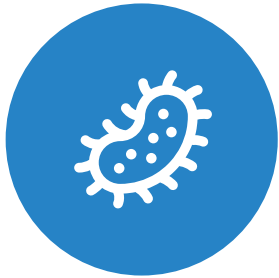


PROFESSOR ELAINE
CLOUTMAN-GREEN

Ask the Wrong Questions,
Get the Wrong Answers

How choosing the right
approach to
environmental IPC is key to
informing practice

Learning Objectives



Evidence of the role of the environment and key organisms of concern



Techniques to map transmission routes outside of outbreak settings



Options to help identify when you have a problem



Key considerations to impact loading and transmission routes

What Is Meant By the Environment?

Air

- Mechanical/naturally ventilated environments

Water

- Water sources
 - Taps>Showers
 - Sterile water
 - Equipment

Surfaces

- Near patient and shared area

Understanding Bi-directionality

Cruz-López F, Martínez-Meléndez A, Garza-González E. How Does Hospital Microbiota Contribute to Healthcare-Associated Infections? Microorganisms. 2023 Jan 12;11(1):192

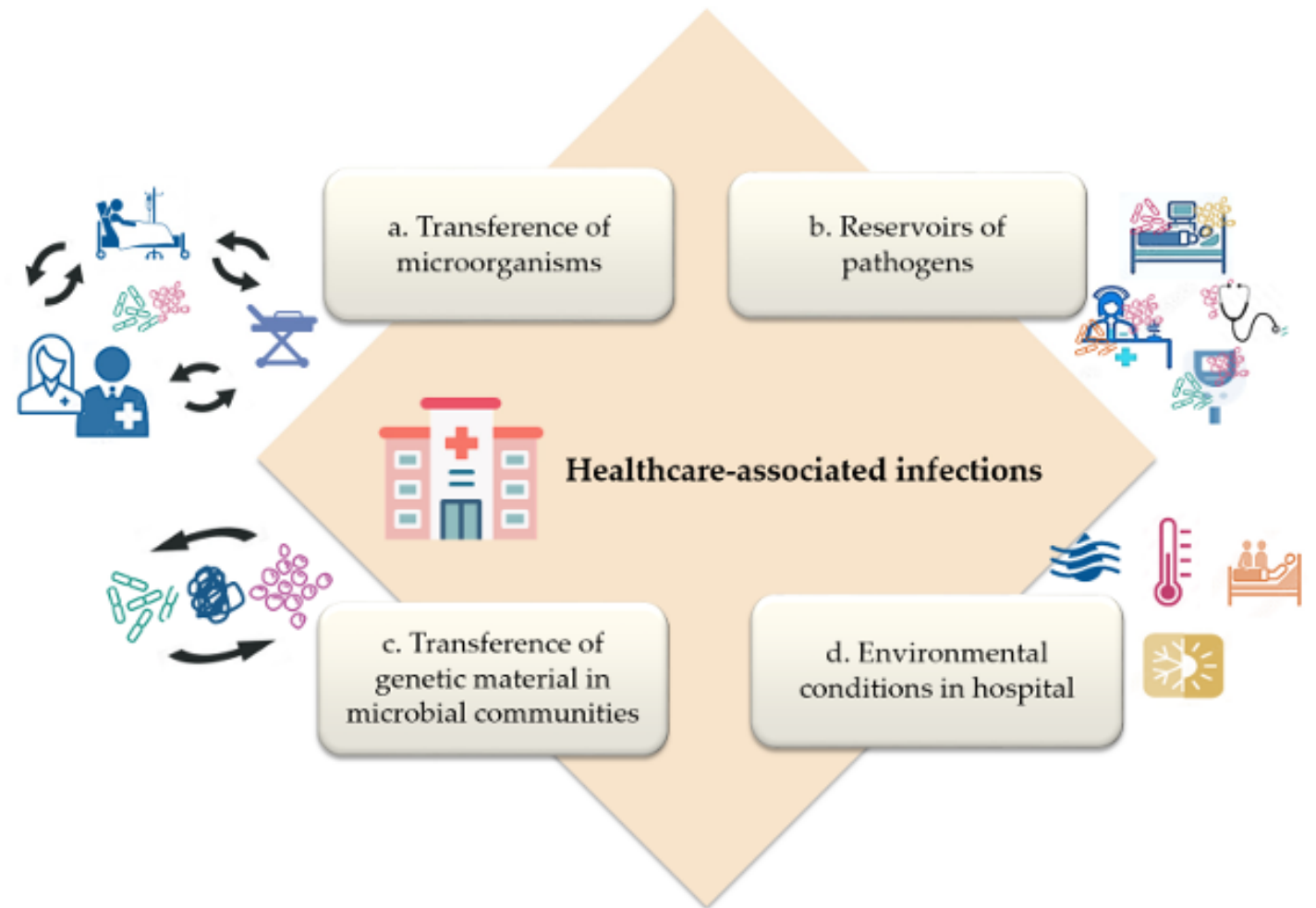
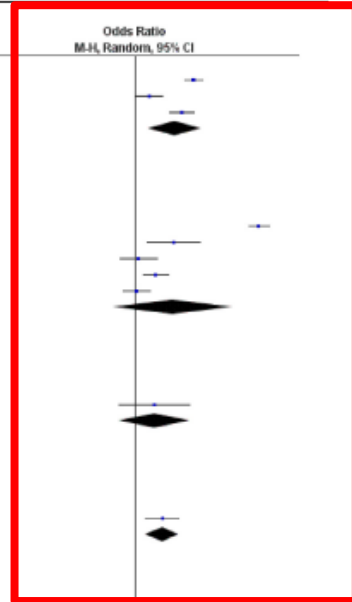


Figure 1. Factors related to healthcare-associated infections development. (a) transference of microorganisms between patients, healthcare workers, and hospital environmental surfaces; (b) hospital environmental surfaces, medical devices, healthcare workers, and patients as reservoirs of pathogens; (c) transference of genetic material associated with virulence, persistence, and antibiotic resistance in microbial communities; (d) environmental conditions, such as temperature, seasonal trend, humidity relative, and occupancy support persistence, diversity, and abundance of microorganisms on environmental surfaces.

Study or Subgroup	Experimental (+ room)		Control (-ve room)		Weight	Odds Ratio	
	Events	Total	Events	Total		M-H, Random, 95% CI	
1.1.1 MRSA							
Anderson	103	11005	725	293388	7.1%	3.81	[3.10, 4.69]
Huang	57	1454	248	8697	7.0%	1.39	[1.04, 1.86]
Mitchell	74	984	163	5344	7.0%	2.90	[2.19, 3.86]
Subtotal (95% CI)		13343		307427	21.1%	2.50	[1.38, 4.54]
Total events	234		1136				
Heterogeneity: Tau ² = 0.26; Chi ² = 31.61, df = 2 (P < 0.00001); I ² = 94%							
Test for overall effect: Z = 3.01 (P = 0.003)							
1.1.2 VRE							
Anderson	88	4083	423	307241	7.1%	16.18	[12.83, 20.36]
Drees	19	138	31	500	6.4%	2.42	[1.32, 4.43]
Ford	47	149	89	300	6.8%	1.09	[0.71, 1.67]
Huang	58	1291	256	9058	7.0%	1.62	[1.21, 2.16]
Zhou	69	3556	92	4929	7.0%	1.04	[0.76, 1.43]
Subtotal (95% CI)		9217		322628	34.3%	2.36	[0.61, 9.15]
Total events	282		891				
Heterogeneity: Tau ² = 2.35; Chi ² = 329.40, df = 4 (P < 0.00001); I ² = 99%							
Test for overall effect: Z = 1.24 (P = 0.22)							
1.1.3 ESBL							
Nzeir	8	50	50	461	5.9%	1.57	[0.70, 3.52]
Subtotal (95% CI)		50		461	5.9%	1.57	[0.70, 3.52]
Total events	8		50				
Heterogeneity: Not applicable							
Test for overall effect: Z = 1.08 (P = 0.28)							
1.1.4 Klebsiella sp. or Escherichia coli							
Ajao	32	648	235	8723	6.9%	1.88	[1.29, 2.74]
Subtotal (95% CI)		648		8723	6.9%	1.88	[1.29, 2.74]
Total events	32		235				
Heterogeneity: Not applicable							
Test for overall effect: Z = 3.26 (P = 0.001)							



1.1.5 Clostridioides difficile							
Anderson	43	3797	1278	307890	7.0%	2.75	[2.02, 3.73]
Shaughnessy	10	91	77	1679	8.2%	2.57	[1.28, 5.14]
Subtotal (95% CI)		3888		309569	13.2%	2.72	[2.05, 3.60]
Total events	53		1355				
Heterogeneity: Tau ² = 0.00; Chi ² = 0.03, df = 1 (P = 0.86); I ² = 0%							
Test for overall effect: Z = 7.01 (P < 0.00001)							
1.1.6 Acinetobacter							
Nzeir	16	52	41	459	6.3%	4.53	[2.32, 8.88]
Subtotal (95% CI)		52		459	6.3%	4.53	[2.32, 8.86]
Total events	16		41				
Heterogeneity: Not applicable							
Test for overall effect: Z = 4.42 (P < 0.0001)							
1.1.7 Pseudomonas							
Nzeir	21	85	61	426	6.5%	1.98	[1.12, 3.45]
Subtotal (95% CI)		85		426	6.5%	1.98	[1.12, 3.45]
Total events	21		61				
Heterogeneity: Not applicable							
Test for overall effect: Z = 2.35 (P = 0.02)							
1.1.8 Norovirus							
Fraenkel	5	1016	49	32772	5.7%	3.30	[1.31, 8.31]
Subtotal (95% CI)		1016		32772	5.7%	3.30	[1.31, 8.31]
Total events	5		49				
Heterogeneity: Not applicable							
Test for overall effect: Z = 2.54 (P = 0.01)							
Total (95% CI)		28299		981865	100.0%	2.45	[1.53, 3.93]
Total events	651		3818				
Heterogeneity: Tau ² = 0.81; Chi ² = 357.84, df = 14 (P < 0.00001); I ² = 96%							
Test for overall effect: Z = 3.71 (P = 0.0002)							
Test for subgroup differences: Chi ² = 7.84, df = 7 (P = 0.35), I ² = 10.8%							

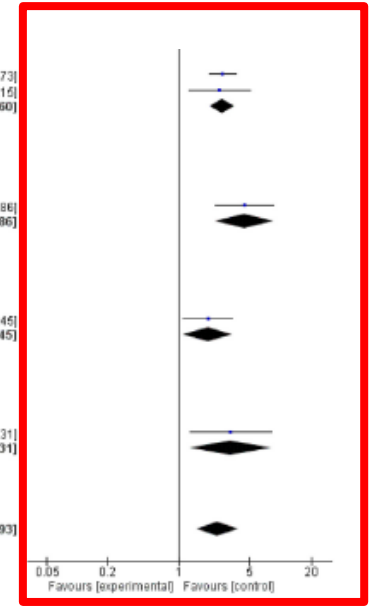


Figure 2 Forest plot for risk of acquisition from prior room occupants by organism, Note: M–H, Mantel-Haenszel; VRE, vancomycin-resistant enterococci; MRSA, methicillin-resistant *Staphylococcus aureus*; Ajao et al.'s study involved extended spectrum b-lactamase producing *Klebsiella* or *Escherichia coli* organisms. *Acinetobacter*: *Acinetobacter baumannii*; *Pseudomonas*: *Pseudomonas aeruginosa*. It was not possible to separate *Klebsiella* species and *Escherichia coli* data in the Ajao et al. study. ESBL includes the organisms *Pseudomonas aeruginosa* or *Acinetobacter baumannii*.

Prior Room Occupation Data

Table II
Range of survival by pathogen

	Pathogen	Range of survival in days (unless otherwise indicated)	Studies (references)
Gram positive	<i>Staphylococcus aureus</i>	<1 min to 318	[7–32]
	<i>Clostridioides difficile</i>	0.13–140	[33–36]
	Coagulase-negative <i>Staphylococcus</i>	<1 min to 28	[12,23,24,37]
	<i>Micrococcus</i> spp.	10–10	[12]
	<i>Streptococcus mutans</i>	0.13–0.2	[21]
	<i>Bacillus</i> spp.	1–28	[22,24]
Gram negative	<i>Enterococcus</i> spp.	0.02–287	[10,12,14,15,19,22,24,39,43,45,47–49]
	<i>Acinetobacter</i> spp.	0.04–90	[12,14,15,22,24,29,38–43]
	<i>Burkholderia cepacia</i>	0.13–8	[12,44]
	<i>Citrobacter freundii</i>	0.06–0.11	[45]
	<i>Escherichia coli</i>	<1 min to 56	[8,10,12–15,20–24,43,45,46]
	<i>Klebsiella pneumoniae</i>	0.57–600	[15,43,45,50,51]
	<i>Proteus mirabilis</i>	0.16–0.16	[43]
	<i>Pseudomonas</i> spp.	0.08–7	[8,10,12,15,18,19,22,24,29,43,44,47,52,53]
	<i>Salmonella</i> spp.	0.29–5	[12]
	<i>Serratia</i> spp.	0.29–20	[12,14,15,22,43]
	<i>Stenotrophomonas maltophilia</i>	0.29–1	[12]
	<i>Haemophilus influenzae</i>	1–1	[19]
	Fungi	<i>Candida auris</i>	14–14
<i>Candida</i> spp.		0.13–28	[20–22,36,54,55]
Virus	Animal virus	0.5–7	[56,57]
	Coronavirus	0.04–20	[58–60]
	Cytomegalovirus	<1 min to 0.01	[61]
	Human virus	<1 min to 12	[57,62–66]
	SARS-CoV	1–2	[67]

Human virus – hepatitis A virus, herpes simplex, human immunodeficiency virus, influenza, parainfluenza, respiratory syncytial virus. Animal virus – pseudorabies, bovine viral diarrhoea virus, feline calicivirus, canine parvovirus.

Not All Organisms Are Created Equal

L. Porter, O. Sultan, B.G. Mitchell, A. Jenney, M. Kiernan, D.J. Brewster, P.L. Russo, How long do nosocomial pathogens persist on inanimate surfaces? A scoping review, *Journal of Hospital Infection*, Volume 147, 2024, 25-31,

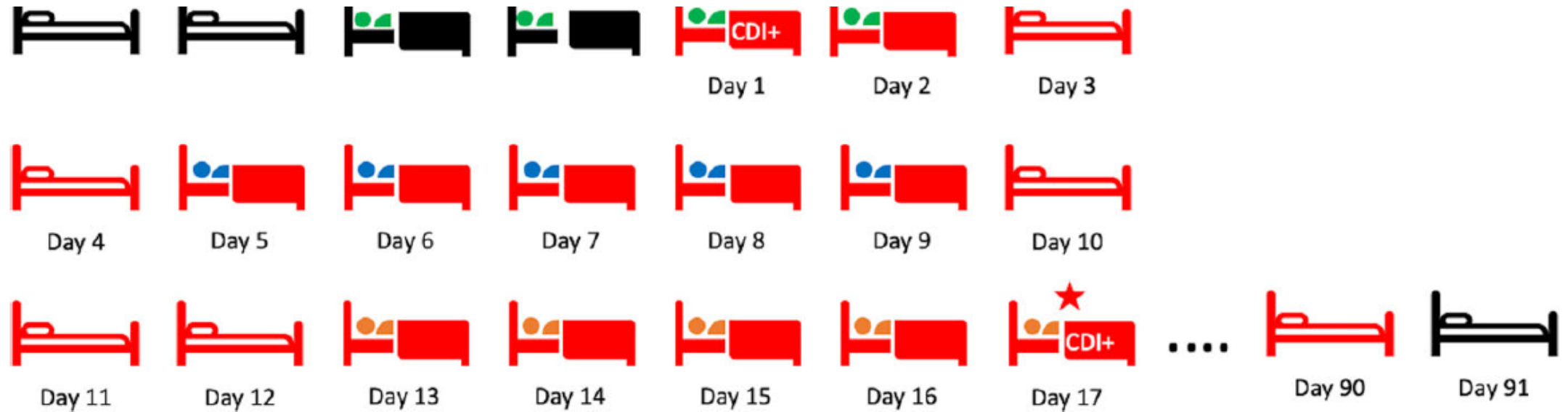


Figure 1. Exposure to a *Clostridioides difficile* “contaminated” bed. Beds are considered contaminated (red) starting with the positive *C. difficile* test of an occupant (green occupant). The bed remains contaminated for 90 days and “resets” every time a new patient with *C. difficile* is identified in that bed. Subsequent occupants (blue and orange) are considered to have an associated hospital-onset *C. difficile* infection (HO-CDI) if they develop their infection ≥ 3 days after being admitted and while residing in the contaminated bed or within 7 days of leaving the contaminated bed (orange occupant with star).

C. difficile Outbreak

Witt LS, Howard-Anderson J, Prakash-Asrani R, Overton E, Jacob JT. The role of the hospital bed in hospital-onset *Clostridioides difficile*: A retrospective study with mediation analysis. *Infection Control & Hospital Epidemiology*. 2024;45(5):599-603

How Do We:

Identify

Identify a problem



Understand

Understand the problem

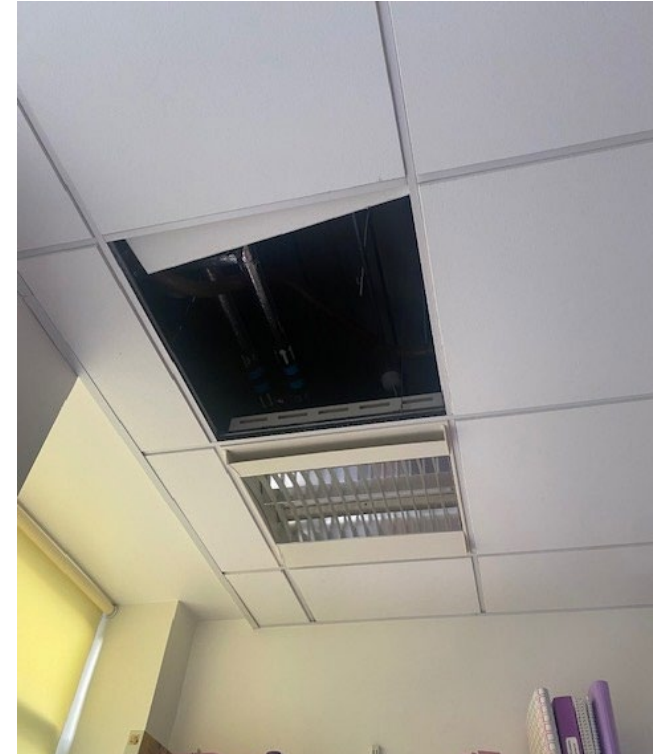


Solve

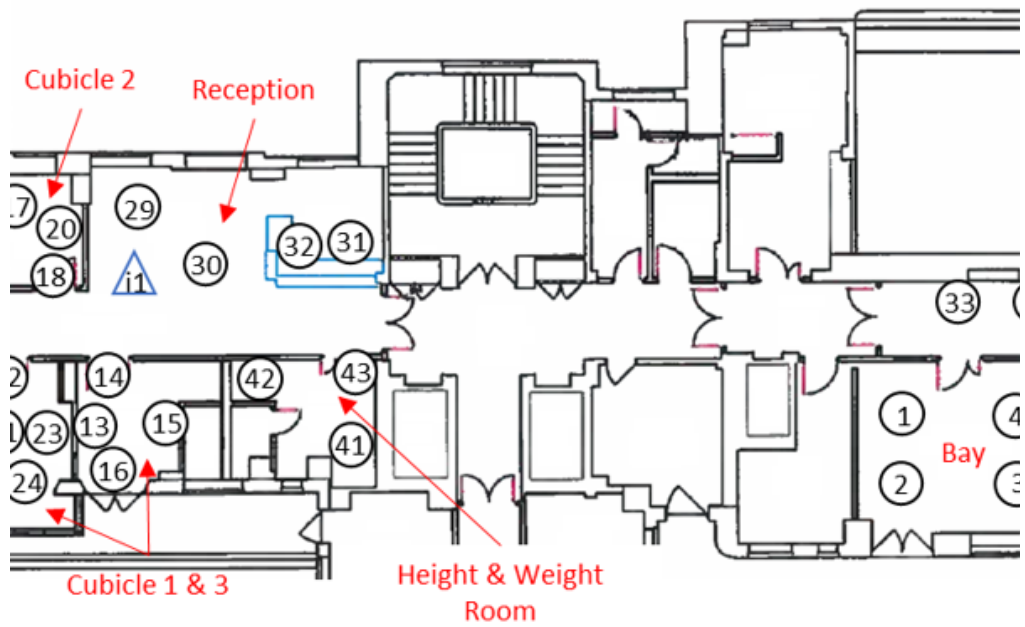
Solve the problem



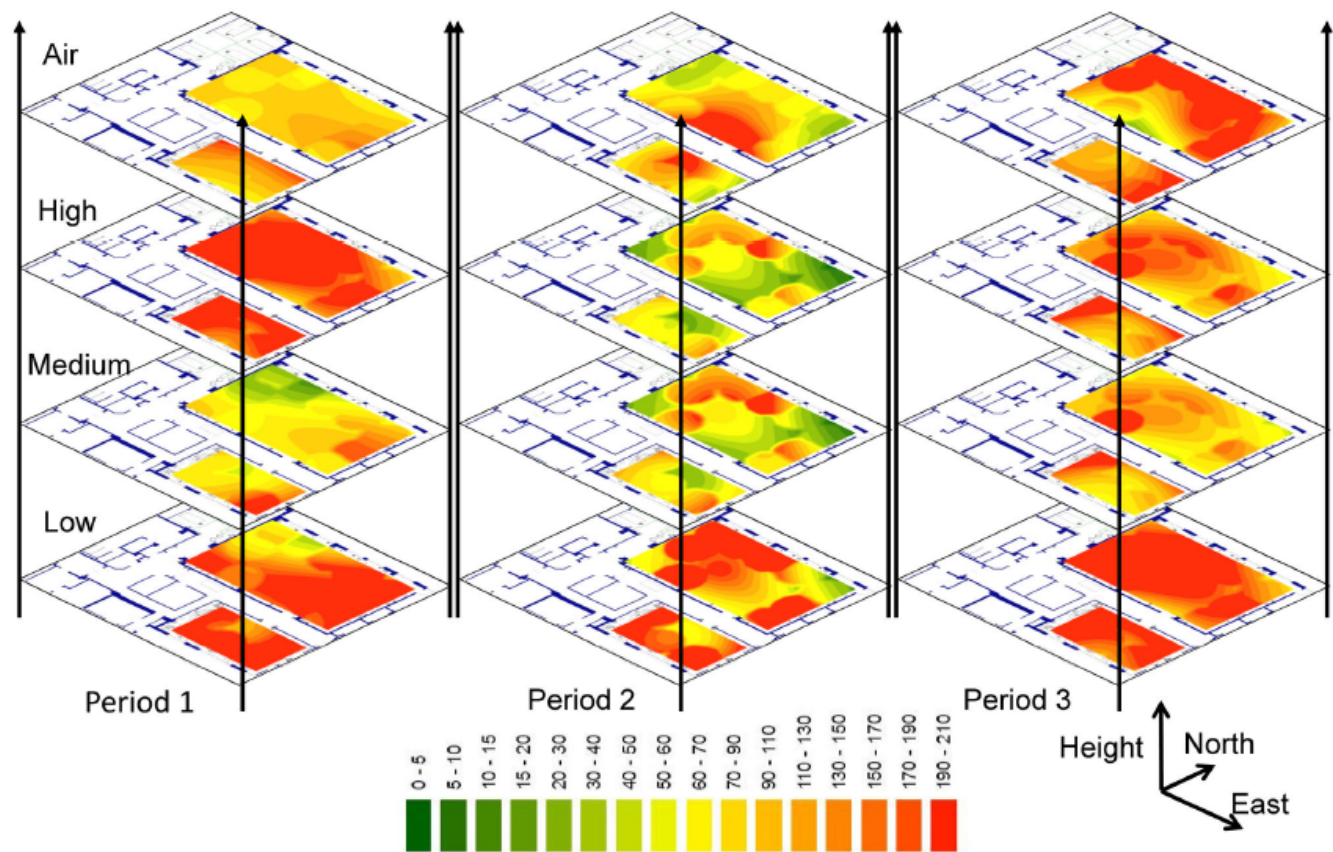
Types of Exposure



Seeing is Believing



Contamination Events are Often Invisible



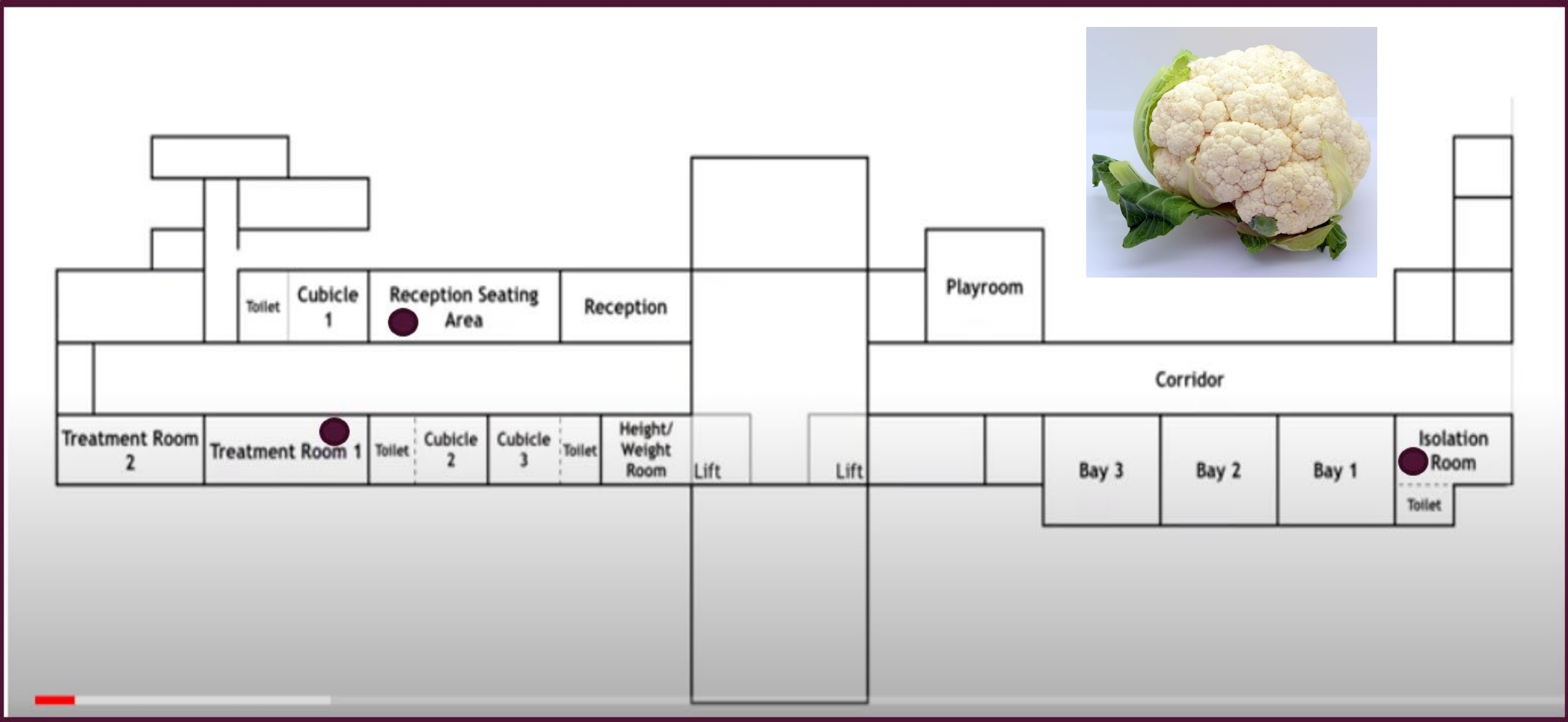
Distribution Isn't Equal

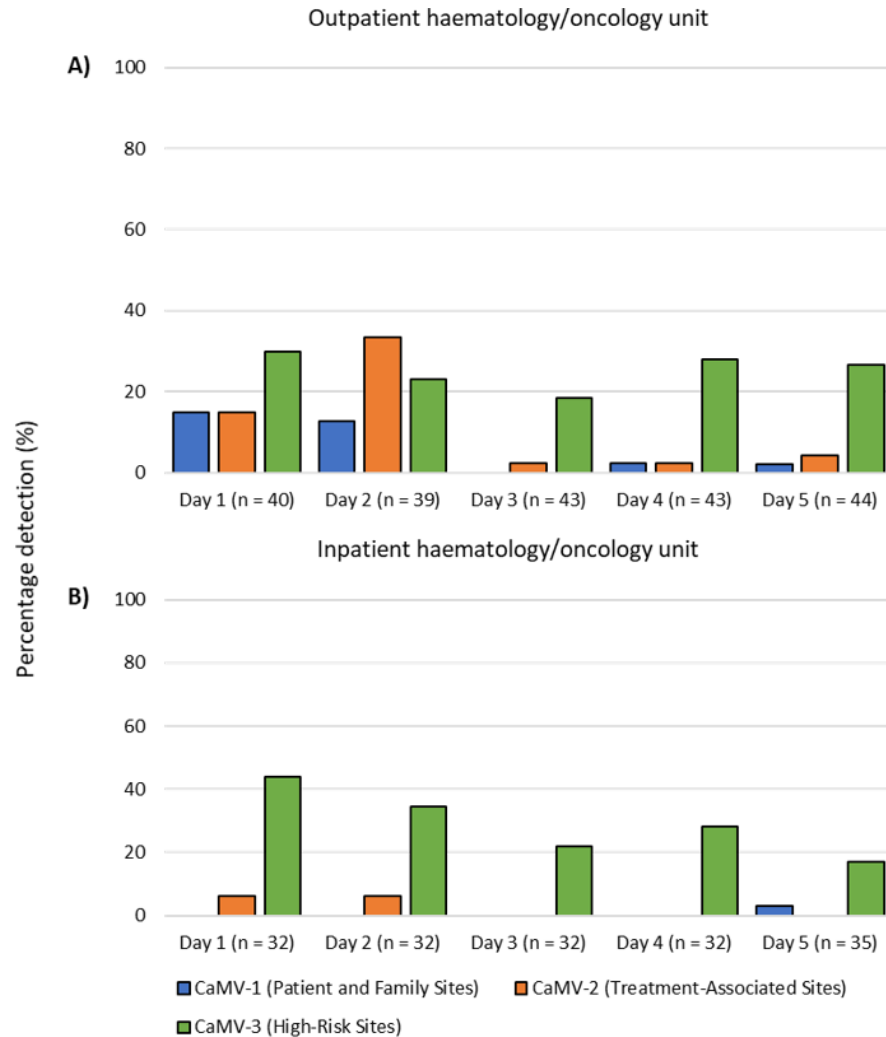
Gaudart J, Cloutman-Green E, Guillas S, D'Arcy N, Hartley JC, Gant V, Klein N. Healthcare environments and spatial variability of healthcare associated infection risk: cross-sectional surveys. PLoS One. 2013 Sep 19;8(9):e76249

Figure 2. Estimation of the counts of micro-organisms. Results were adjusted on bedside, bed occupancy, height level (for surface analysis), Ward and location. Total Viable Count (TVC) estimations for the three cross-sectional surveys at the different height levels including air sampling are presented at each location. The coloured scale showed the values of TVC.

doi: 10.1371/journal.pone.0076249.g002

Routes of Spread VIA Equipment and Other Surfaces





The Environment is a Dynamic Space

DATA FROM SAM WATKIN
 – MANUSCRIPT IN PREPARATION

Tools to Help

What Is Your Question?



SOURCE
IDENTIFICATION



RISK
ASSESSMENT



MAPPING



VALIDATION



TREND
ANALYSIS



SURVEILLANCE

Does the Triumvirate Work?

Person

Place

Time



Identifying the Problem

Surveillance

- Clinical
- Environmental

Risk assessment

Alerts

- Routes of transmission

- Patient loads

- Environmental persistence

- Infectious dose

- Colonised/infectious state

- Patient susceptibility

- Timing of infection (community vs hospital acquired)

- Endogenous vs exogenous

- Surveillance

- Clinical (active vs symptom lead)
- Environmental

Risk Assessment

BS 8580-2:2022



BSI Standards Publication

Water quality

Part 2: Risk assessments for *Pseudomonas aeruginosa* and other waterborne pathogens — Code of practice



BS 8580-1:2019

Water Quality. Risk assessments for Legionella control

The British Standard on conducting Legionella risk assessments has been updated in line with changes to the HSE's Code of Practice.

BS 8580-1:2019 Water quality. Risk assessments for Legionella control. Code of practice applies to risk assessments undertaken on premises, plant and systems and where control measures may have been implemented.

This revision now aligns the standard with HSE ACoP L8 and its associated guidance documents.

Legionella risk assessment is a legal requirement, making this standard invaluable to anyone responsible for the safe management of water systems, especially within hospitals, the wider healthcare industry, leisure centres and schools.

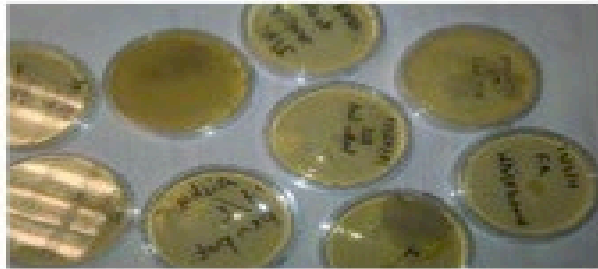
Risk Assessment Guidance



Nothing Beats a Walk Around

Monitoring Microorganisms

Contact Plates

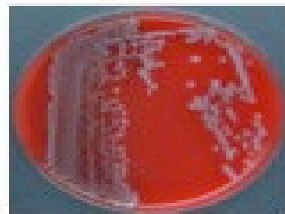


Non-selective
Selective

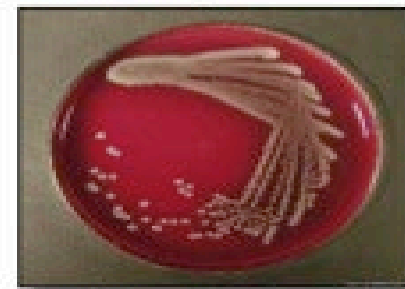
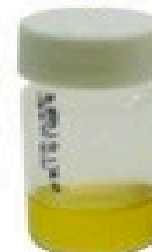


Swabs

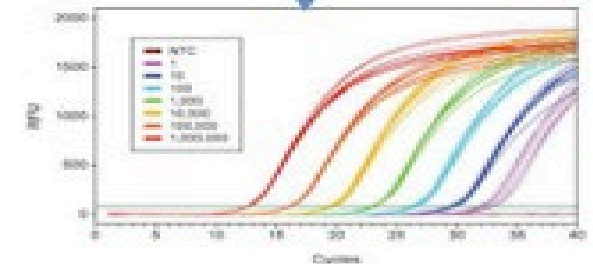
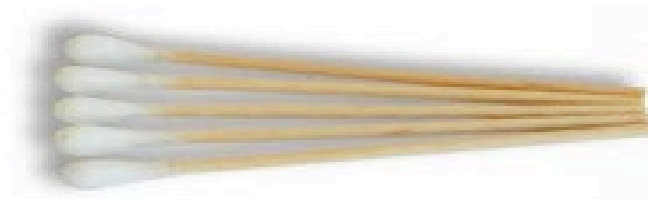
Direct Culture



Enrichment



Molecular



Dip slides



Enzyme
based
tests

Interpretation Criteria



Colony Forming Units:
 $<2.5 \text{ CFU/cm}^2$
 $<5 \text{ CFU/cm}^2$
 10 CFU/m^3



Pathogen detection:
 present/absent



Organism specific:
Pseudomonas aeruginosa/*Legionella pneumophila*



Trend analysis



Custom

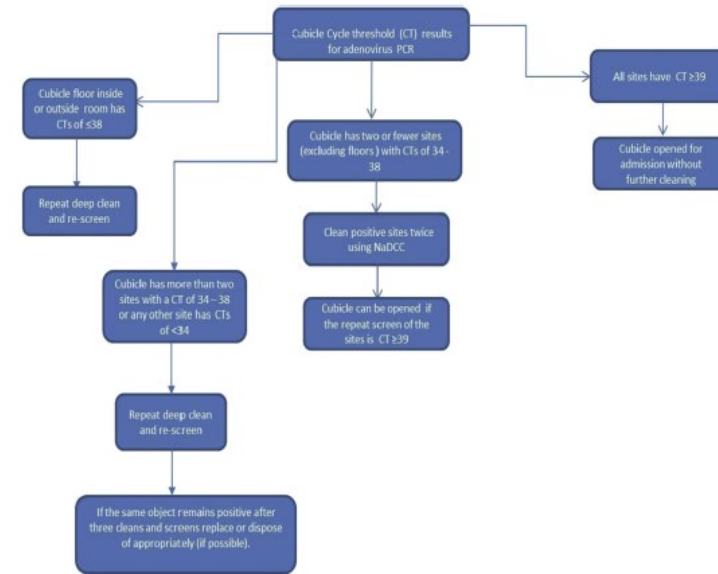


Fig 1. Routine monitoring algorithm for interpreting and using adenovirus polymerase chain reaction (PCR) results in relation to environmental screening. CT, cycle threshold; NaDCC, 1,000 ppm chlorine.

Cloutman-Green E, Canales M, Pankhurst L, et al. Development and implementation of a cleaning standard algorithm to monitor the efficiency of terminal cleaning in removing adenovirus within a pediatric hematopoietic stem cell transplantation unit. American journal of infection control. 2015 Sep 1;43(9):997-9.



Review

How to carry out microbiological sampling of healthcare environment surfaces? A review of current evidence

S. Rawlinson^a, L. Ciric^a, E. Cloutman-Green^{a,b,*}

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SUMMARY

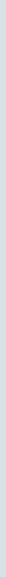
There is increasing evidence that the hospital surface environment contributes to the spread of pathogens. However, evidence on how best to sample these surfaces is inconsistent and there is no guidance or legislation in place on how to do this. The aim of this review was to assess current literature on surface sampling methodologies, including the devices used, processing methods, and the environmental and biological factors that might influence results. Studies published prior to March 2019 were selected using relevant keywords from ScienceDirect, Web of Science, and PubMed. Abstracts were reviewed and all data-based studies in peer-reviewed journals in the English language were included. Microbiological air and water sampling in the hospital environment were not included. Although the numbers of cells or virions recovered from hospital surface environments were generally low, the majority of surfaces sampled were microbiologically contaminated. Of the organisms detected, multidrug-resistant organisms and clinically significant pathogens were frequently isolated and could, therefore, present a risk to vulnerable patients. Great variation was found between methods and the available data were incomplete and incomparable. Available literature on sampling methods demonstrated deficits with potential improvements for future research. Many of the studies included in the review were laboratory-based and not undertaken in the real hospital environment where sampling recoveries could be affected by the many variables present in a clinical environment. It was therefore difficult to draw overall conclusions; however, some recommendations for the design of routine protocols for surface sampling of healthcare environments can be made.

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Planning Ahead

Rawlinson S, Ciric L, Cloutman-Green E. How to carry out microbiological sampling of healthcare environment surfaces? A review of current evidence. *J Hosp Infect.* 2019 Jul 29



Interventions

How Can We Get This Right?



Patient/visitor interactions



Environmental control actions



Engineering actions



Staff interactions



ASKING THE RIGHT
QUESTIONS



HAVING THE RIGHT
PEOPLE IN THE ROOM



CLARIFYING THE
KNOWN RISKS



IDENTIFYING THE
UNKNOWN RISKS

Hierarchy of Controls

Most effective



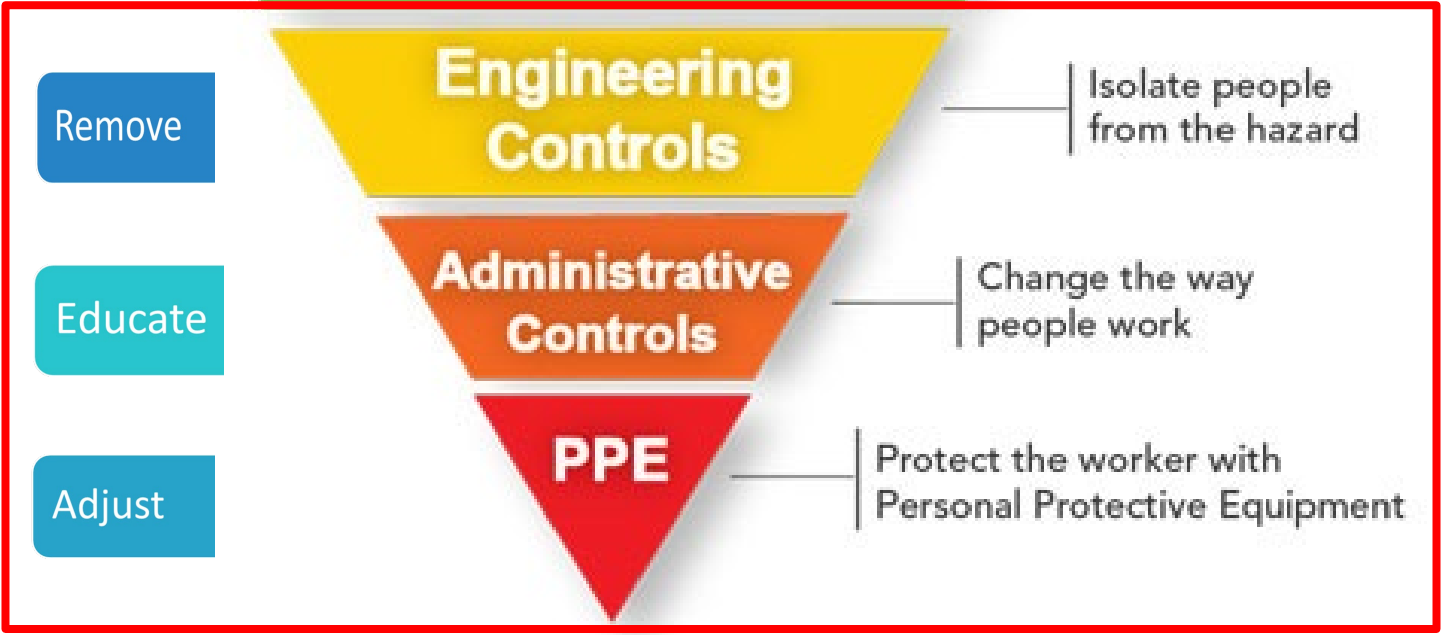
Least effective



Physically remove the hazard



Replace the hazard



Isolate people from the hazard



Change the way people work

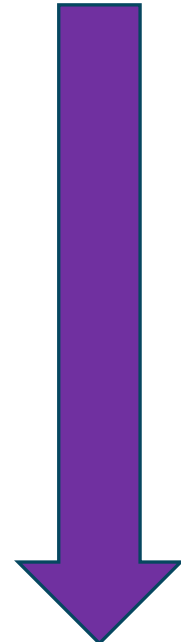


Protect the worker with Personal Protective Equipment

Remove

Educate

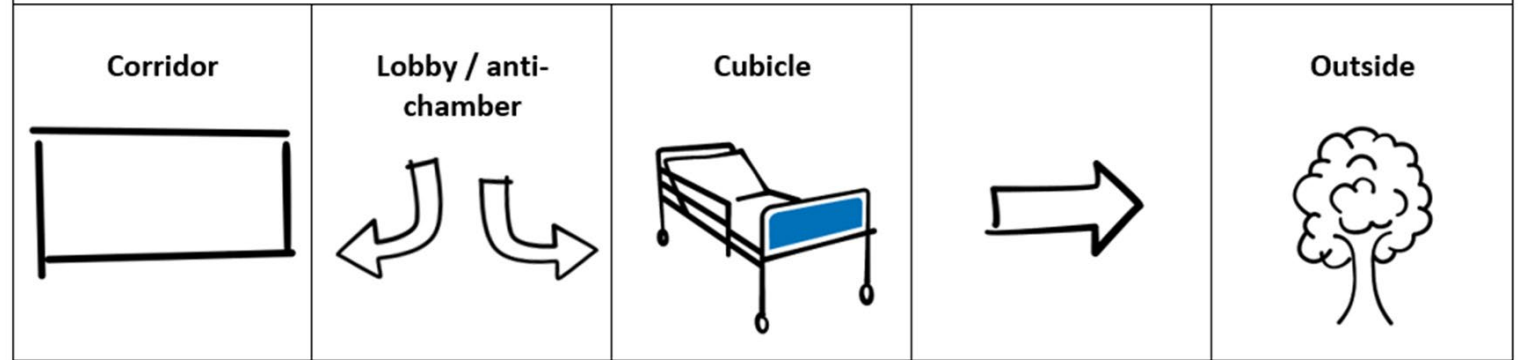
Adjust





Room Type: Positive pressure ventilated lobby (PPVL)

Full protection if both doors are closed. The air is replaced at a faster rate of 10 air changes per. These rooms are used for patients that are both infectious and also susceptible to infection. These rooms are also used for high-risk infections such as measles and TB.



Design Interventions

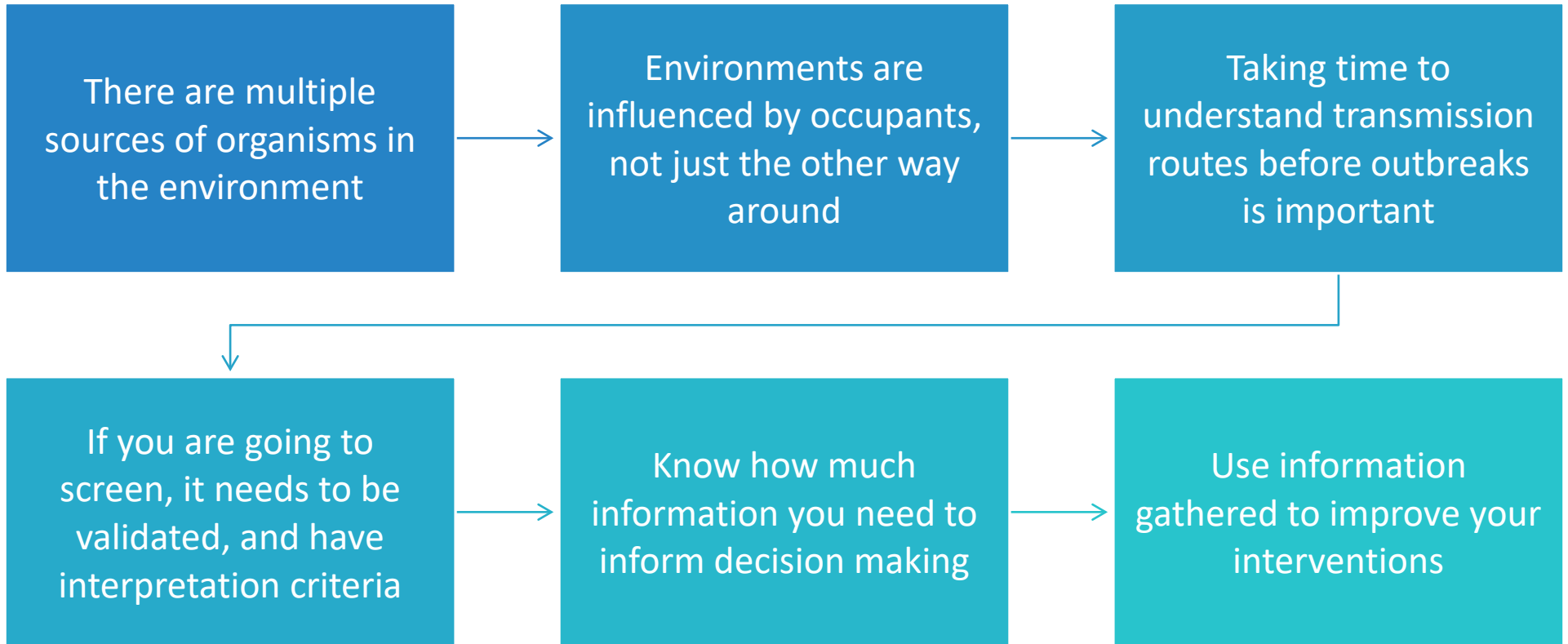
REMOVAL AND BEHAVIOURAL INTERVENTIONS

AIRFLOWS			
Grille Reference	Design Flowrate (m³/s)	Measured Flowrate (m³/s)	Calculated Air Change Rate/ Hour
Supply Grille 1	250	271	26.9
Supply Grille 2	250	298	
Supply Grille 3	250	302	
Supply Grille 4	250	306	
Totals	1000	1177	118%
Grille Reference	Design Flowrate (m³/s)	Measured Flowrate (m³/s)	Calculated Air Change Rate/ Hour
Supply Grille 5	330	354	30.3
Totals	330	354	107%
Grille Reference	Design Flowrate (m³/s)	Measured Flowrate (m³/s)	Calculated Air Change Rate/ Hour
Supply Grille 6	200	210	15.8
Totals	200	210	105%
Extract Grille 1	200	205	15.4
Totals	200	205	103%
Grille Reference	Design Flowrate (m³/s)	Measured Flowrate (m³/s)	Calculated Air Change Rate/ Hour
Extract Grille 2	410	438	55.7
Totals	410	438	107%
DIFFERENTIAL PRESSURES			
Direction of Airflow	Room Reference	Design DP (pa)	Measured DP (pa)
↕	Clean Corridor	15	16
	Anaesthetic 8	10	17
	Dirty Utility 8	30	44
	Theatre 8	10	23
	Clean Corridor	35	56
↕	Clean Corridor	15	18
	Dirty Utility 8	5	6
ROOM CONDITIONS			
Temperature (°C) (18°C - 24°C)	Humidity (% RH) (50% to 70% RH)	Noise Level (dBA)	Avg Wound Site (0.20m x 0.30m)
19.2	52.5	51.0	0.10
19.2	53.0	51.0	n/a
19.4	52.8	51.0	n/a
ROOM VOLUMES			
Length (m)	Width (m)	Height (m)	Room Volume (m³)
			157.30
			42.00
			48.00
4.47	3.64	2.40	28.32

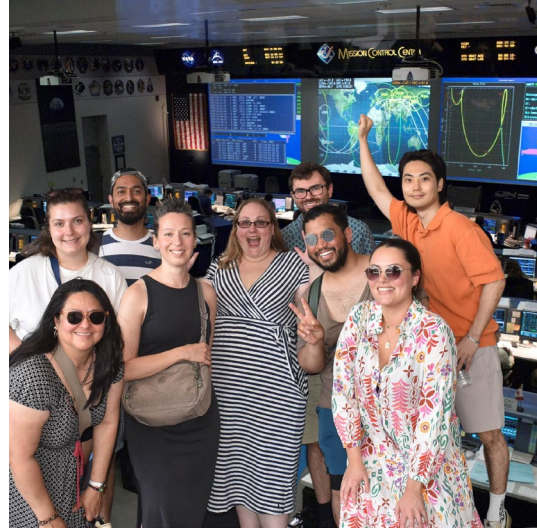




Tales of the
Unexpected



Conclusions



It Takes a Village

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