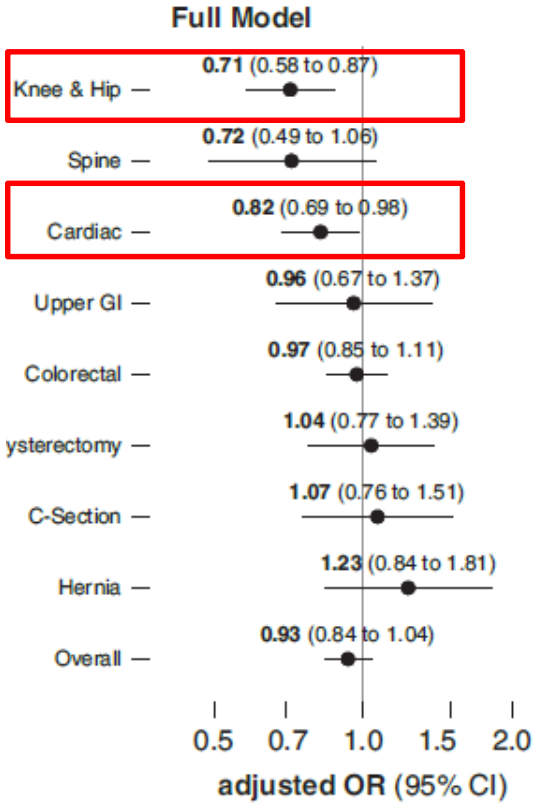
Calculation of the Ventilation Index:

- Air flow (m3/h)
- Size of ceiling unit
- Location of air return outlets
- Air guide at ceiling unit
- Operating room lamps
- Patient-table position

- Performing orthopedic/cardiac interventions in ORs with good ventilation properties associated with lower **superficial/deep** SSIs rates
- Examining the influence of each component of the ventilation index on SSI

–0.38% of SSI per 5 steps increase in ventilation index

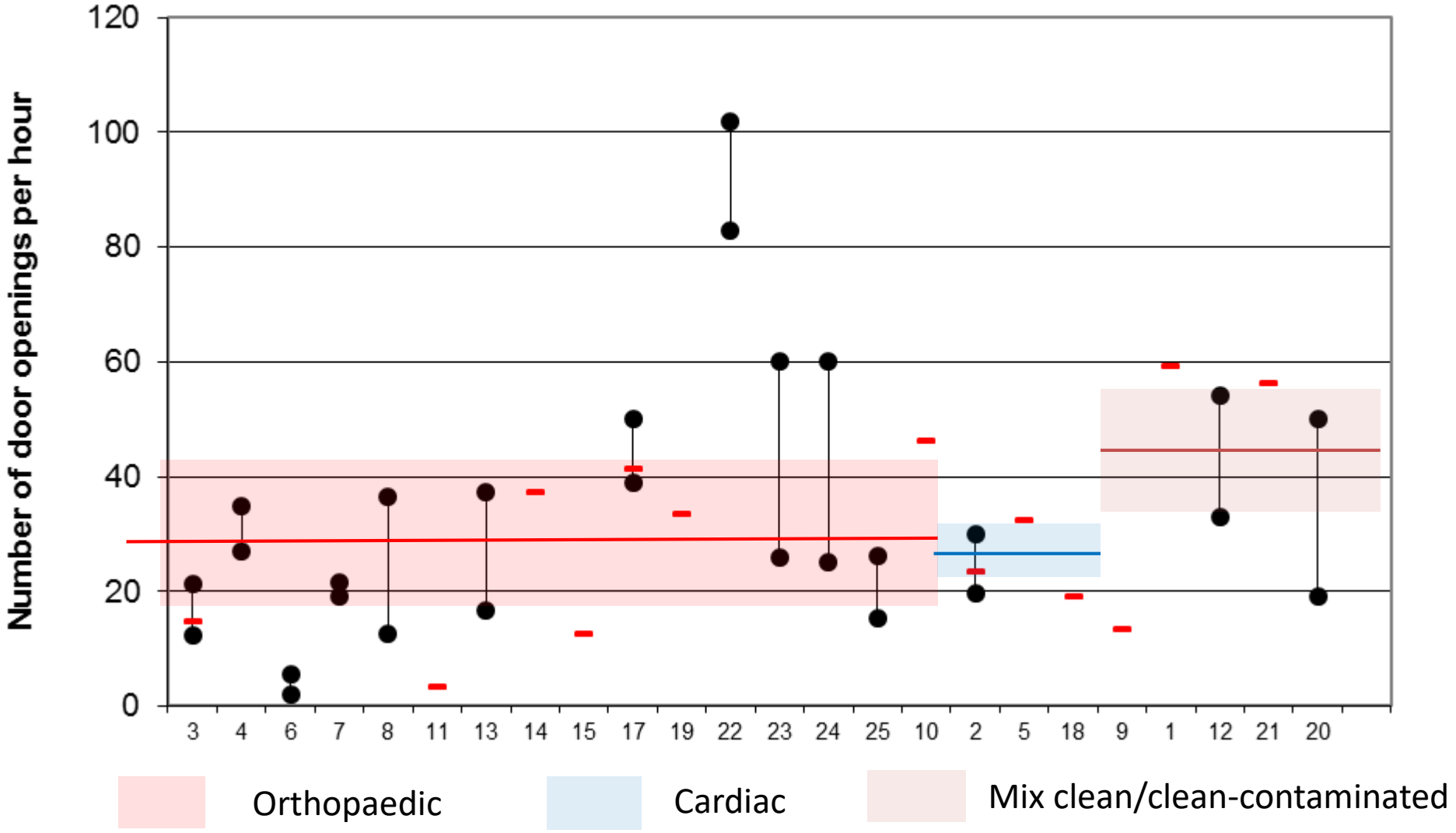




Bernard Surial et al Ann Surg 2022;276:e353–e360)

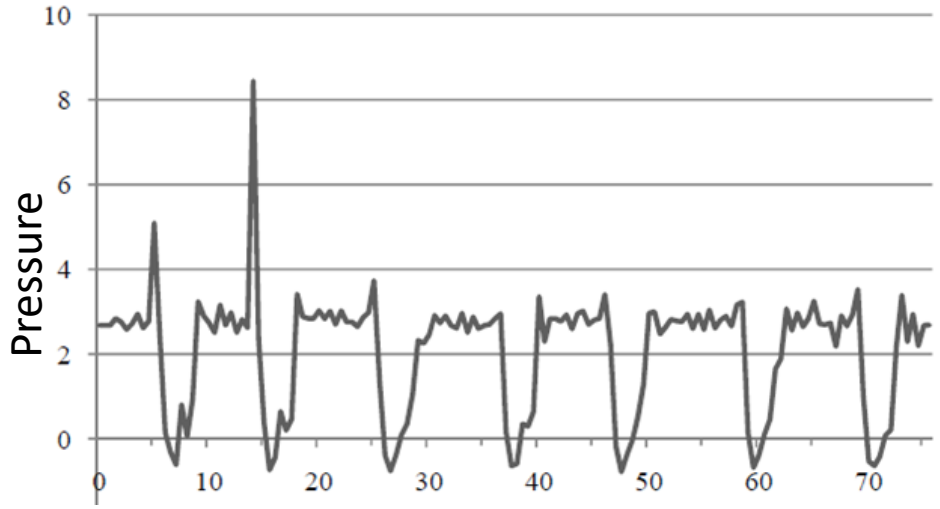
Door opening frequency

25 studies identified

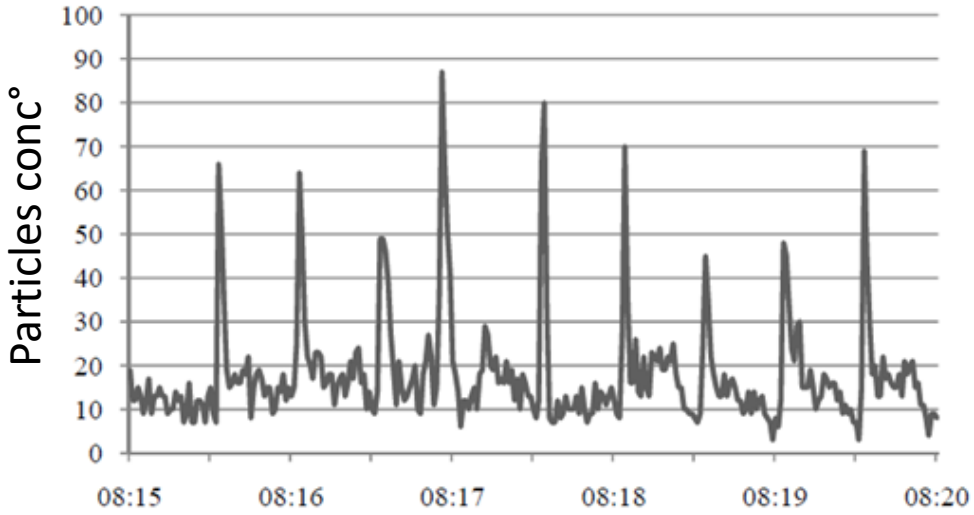


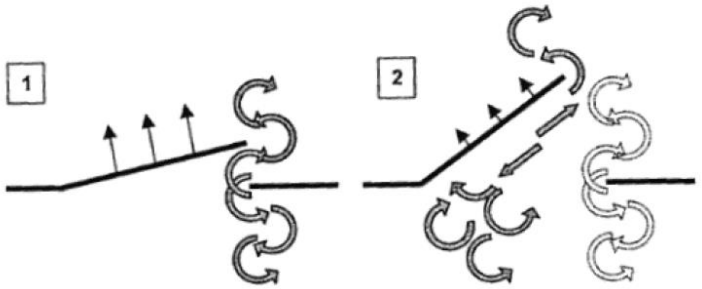
Door opening and air particles

Door opened 45°, 4 seconds



1.m, door openings every 30 sec of 45°





- Most common door opening angle = 45° with a total door opening time = 3.5-5 sec
- **Pressure difference** = dominating driving force
- **Door openings disturb the air flow** in the OR
- **Vortices created by the door swing** → transfer of air from the corridor, even with positive pressure and no temperature difference

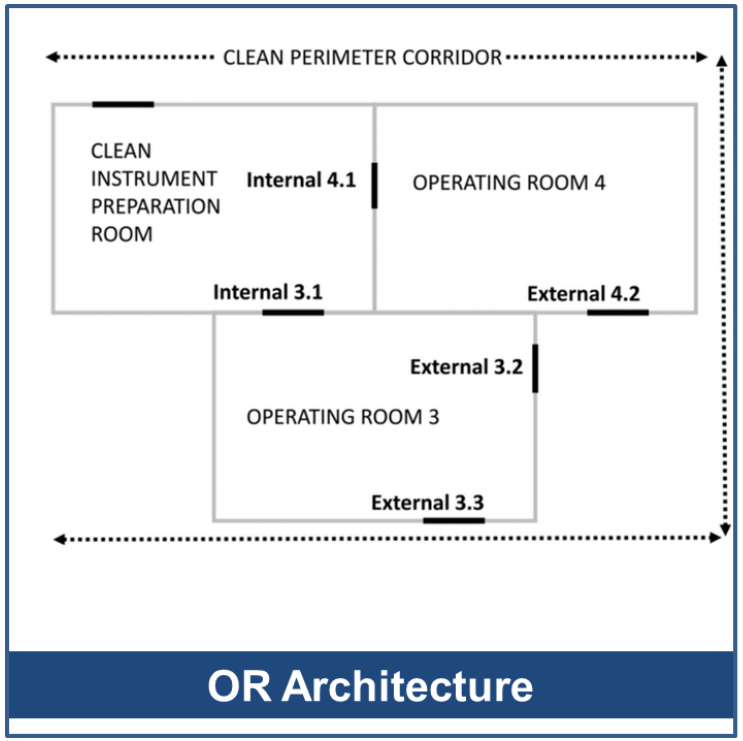
CHALMERS, Energy and Environment, Master's Thesis E2010:12

Association between door openings and Particles/CFU?

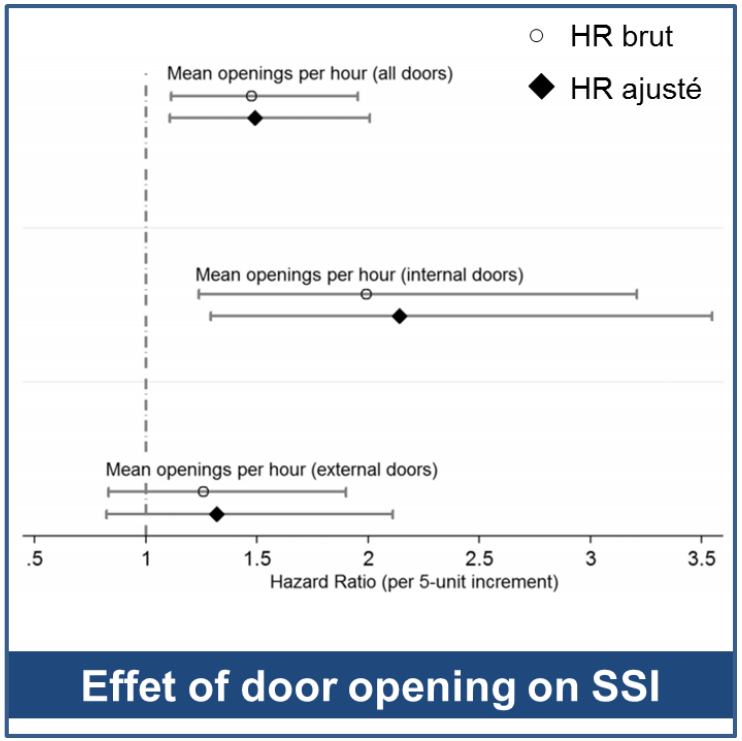
Authors (year)	Type of surgery	Ventilation type	Association
Birgand et al. (2019)	Orthopaedic	LAF	Yes
Alsved et al. (2018)	Orthopedic	LAF/Mixing/	No
Perez et al. (2018)	Orthopaedic/general	LAF	Yes
Mathijssen et al. (2916)	Hip revision	Mixing	Yes
Smith et al. (2013)	Orthopaedic	LAF	Yes
Andersson et al. (2012)	Orthopaedic	Displacement	Yes
Stocks et al. (2010)	Joint Arthroplasty	Mixing	-/No
Tjade (1980)	Orthopaedic		No
Birgand et al. (2019)	Cardiac	LAF/Mixing	Yes
Teter et al. (2017)	Plastic surgery	Unknown	Yes
Scaltriti et al. (2007)	Orthopaedic/urology/general	Mixing	No/Yes

Association between door openings and SSI rate?

- Retrospective cohort, cardiac surg
  - 2 OR, 688 patients, 24 SSI
- SSI at 30 days associated with internal OR door openings
  - Poor coordination among surgical teams
  - differences in air pressure
  - internal OR door openings could be more disturbing for cardiac surgeons



OR Architecture



Effet of door opening on SSI

Need to clarify the role of OR door openings as a marker or independent risk factor for SSI.

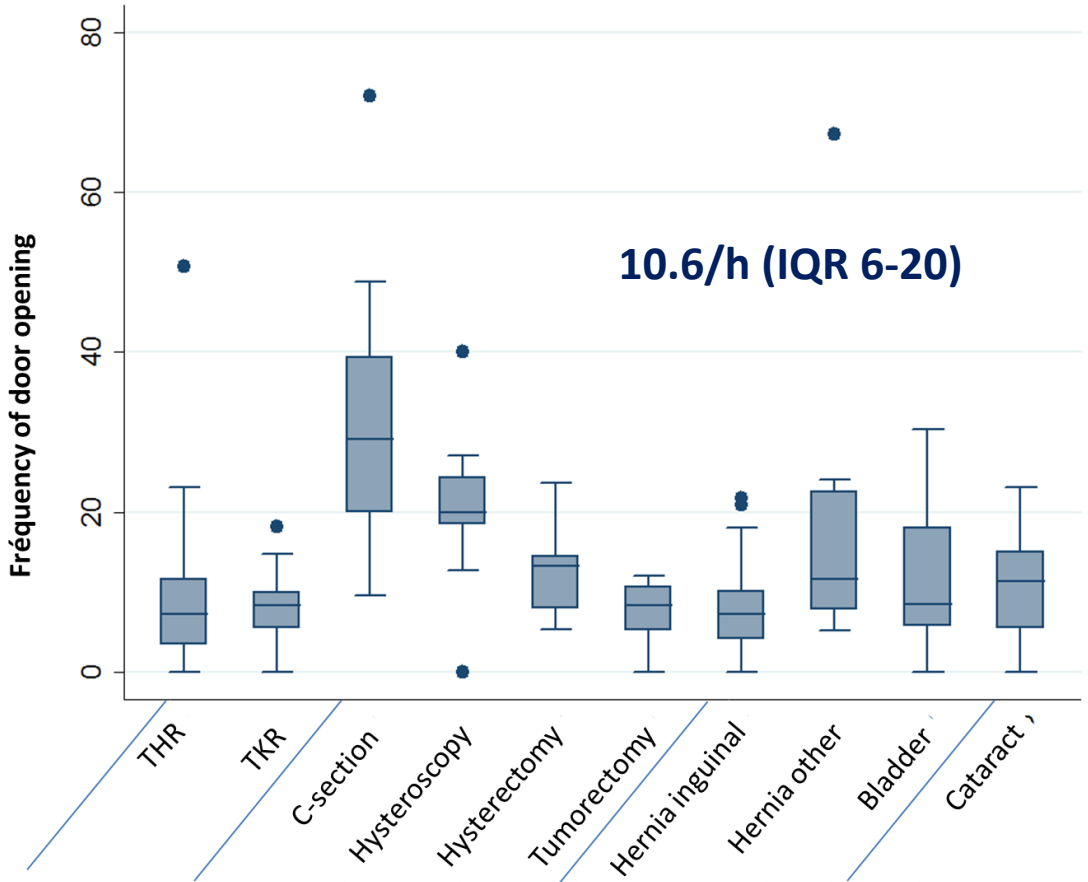
Jan Roth, Clin Infect Dis. 2019 Jul 2;69(2):290-294.

Association between door openings and SSI rate?

Authors (year)	Type of surgery	Ventilation type	Association
Mears et al. (2015)	Joint Arthroplasty	Mixing	Unclear
Pryor (1998)	Orthopaedic	Unknown	Yes
Bohl et al. (2016)	Neurosurgery	LAF	No
Roth et al. (2019)	Cardiac	LAF	Yes
Young and O'Regan (2010)	Cardiac	Unknown	Yes
Bediako-Bowan (2020)	Abdominal	Mixing	Yes
Crolla et al. (2012)	Colorectal	Unknown	Yes

Door opening frequency

- 2015, 15 HCFs and 43 surgical teams, 212 operations
  - Direct observations of number, reasons, entries to/exits from incision-closure
  - Number of people present in the OR at cutaneous incision



Who is opening door?

43% Nurses > 24% Other HCWs
> 21% Anaesthesia team > 11% Surgeons

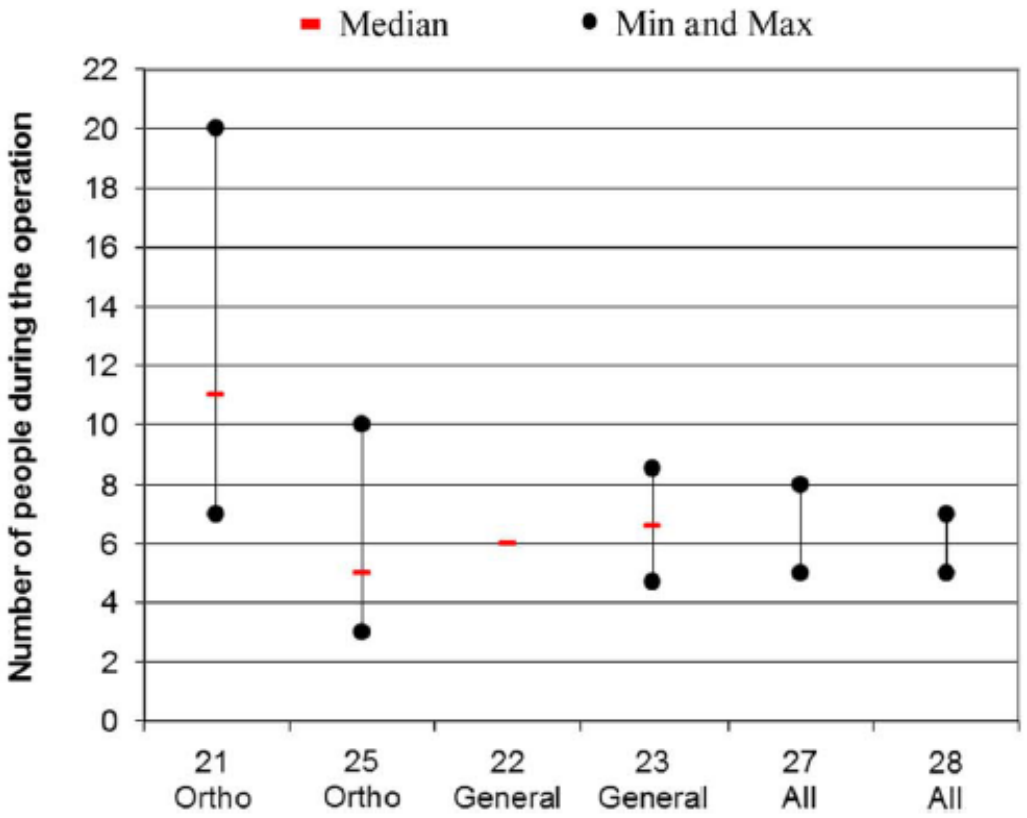
≈60% avoidable

Why?

44.5% for equipment > 13.8% for communication
> 13.1% linked to staffing (switch, break)
Remaining reasons not classifiable.

G. Loison et al. / Journal of Hospital Infection 96 (2017) 281e285

Number of people during procedures



- 212 procedures: Median: 5 Min-Max: 2-10
- Difference according to specialties (i.e. C-section)
- No difference elective/urgent, Public/private

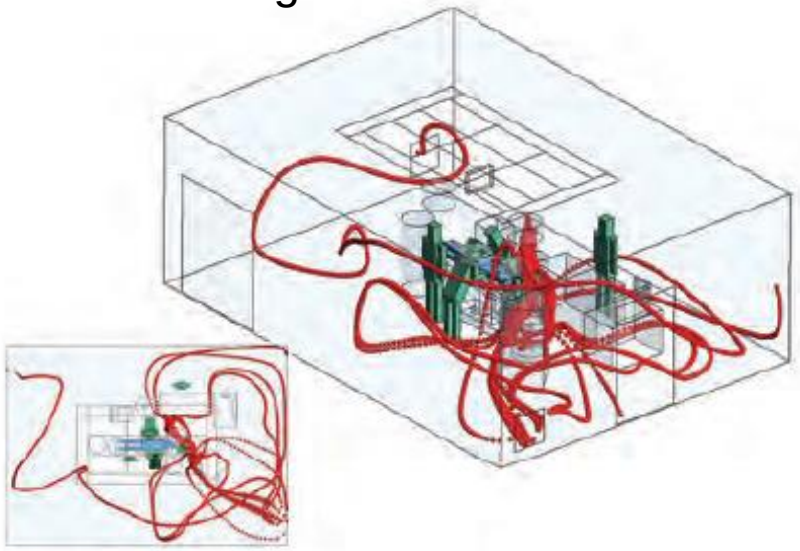
Study	Type surg	Endpoint	Nb proc.	Assoc.
Scaltitri	All	ABC	12	Yes
Wan	Clean	ABC/APC	33	Yes
Agodi	Ortho	ABC	1228	Yes
Andersson	Ortho	ABC	82	Yes
Durando	All	APC	23	No
Pryor	Clean	SSI	3259	Yes
Wanta	Clean	SSI	1277	Yes

But poor quality, not considering confunders..

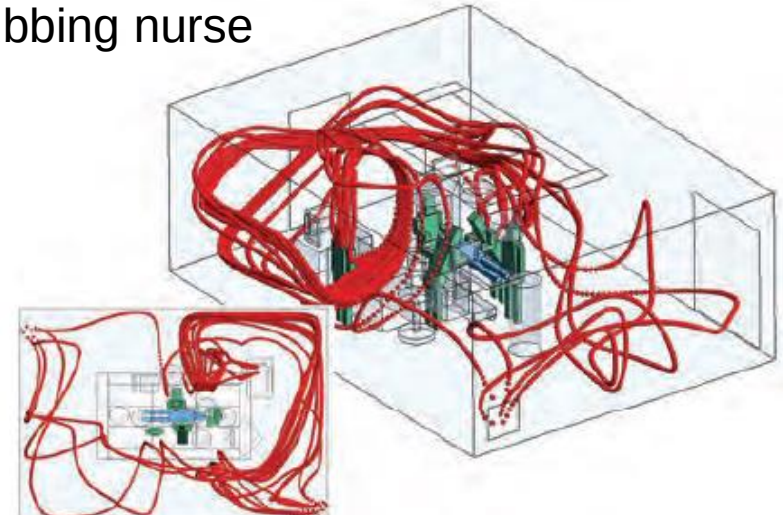
Birgand et al infection control & hospital epidemiology january 2015, vol. 36, no. 1

Surgical staff & Flow path of airborne particules

The anesthesiologist



The scrubbing nurse



CFD analyses

- Particulates originated within/edge of sterile zone generally swept away into the non-sterile zone
- **Particulates originate in non-sterile zone** (ie scrubbing nurse) get entrained into the sterile zone.
- Particulates tend to **stay and circulate in the non-sterile zone** before exiting the OR → deposition on the back table
- HVAC configuration (size, number, locations of supply and return) may play a role in determining the flow path of airborne contaminants

ASHRAE Journal, May 2018.

Joint guidelines of The HIS and ESCMID

- ***Does the movement of theatre staff in and out of the operating room impact on air counts of bacteria and infection rates?***
- 9.1: Minimise non-essential staff movement and hence door openings during surgical procedures to minimise bacterial air counts.
  - Door opening **in itself not likely to have effect on SSI**
  - Microbial counts observed with door openings → result of increased staff movement
  - Door opening should be limited to essential activities
  - **Each additional individual** not required for the surgical procedure increases the bacterial air counts and potentially leads to an increased risk of SSI (except students)
  - Other benefits: protecting patient dignity and leading to fewer distractions

H. Humphreys et al. / Journal of Hospital Infection 2023

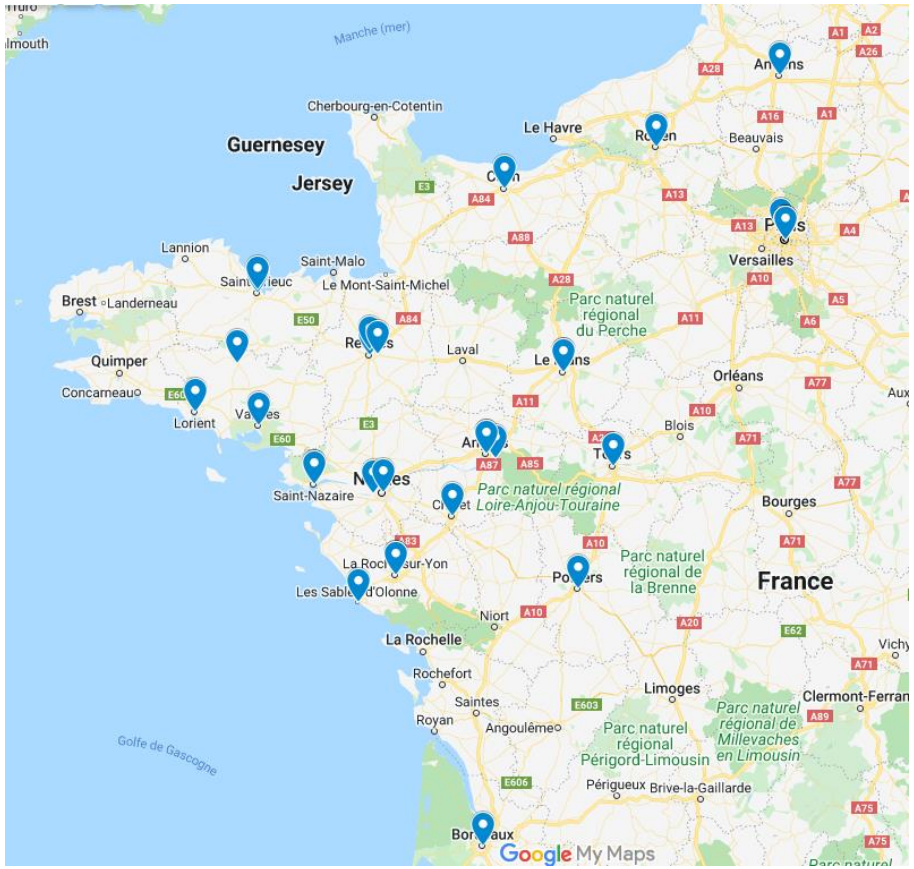
How can we improve OR behaviours?

- All but 2 were bundle
- Decrease from **5 to 78%** of door openings
- Various (often non-rigorous) methods of analysis and measurement used
- Need to assess the effect of individual interventions on OR traffic

	1	2	3	4	5	6	7	8	9	10	11	12	
Overall result	↘	↘	↘	↘	↘	↘	↘	↘	↘				
Intervention													
Education	■	■			■	■	■						4/5
Guideline	■	■											1/2
Door sign	■			■	■		■			■		■	4/4
Door alarms			■										1/1
Door counters	■					■							1/2
Locked door policy											■		
Video observation decks					■								
Verbal interventions									■				
Sugeon leadership			■										
Telephone			■		■								2/2
Rule on breaks	■									■			1/1
Anticipation of supplies								■		■			1/1
Retractable tape								■					
Pull shades								■					

Laura Buckner J Patient Saf • Volume 18, Number 2, March 2022

How can we improve OR behaviours?



- Cluster randomised control trial
  - 16 centers control harm
  - 16 centers intervention

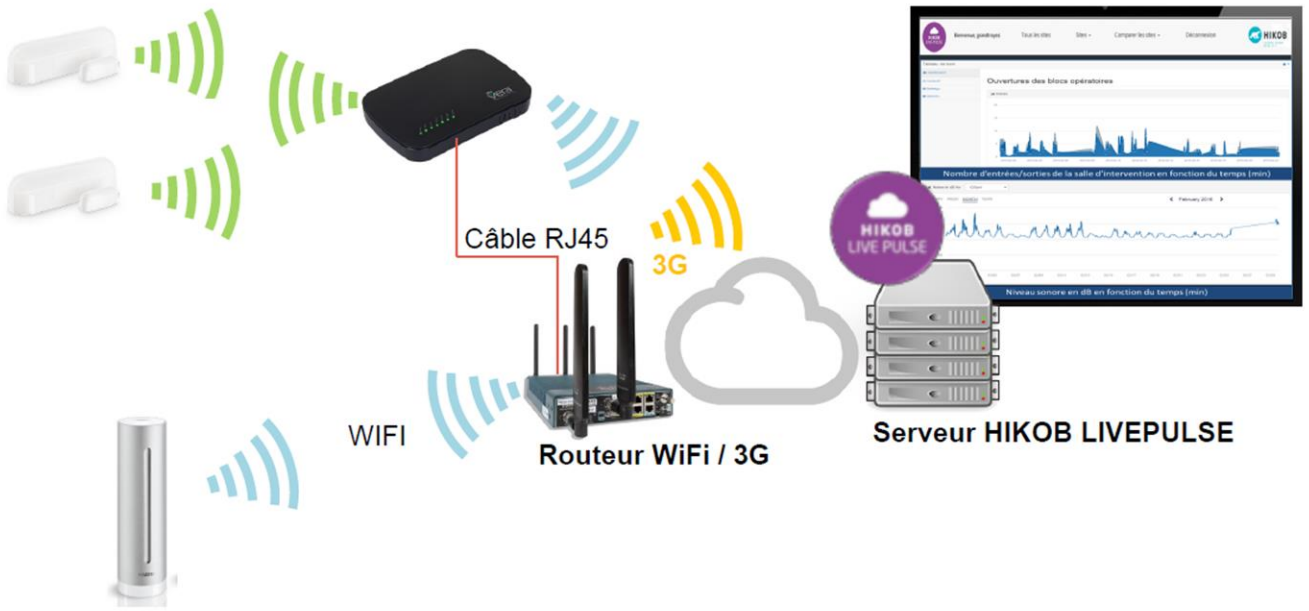
10000 operations Hip and knee replacement

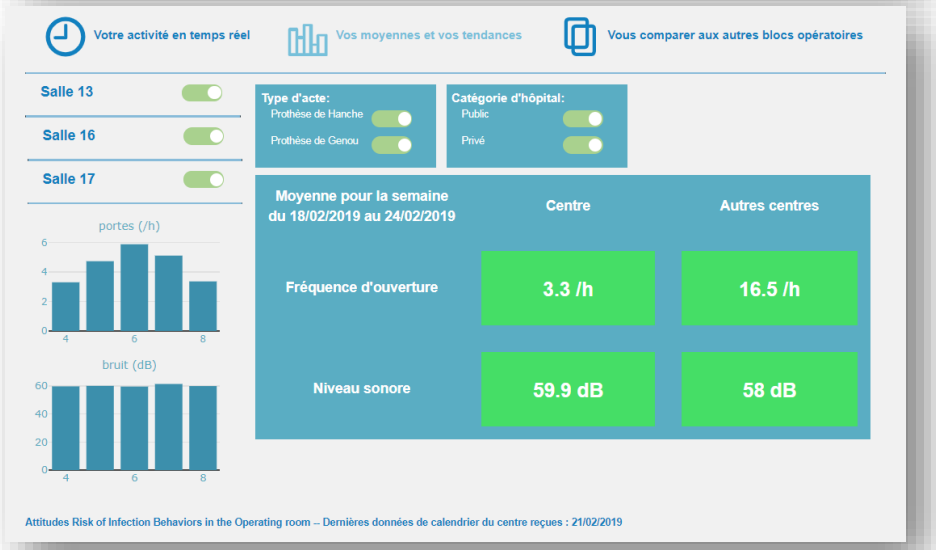
- Intervention to improve intraoperative behaviours
  - Door openings, noise level
  - Monitoring, feedback and benchmarking process
  - Adaptive approach
- Endpoint: All post-operative complications

Birgand et al. Trials (2019) 20:275

Methods

Monitoring and feedback





Methods

Awareness tools

Target of 100% HCP trained

- Ventilation
- Impact of door opening and noise
- Use of monitoring system
- Methods to improve behaviors


ARIBO²

Amélioration des comportements peropératoires des personnels pour prévenir les complications post-opératoires.

Présentation de la thématique – Notes facilitatrices

Titre de diapositive et commentaires	*Numéro de diapositive*
Titre de la diapositive **Impact des comportements sur le risque de complications post-opératoire** Dire: Le projet ARIBO² est une opportunité d'explorer et d'optimiser nos comportements au bloc opératoire. Cette présentation a pour objectif de vous expliquer pourquoi.	***Diapo 1*** ARIBO² Impact des comportements sur le risque de complications post-opératoire
Surveillance ISO - RAISIN Dire: Voici les résultats de la surveillance ISO raisin 2012-2016. Vous pouvez constater une augmentation des taux d'infections du site opératoire pour les prothèses de genou primaire ou de première intention entre 2013 et 2016. Ce constat est également partagé pour les prothèses de hanche cette même période. Ces résultats tendent à prouver que la tendance des taux d'ISO en orthopédie est à la hausse.	***Diapo 2*** ARIBO² ISO - RAISIN
Contamination de l'air Dire: L'air dans lequel nous vivons contient des particules. Tout individu produit des particules ou des squames. Au repos, nous produisons environ 100 000 particules par minute, alors qu'en activité nous pouvons produire jusqu'à 15 à 30 million de particules par minute. Il existe une corrélation entre le nombre de particules trouvé dans l'air est la quantité de bactéries tendant à prouver qu'une partie de ces particules sont des bactéries.	***Diapo 3*** ARIBO² Contamination de l'air

Methods

Adaptative approach

Search for root causes of door opening/high noise levels → **Tailored action plan**

- Lean methods based on plan-do-check-act (PDCA)
  - Designation of:
    - Local project liaison (IPC/quality specialist) +
    - Local project champion (member of the OR staff with strong leadership skills)
  - Multidisciplinary team in each centre:
    - Ortho surg, anaesth, surg nurses and quality coordinators, mentored by a lean coach

Adaptive method in 7 successive phases:

1. Clarifying the problem: baseline data
2. Specifying the current situation
3. Multidisciplinary analysis of data
4. Determining the target condition:
5. Analysing the root cause(s)
6. Action plan: taking countermeasures.
7. Evaluating the impact of the action plan using the monitoring system.

Birgand et al. Trials (2019) 20:275

Methods

Adaptative approach

- Key elements for the implementation of intervention
  - Leadership and engagement of the project team
    - Clarity of the roles: Local project liaison/champion, multidisciplinary team members
    - Planification of project meetings
    - Engagement of a surgeon as champion
  - Engage OR staff
    - Organise a friendly kick off meeting
    - Accurate feedback of data/efficient communication: simple, timely, accessible
    - Reward successes: HARIBO delivered throughout the study period
  - Engage managers
    - Credits for education and training
    - Validation as practive evaluation for quality report

Implementation guide
+
Online folder shared

Birgand et al. Trials (2019) 20:275

What to take from all of it?

- SSI **may occur** from staff or environment **through the air, but %?**
- We are **oversimplifing** the problem of air ventilation
  - Multiple influencing factors including human behaviours
- Ventilation effectiveness **variable according structural factors**
  - Location of lights, equipments…
  - Need for more collaborative works: engineering (CFD)
- **Staff behaviours associated with air contamination**
  - Proof of concept still needed, impact of DO, movements on SSI
  - Simple actions improve DO (signs, supplies, communication, anticipation)
    - Need for tangible rules/risk assessment + leadership from surgeons
  - Perspective: Assessment of organization and sociologic evaluation in OR

Acknowledgments

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- Statistics:
  - S. Rukly, J.F. Timsit, B. Giraudeau, E. Tavernier, L. Grammatico-Guillon
- Participating centers:
  - CHU de Nantes; CHU de Rennes; CH Saint Nazaire; CHU d'Angers; CH Le Mans; Hopital Bichat et Beaujon; Hopital Lariboisière; Institut Mutualiste Montsouris (IMM); CHD Vendée; Centre hospitalier privé Saint Grégoire; Hopital Privé du confluent; Clinique Saint Léonard; CHU de Tours; CH de Vannes; Clinique chirurgicale du Pré; CHU d'Amiens; CHU de Poitiers; Clinique Saint Charles; Polyclinique du Kerio; Clinique Porte Océane (Sables d'Olonne); CH Yves Le Foll (Saint Brieuc); ELSAN - Santé atlantique; CHU Bordeaux; Clinique Saint Martin; CH Cholet; CHU de Rouen; Clinique de Cesson Sévigné; Clinique de l'Anjou; Clinique porte de Lorient; Hopital Privé Cote d'Armor; Hopital Cochin; Polyclinique Europe

Thank you for your attention

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Preliminary results

Adaptative approach

Study of determinants of the adoption, implementation and sustainability

FACILITATORS

- **Leadership** from surgeons and involvement of OR Nurses
- **Local safety culture** and quailty of care
- **Cohesion** and **communication** between professionals in the OR

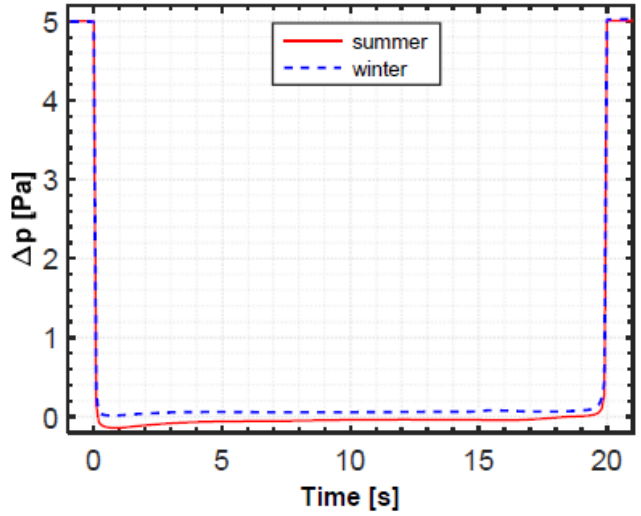
BARRIERS

- **Professional fragmentation** between anesthesia and surgery
- ***Turnover*** of staff
- **Work conditions** and infrastructures dégradées
- Lack of time generated by staff cut/low resources

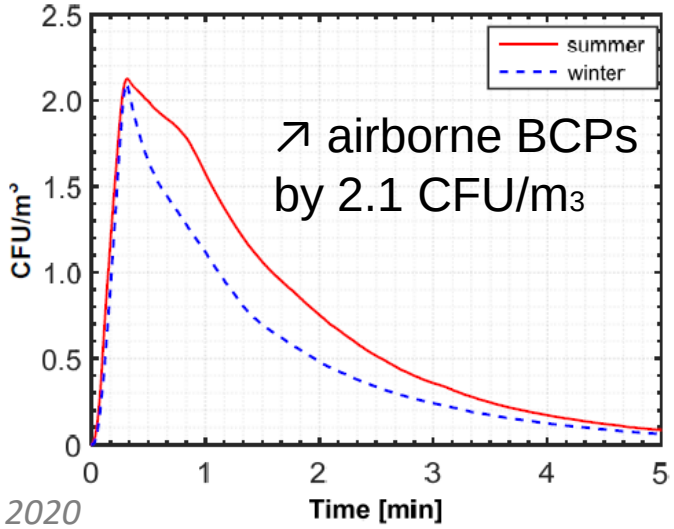
Birgand et al. Trials (2019) 20:275

Door opening and air flow

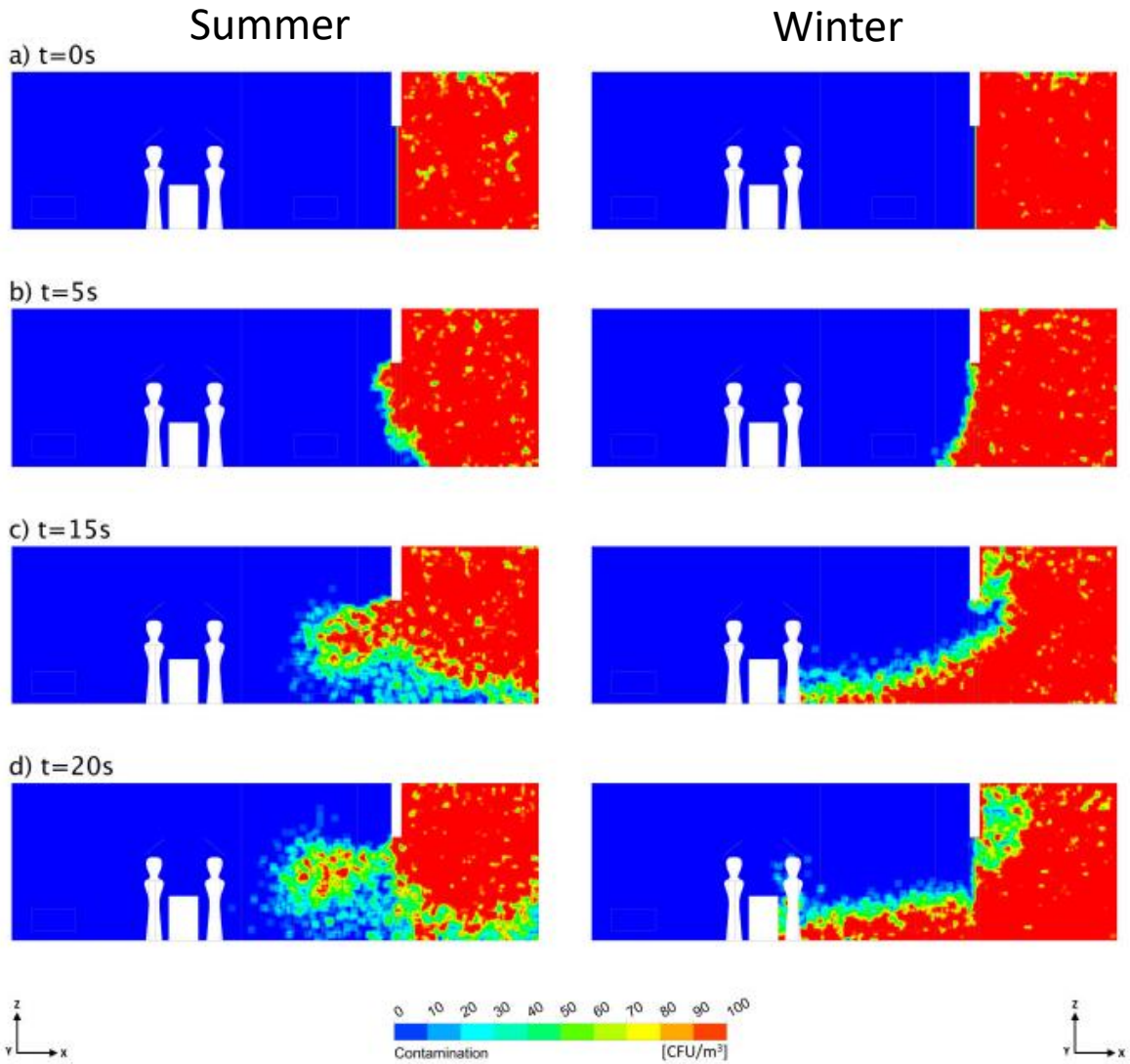
OR/corridor pressure ≠ during the door opening



Contamination in OR within 5-minute



Airborne BCPs concentration at center-plane of sliding door



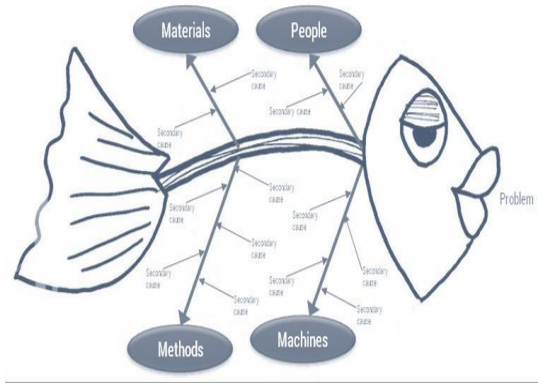
Kong Wang, PhD 2020

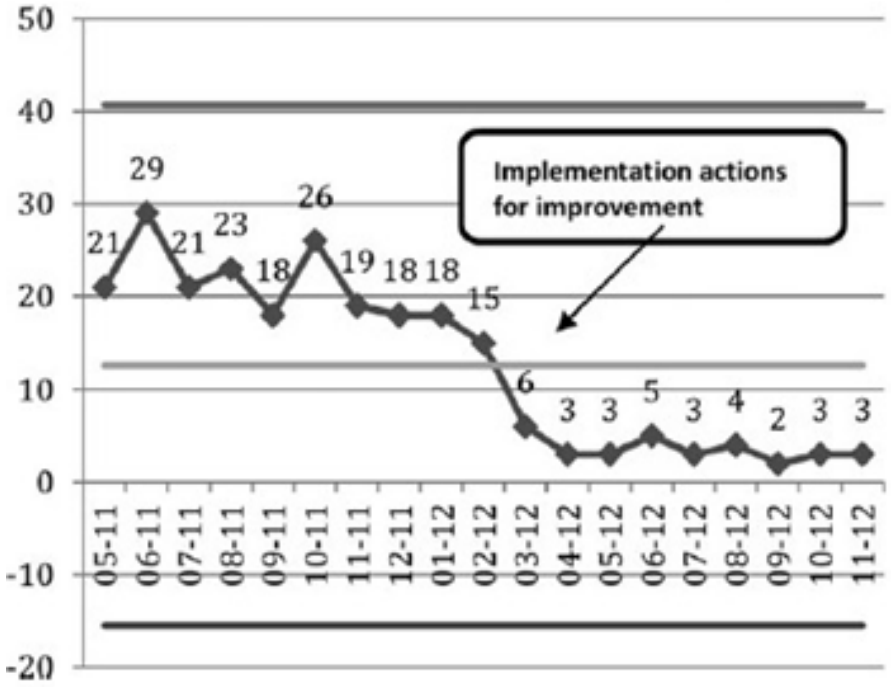
Methods

Adaptative approach

- **Target: 0(zero) door movements**
  - Need for X-rays, Unexpected material, Instruments or blood products, Breaks or service shifts of employees, Emergencies, Supervision for the orthopaedics or anaesthetist

- **13 root causes, 3 with biggest impact:**
  - Visible phone number
  - Leadership of surgeon
  - Revised warning sign





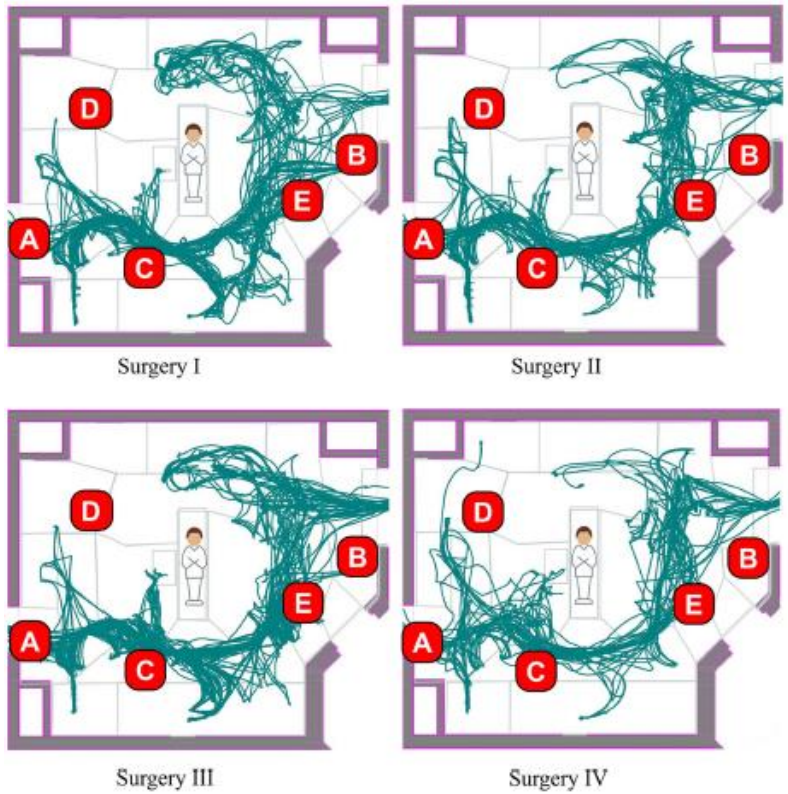
- ✓ In-depth understanding root causes = effective countermeasures
- ✓ Collaboration, sharing, dialogue
- ✓ Direct feedback loop by a metric (door counter)
- ✓ Setting staff own countermeasures

Frederique Simons MSc, Erasmus MC Rotterdam 2018

Ergonomics and infectious risk

27 videotaped procedures in orthopaedic surgery

Traffic, Area Location



High microbial load corraleted with:

- Physical movement of people in the same area
  - **Passage away from the operating site**
  - Internal storage points
  - **Bring high traffic areas closer together**
  - Consider visual and auditory constraints
- Hygrometrie > en septembre

Conclusions:

- Informed workflow design could potentially reduce the amount of movement which would ultimately reduce microbial loads, and thereby lessen SSI risk

Taaffe Infect Control Hosp Epidemiol . 2018 Apr;39(4):391-397.

Discipline in the OR

	Particle Log_{10} 0.3 µm		Air microbial count	
	Univariate analysis	Multivariate analysis	Univariate analysis	Multivariate analysis
Surgical specialty				
Cardiac surgery	0.11	-	0.04	-
Procedure type				
Total knee replacement	0.93	-	0.07	-
Total hip replacement	0.41	-	0.03	-
CABG	0.01	-	0.20	-
CABG + valve	0.32	-	0.28	-
Valve				
Ventilation system and OR architecture				
Conventional airflow	**0.05**	-	0.03	**0.04**
Volume of the OR, m3	0.85	-	0.79	-
Behaviors per period				
No. of door openings	0.01	**0.01**	0.02	**0.03**
Duration of door openings	0.05	-	0.06	-
Cumulated distance	<0.001	**<0.001**		

Controlling the movements of staff members > Restricting their number

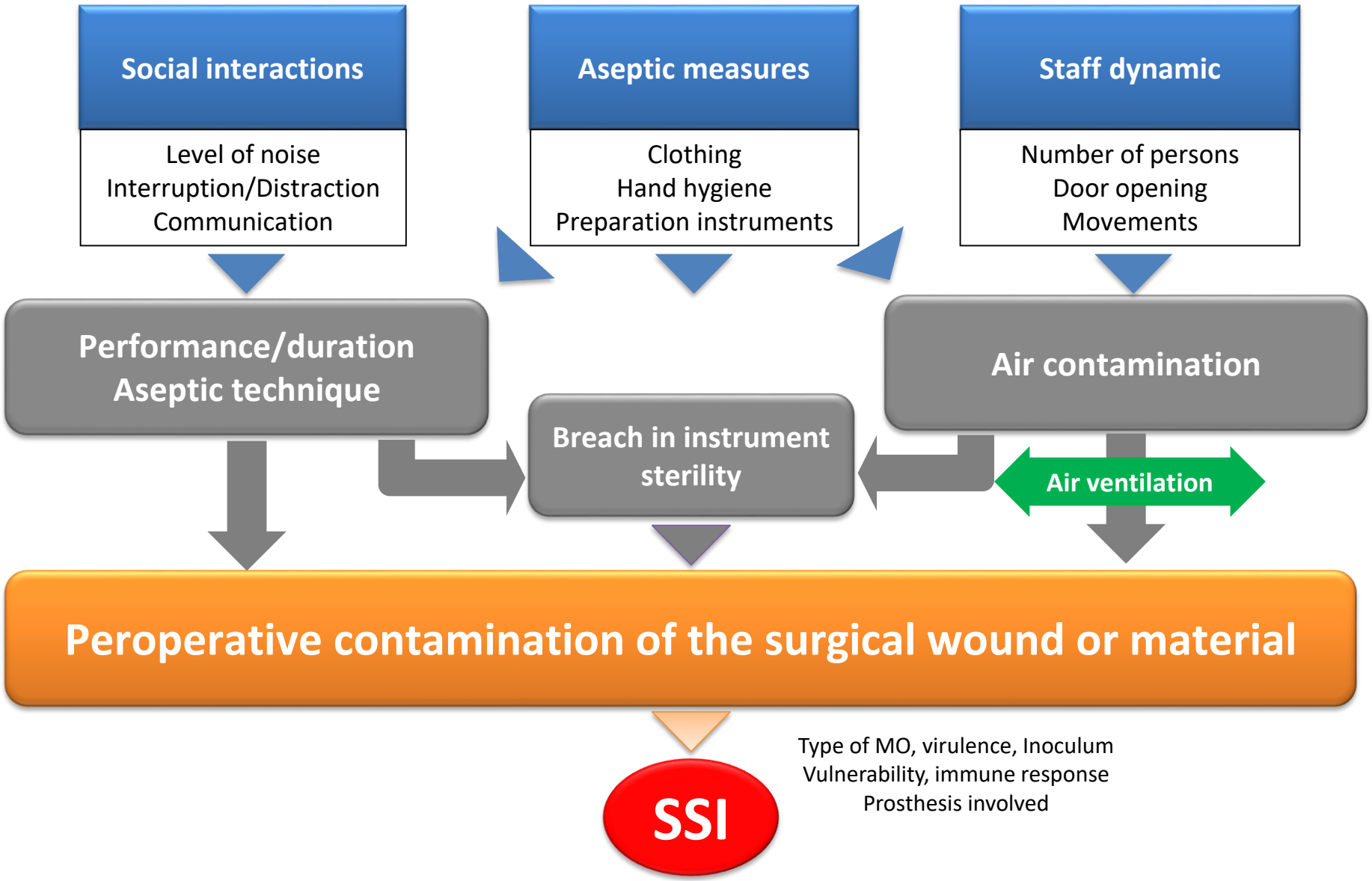
Birgand et al, Infect Control Hosp Epidemiol. 2019 May;40(5):566-573.

How can we improve OR behaviours?

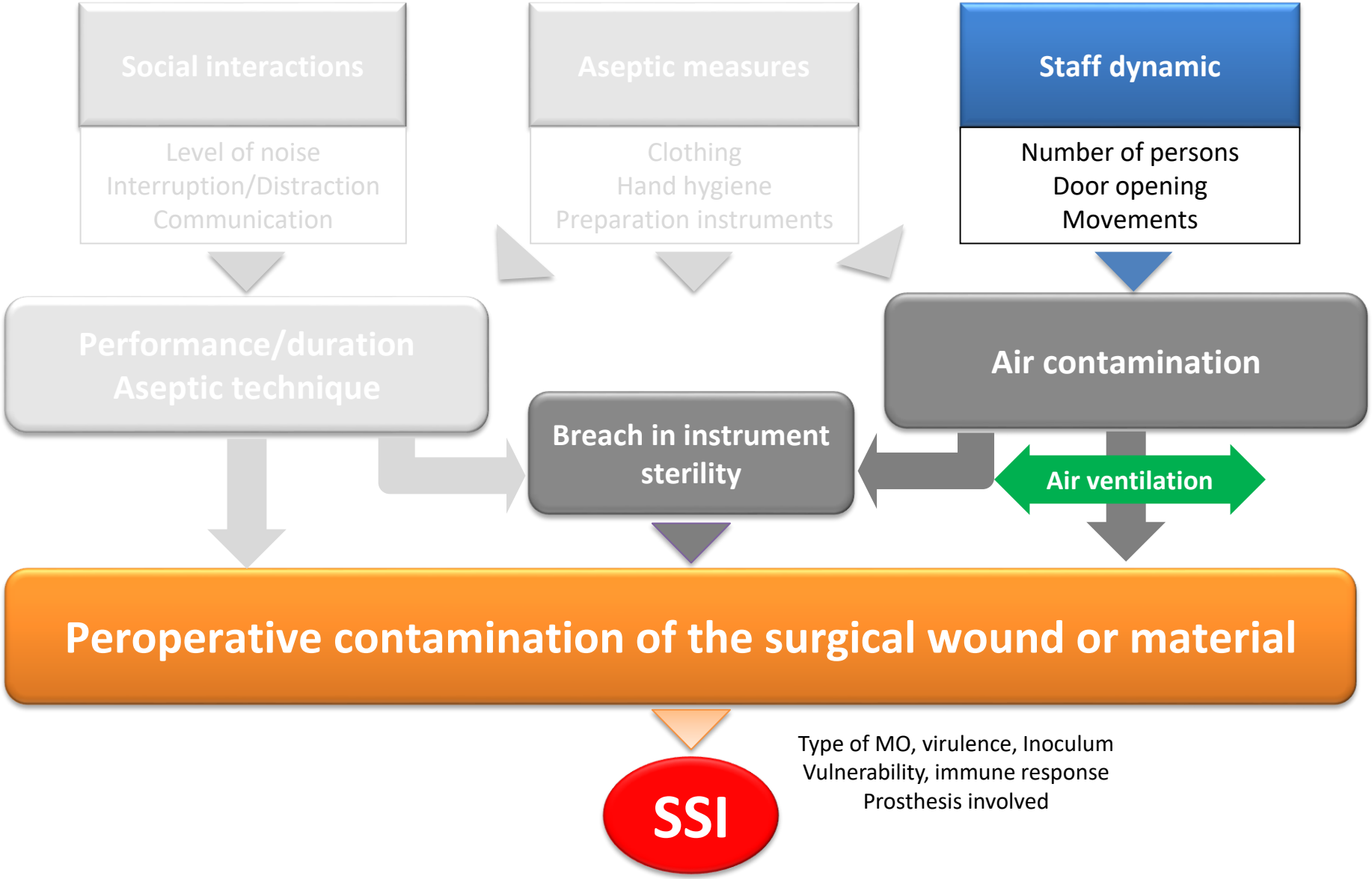
Studies	Specialties	Interventions	Results
DiBartola	Ortho	Guideline, education, rules on OR breaks, door sign, door counters	
Elliott		Education, standardization of OR supplies, procedure carts on nursing traffic and OR door swings	23 to 17%
Eskildsen	Ortho	Door alarm	
Yinnon 2012	General	Checklist including monthly report traffic flow	CFU
Van der Slegt 2013 Crolla 2012	Vascular, Digestive	Bundle compliance on team behaviours	↘30 to 80% compliance
Bohl 2016	Neurosurg	Signs with instructions, reduction of student access	SSI
Simons 2014	Ortho	Lean A3 intervention, dialogical learning	↘78% of traffic
Esser 2016	Pediactic	Education, clinical process changes (signs, wireless phone, video observation)	↘13% of traffic
Rovaldi 2015	Ortho	DO detterents and changes in traffic process	↘50% of traffic
Prager 2015		Needed equipment, door signs, discouraging breaks during procedures	
Ralte 2015	Ortho	Bundle including a locked door policy	↘50% in SSI rates

Laura Buckner J Patient Saf • Volume 18, Number 2, March 2022

OR behaviours and SSI



OR behaviours and SSI



Air contamination in the OR

- OR staff disseminating MRSE in the air

  25% among women 43% among men

- Identical *S. aureus strains* (PFGE) found in the air and in the wound

  Tammelin et al JHI 2000 & ICHE 2001

- Heater-Coolers devices in cardiac surgery
  - *M. chimaera* produced up to 5 m
  - 156-282 SSI cases/year

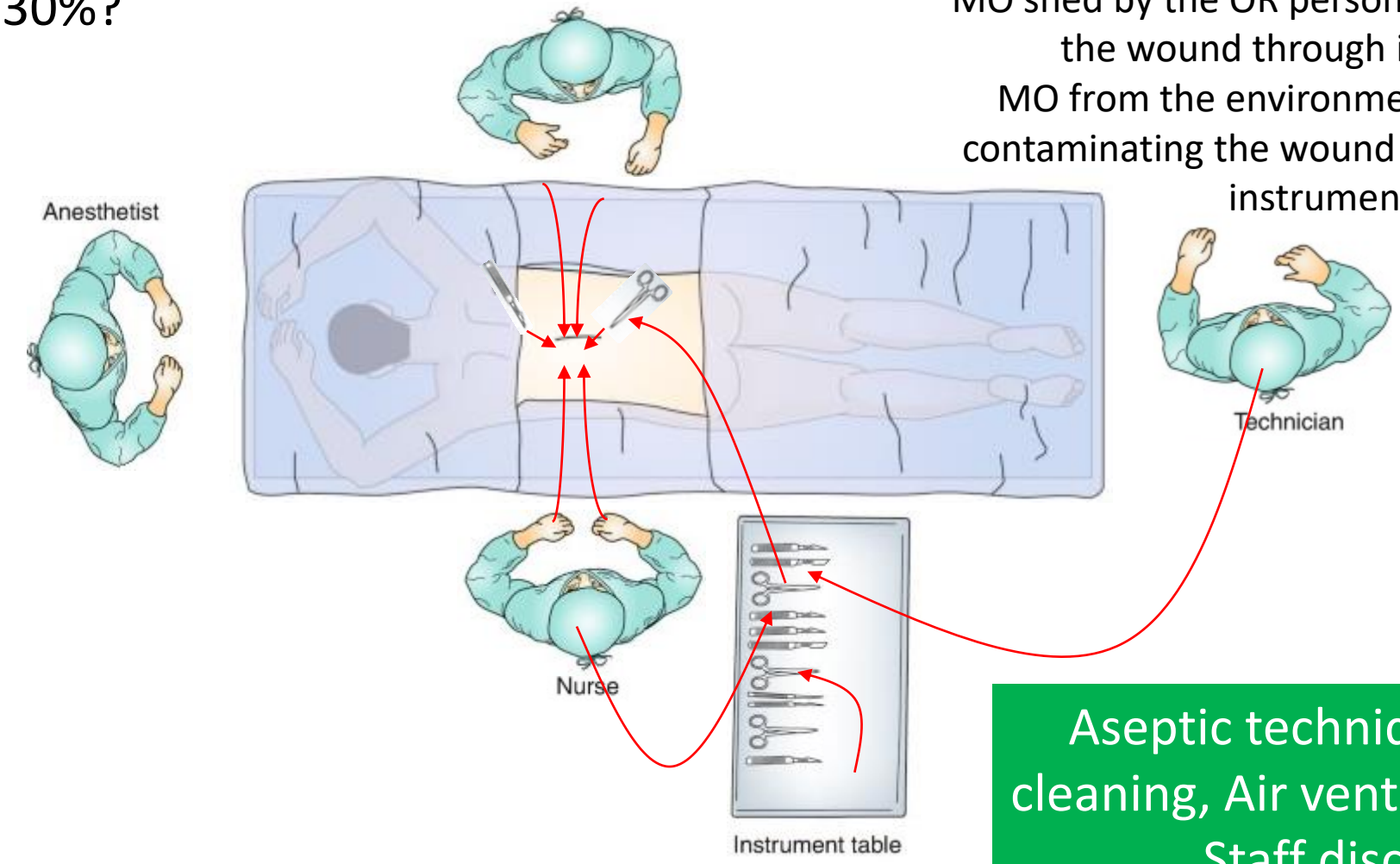
  Sommerstein EID 2016 & 2018

Physiopathology of SSI

Intraoperative contaminations

Exogenous flora

≈ 5% to 30%?



Indirect contact

MO shed by the OR personnel contaminating the wound through instruments

MO from the environment (surface, air) contaminating the wound through hands or instruments

Aseptic technique, Surface cleaning, Air ventilation system, Staff discipline