Welcome to the webinar

Surface to patient:

Evidence-based insights on the spread of pathogens and AMR

gama healthcare | ACIPC Australasian College for Infection Prevention and Control

ROLE OF HOSPITAL ENVIRONMENTAL SUFACES IN THE TRANSMISSION OF PATHOGENS AND STRATEGIES FOR REDUCING HAIs

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Disclosures: Consultancy; Pfizer, GSK, Merck, PDI, BD, Germitec, GAMA
All devices/methods discussed consistent with FDA and EPA regulations

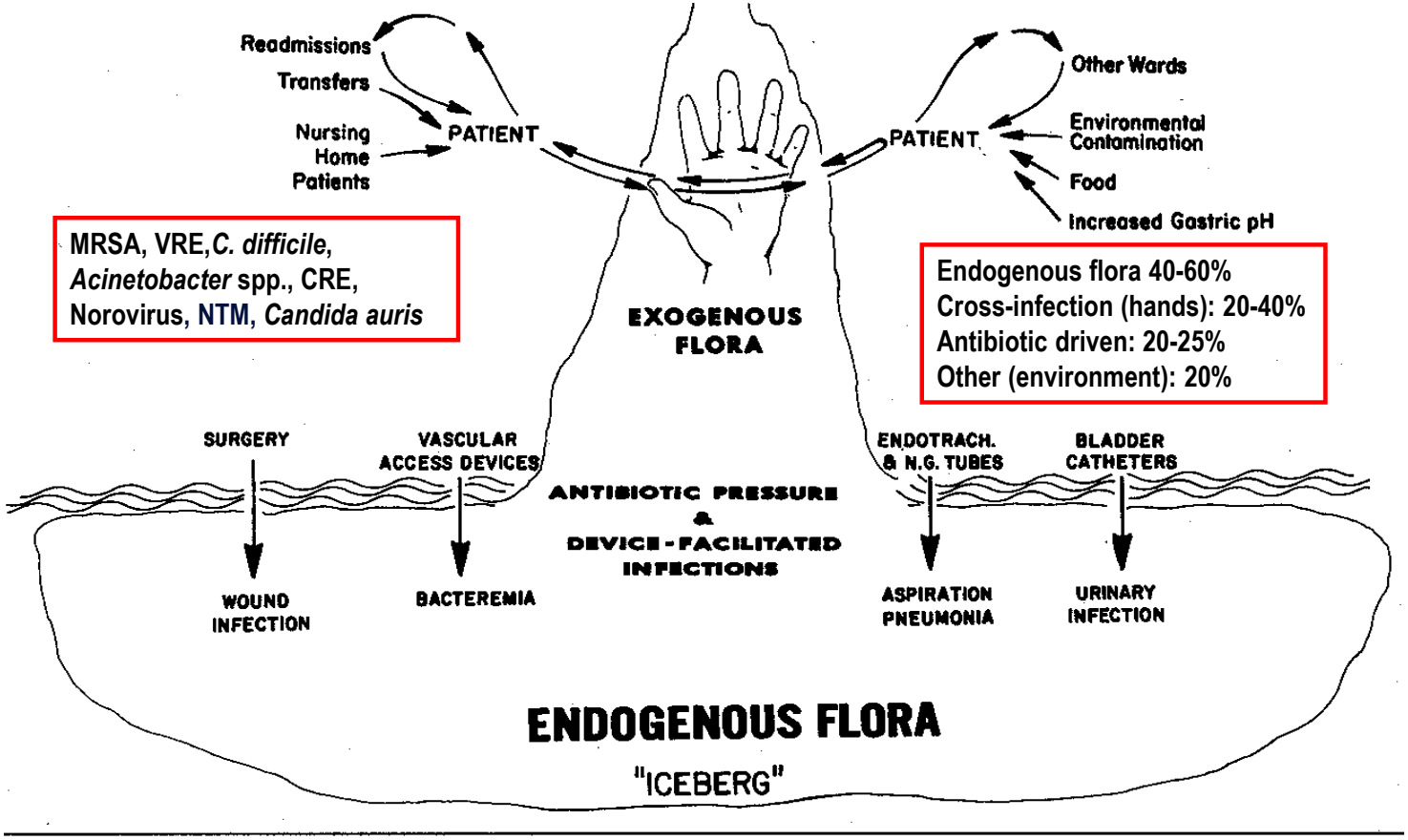
LECTURE OUTLINE

- Conceptual models of transmission pathways and interventions to reduce HAIs
- Summary of evidence that the contaminated surface environmental of hospitals leads to healthcare-associated infections (also demonstrated for long term care facilities)
- Survival of pathogens on environmental surfaces
- Risk of acquiring pathogens (colonization or HAIs) from admission to a hospital room in which the previous occupant has a multidrug-resistant pathogen
- Relationship between environmental burden of microbes and HAIs
- Quantitating bacterial transfer events between a patient and their environment, and the environment and a patient
- Recommendations for patient room cleaning/disinfection
- Demonstration that improved cleaning/disinfection leads to reduced HAIs

LECTURE GOALS

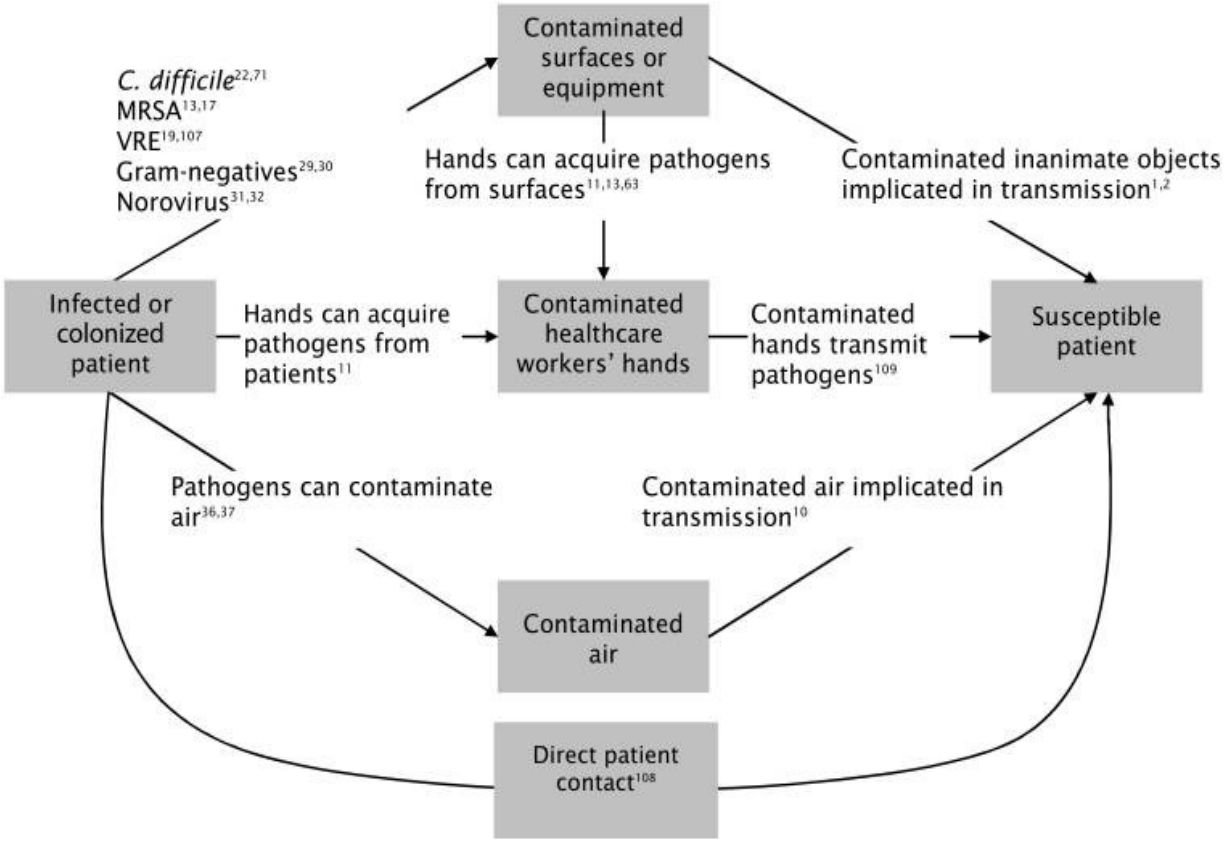
- Understand the role of contaminated surfaces in pathogen transmission and HAI risk within hospitals and long-term care facilities
- Explore the risk of acquiring MDRO from colonized patients' rooms
- Examine the relationship between environmental microbial burden and HAI rates
- Learn methods to quantify bacterial transfer events between patients and their environment
- Gain evidence-based recommendations for patient room cleaning and disinfection protocols to reduce HAIs
- Learn about disinfectants and antiseptics: tolerance, resistance and potential impact on antibiotic resistance

SOURCE OF HAI PATHOGENS



Weinstein RA. Am J Med 1991;91(suppl 3B

TRANSMISSION MECHANISMS INVOLVING SURFACE ENVIRONMENT



Otter JA, et al. Infect Control Hosp Epidemiol 2011;32:687-699

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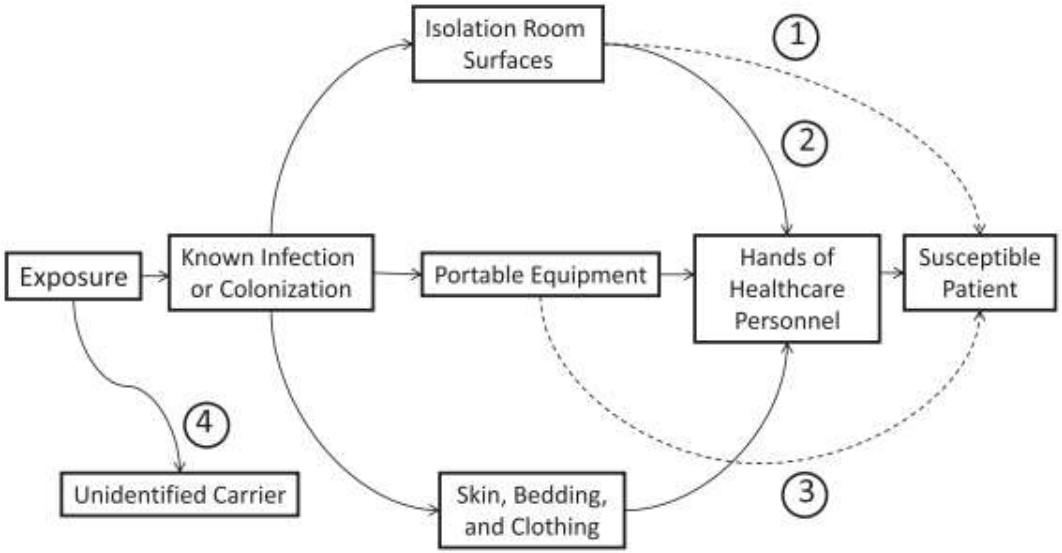
TRANSMISSION MECHANISMS INVOLVING SURFACE ENVIRONMENT



Donskey CJ.
AJIC 2013:41:S12-S19

Fig 1. Overview of common routes of transmission of health care-associated pathogens and potential environmental disinfection strategies (adapted from Donskey[12]). Patients colonized or infected with health care-associated pathogens shed organisms onto their skin, clothing, and nearby environmental surfaces. Susceptible patients may acquire pathogens through direct contact with surfaces or equipment or via the hands of health care personnel. Four sources of transmission and potential environmental disinfection strategies to interrupt transmission are shown: (1) contamination of surfaces after terminal cleaning of isolation rooms resulting in risk of acquisition by patients subsequently admitted to the same room (intervention: improve terminal room cleaning and disinfection); (2) contamination of surfaces in isolation rooms resulting in risk for contamination of health care personnel hands (intervention: daily disinfection of high-touch surfaces); (3) contamination of portable equipment (intervention: disinfection of portable equipment between patients or use of disposable equipment in isolation rooms); and (4) contamination of surfaces in rooms of unidentified carriers of health care-associated pathogens (intervention: improve cleaning and disinfection of all rooms on high-risk wards or throughout a facility).

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ENVIRONMENTAL CONTAMINATION LEADS TO HAIs

- The surface environment in rooms of colonized or infected patients is frequently contaminated with the pathogen **(~25%)**
- Pathogens are capable of surviving on hospital room surfaces and medical equipment for a prolonged period of time **(i.e., days to weeks; months for *C. difficile*)**
- Contact with hospital room surfaces or medical equipment by HCP frequently leads to contamination of hands and/or gloves (>50%)
- The frequency with which room surfaces are contaminated correlates with the frequency of hand and/or glove contamination of healthcare personnel
- Clonal outbreaks of pathogens contaminating the room surfaces of colonized or infected patient are demonstrated to be due to person-to-person transmission or shared medical equipment
- The patient admitted to a room previously occupied by a patient colonized or infected with a pathogen (e.g., MRSA, VRE, *C. difficile*, *Acinetobacter*) has an increased likelihood of developing colonization or infection with that pathogen
- Improved terminal cleaning of rooms leads to a decreased rate of infections
- Improved terminal disinfection (e.g., ultraviolet light or vaporized hydrogen peroxide) leads to a decreased rate of infection in patients subsequently admitted to the room where the prior occupant was colonized or infected

Weber, Kanamori, Rutala.
Curr Op Infect Dis 2016:29:424-431

How Long Do Nosocomial Pathogens Persist on Inanimate Surfaces? A Systematic Review

Table 1: Persistence of clinically relevant bacteria on dry inanimate surfaces.

Type of bacterium	Duration of persistence (range)	Reference(s)
Acinetobacter spp.	3 days to 5 months	[18, 25, 28, 29, 87, 88]
Bordetella pertussis	3 – 5 days	[89, 90]
Campylobacter jejuni	up to 6 days	[91]
Clostridium difficile (spores)	5 months	[92–94]
Chlamydia pneumoniae, C. trachomatis	≤ 30 hours	[14, 95]
Chlamydia psittaci	15 days	[90]
Corynebacterium diphtheriae	7 days – 6 months	[90, 96]
Corynebacterium pseudotuberculosis	1–8 days	[21]
Escherichia coli	1.5 hours – 16 months	[12, 16, 17, 22, 28, 52, 90, 97–99]
Enterococcus spp. including VRE and VSE	5 days – 4 months	[9, 26, 28, 100, 101]
Haemophilus influenzae	12 days	[90]
Helicobacter pylori	≤ 90 minutes	[23]
Klebsiella spp.	2 hours to > 30 months	[12, 16, 28, 52, 90]
Listeria spp.	1 day – months	[15, 90, 102]
Mycobacterium bovis	> 2 months	[13, 90]
Mycobacterium tuberculosis	1 day – 4 months	[30, 90]
Neisseria gonorrhoeae	1 – 3 days	[24, 27, 90]
Proteus vulgaris	1 – 2 days	[90]
Pseudomonas aeruginosa	6 hours – 16 months; on dry floor: 5 weeks	[12, 16, 28, 52, 99, 103, 104]
Salmonella typhi	6 hours – 4 weeks	[90]
Salmonella typhimurium	10 days – 4.2 years	[15, 90, 105]
Salmonella spp.	1 day	[52]
Serratia marcescens	3 days – 2 months; on dry floor: 5 weeks	[12, 90]
Shigella spp.	2 days – 5 months	[90, 106, 107]
Staphylococcus aureus, including MRSA	7 days – 7 months	[9, 10, 16, 52, 99, 108]
Streptococcus pneumoniae	1 – 20 days	[90]
Streptococcus pyogenes	3 days – 6.5 months	[90]
Vibrio cholerae	1 – 7 days	[90, 109]

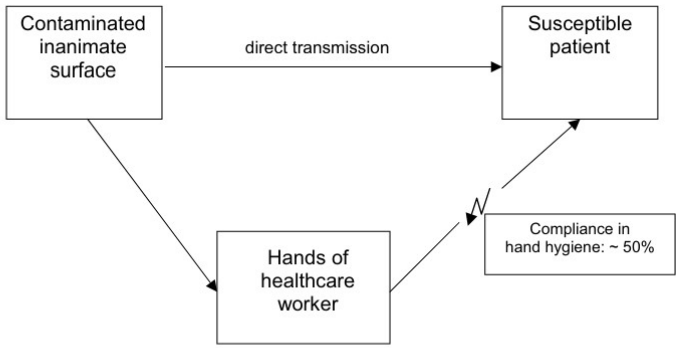

Figure 1
Common modes of transmission from inanimate surfaces to susceptible patients.

Kramer A, et al. BMC Infect Dis 2006;Aug 16

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How Long Do Nosocomial Pathogens Persist On Inanimate Surfaces? A Scoping Review

Range of survival by pathogen

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

Porter L, et al
J Hosp Infect 2024:147:25-31

Virus Mpox Days to months

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How Long Do Nosocomial Pathogens Persist On Inanimate Surfaces? A Scoping Review

Table III
Range of survival time by pathogen and surface

Surface	Pathogens of interest [c]	Range of survival in days (across studies)	Studies (references)
Non-porous[a]	*Acinetobacter* spp.	0.29–60	[12,14,15,22,24,29,41]
	Clostridioides difficile	0.13–140	[33,35,36]
	Escherichia coli	0.25–11	[8,12,14,15,20,22,24]
	Klebsiella pneumoniae	2–2	[15]
	Pseudomonas spp.	0.21–7	[8,12,15,22,24,29,47,52]
	Staphylococcus aureus	0.04–60	[8,14,17,20,22,24,26,27,29,31,32]
Porous[b]	*Acinetobacter* spp.	1.5–90	[12,40,42,43]
	C. difficile	0.25–3	[35]
	E. coli	0.29–25	[12,13,22,43]
	K. pneumoniae	4–600	[43,50]
	Pseudomonas spp.	0.08–7	[12,18,43,47]
	S. aureus	1–168	[7,12,13,16–18,22,30–32]

[a] Examples of non-porous samples identified included: glass, vinyl, stainless steel, plastic, metal, ceramic, copper, Formica, enamel.
[b] Examples of porous surfaces included: paper, linen, wood, sponge, cotton, polyester, wool, fabric.
[c] Selected pathogens chosen, of important relevance to infection prevention. Full details of all papers and results are provided in Supplementary data.

Porter L, et al
J Hosp Infect 2024:147:25-31

In studies where the type of surface a pathogen was tested on could be easily identified and classified into a porous or nonporous surface, we identified the reported range of survival times for various pathogens. There are instances where surfaces could not be classified into porous or nonporous and therefore, the data at the pathogen level may appear inconsistent. From the available data, the maximum survival time on porous surfaces was higher for *Acinetobacter* sp., *E. coli*, *K. pneumoniae* and *S. aureus*.

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Risk of organism acquisition from prior room occupants: An updated systematic review

Background: Evidence from a previous systematic review indicates that patients admitted to a room where the previous occupant had a multidrug-resistant bacterial infection resulted in an increased risk of subsequent colonization and infection with the same organism for the next room occupant.

Results: From 5175 identified, 12 papers from 11 studies were included in the review for analysis. From 28,299 patients who were admitted into a room where the prior room occupant had any of the organisms of interest, 651 (2.3%) were shown to acquire the same species of organism. In contrast, 981,865 patients were admitted to a room where the prior occupant did not have an organism of interest, 3818 (0.39%) acquired an organism(s). The pooled acquisition odds ratio (OR) for all the organisms across all studies was 2.45 (95% CI: 1.53, 3.93]. There was heterogeneity between the studies (I2 89%, P < 0.001).

Conclusions: The risk of pathogen acquisition appears to remain high.

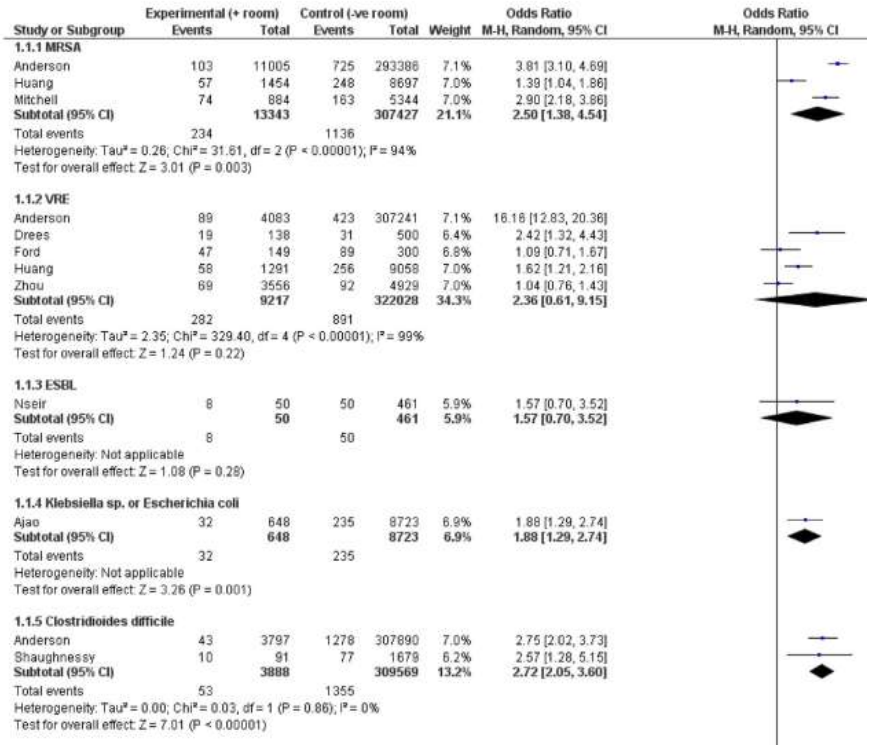
Table 1 Overview of studies.

Study	Publication year	Study duration	Study setting (country)	Study design	Organisms evaluated
Huang et al. [13]	2005	20 months	USA	Cohort	VRE, MRSA
Mitchell et al. [16]	2014	24 months	Australia	Cohort	MRSA
Datta et al. [12]	2011	20 months	USA	Cohort	VRE, MRSA
Ajao et al. [24]	2013	93 months	USA	Cohort	ESBL-producing Gram negative
Drees et al. [20]	2008	14 months	USA	Cohort	VRE
Nseir et al. [14]	2011	12 months	France	Cohort	*A. baumannii*, ESBL-producing Gram negative *P. aeruginosa*
Shaughnessy [25]	2011	16 months	USA	Cohort	*C. difficile*
Zhou [19]	2019	72 months	USA	Cohort	VRE
Anderson [2,3]	2017 & 2018	28 months	USA	RCT	VRE, MRSA, *C. difficile*
Ford [17]	2016	93 months	USA	Cohort	VRE
Fraenkel [15]	2021	72 months	Sweden	Cohort	Norovirus

Note: VRE, vancomycin-resistant enterococci; MRSA, meticillin-resistant *Staphylococcus aureus*; ESBL, extended spectrum b-lactamase; *C. difficile*, *Clostridioides difficile*. Anderson 2017 and 2018 are the same study. Data from both of Anderson's papers were used to provide data to answer the research question.

Mitchell BG, et al. Infection, Disease & Health 2023:28:290-297

Risk of organism acquisition from prior room occupants: An updated systematic review



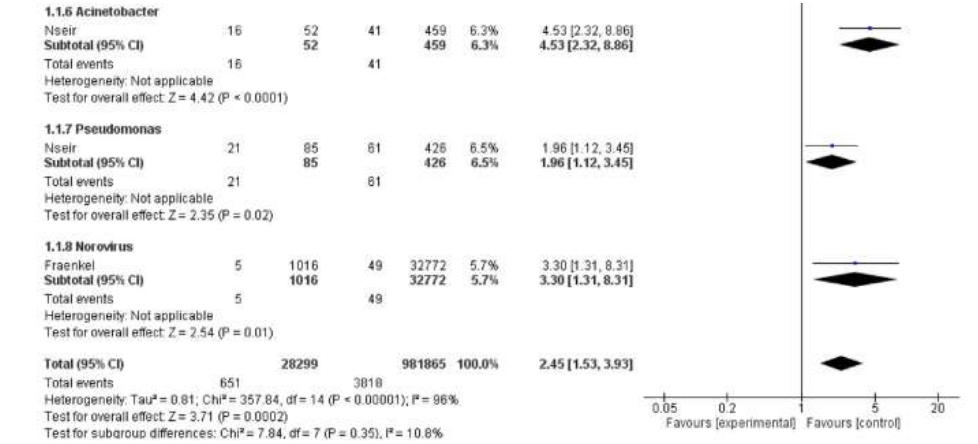


Figure 2 Forest plot for risk of acquisition from prior room occupants by organism, Note: M–H, Mantele Haenszel; VRE, vancomycin-resistant enterococci; MRSA, meticillin-resistant *Staphylococcus aureus*; Ajao et al.'s study involved extended spectrum b-lactamase producing Klebsiella or *Escherichia coli* 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.

Mitchell BG, et al. Infection, Disease & Health 2023:28:290-297

RELATIONSHIP BETWEEN MICROBIAL BURDEN AND HAIs

Table 1. Epidemiologically-important pathogens (EIP) by intervention and contamination in 92 patient rooms during the benefits of enhanced terminal room disinfection study.

Room type	Pathogen	Mean CFU/125 cm² (5 Rodacs) per room by treatment type				P-value		
		Quat (N=21 rooms)	Quat/UV (N=28 rooms)	Bleach (N=23 rooms)	Bleach/UV (N=20 rooms)	Quat vs Quat/UV	Quat vs Bleach	Quat vs Bleach/UV
Patient room only	MDR-*Acinetobacter*	8.76	0.18	0.39	0.25			
	C. difficile	0	0.07	0.04	0			
	MRSA	2.33	0.11	2.13	0.05			
	VRE	8.62	0.07	0.78	0.35			
	EIP[a]	19.71	0.43	3.35	0.65	0.013		
Bathroom only	MDR-*Acinetobacter*	0.19	0	0	0	0.018	0.032	0.045
	C. difficile	3.76	2.79	4.43	3.25			
	MRSA	6.19	0	2.26	0.80	0.044		
	VRE	30.95	0.14	1.65	1.55			
	EIP[a]	41.10	2.93	8.35	5.60	0.015		
Patient/Bathroom[b]	MDR-*Acinetobacter*	8.95	0.18	0.39	0.25	0.017	0.035	
	C. difficile	3.76	2.86	4.48	3.25			
	MRSA	8.52	0.11	4.39	0.85	0.032		
	VRE	39.57	0.21	2.43	1.90	0.034		
	EIP[a]	60.81	3.36	11.70	6.25	0.001		

Table 2. Relationship between microbial reduction of epidemiologically-important pathogens (EIP) and colonization/infection in a patient subsequently admitted to a room of a patient colonized/infected with an EIP by decontamination method.

	Standard Method	Enhanced method		
	Quat	Quat/UV	Bleach	Bleach/UV
EIP (mean CFU per room)[a]	60.8	3.4	11.7	6.3
Reduction (%)		94	81	90
Colonization/Infection (rate)[a]	2.3	1.5	1.9	2.2
Reduction (%)		35	17	4

Rutala WW, …Weber DJ, et al. ICHE 2018;39:1118-1121

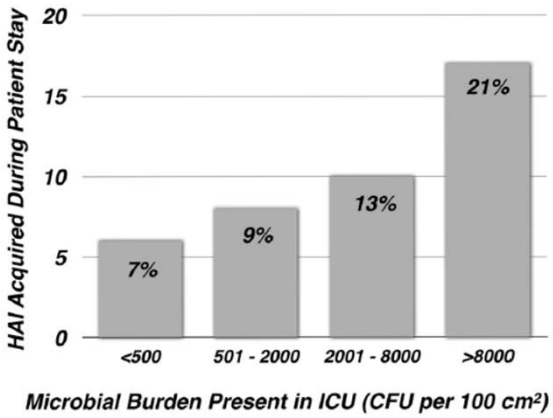


FIGURE 2. Quartile distribution of healthcare-acquired infections (HAIs) stratified by microbial burden measured in the intensive care unit (ICU) room during the patient's stay. There was a significant association between burden and HAI risk ($P = .038$), with 89% of HAIs occurring among patients cared for in a room with a burden of more than 500 colony-forming units (CFUs)/100 cm².

Study on the left demonstrated that reduction of MDROs leads to decreased environmental contamination which leads to decrease patient colonization

Study above demonstrates that HAI frequency rises with increased environment microbial bioburden

Salgado CD, et al. ICHE 2013;34:479-86

Transfer of Pathogens to and from Patients, HCP, and Medical Devices During Care Activity: A Systematic Review and Meta-analysis

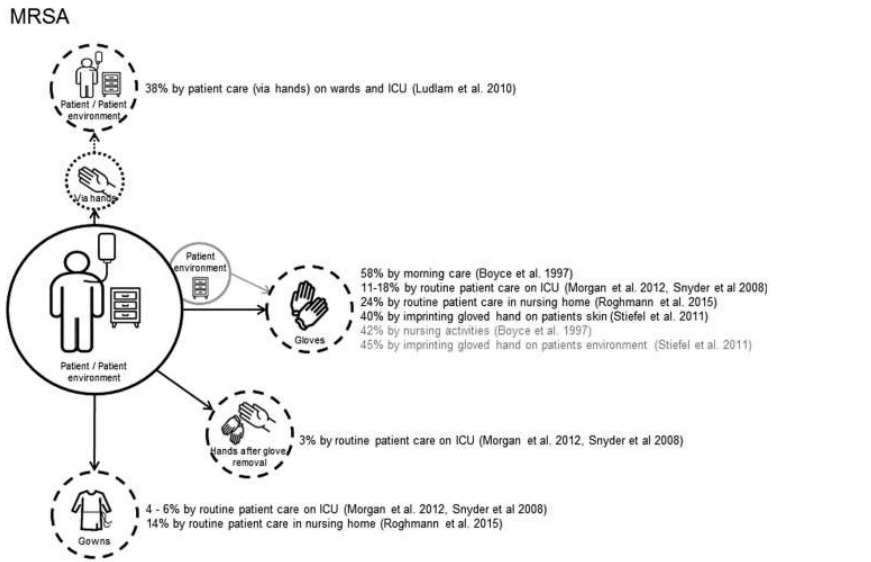


Fig. 3. Transfer frequency of MRSA. Abbreviations: ICU, intensive care unit; MRSA, methicillin-resistant *S. aureus*; black circle, surface of origin, patient, and the patient environment; grey circle, surface of origin, patient environment, or inanimate objects; dotted circle, transfer surface; dashed circle, destination surface. Percentage is the transfer frequency or percentage of destination sites colonized or contaminated with corresponding microorganism.

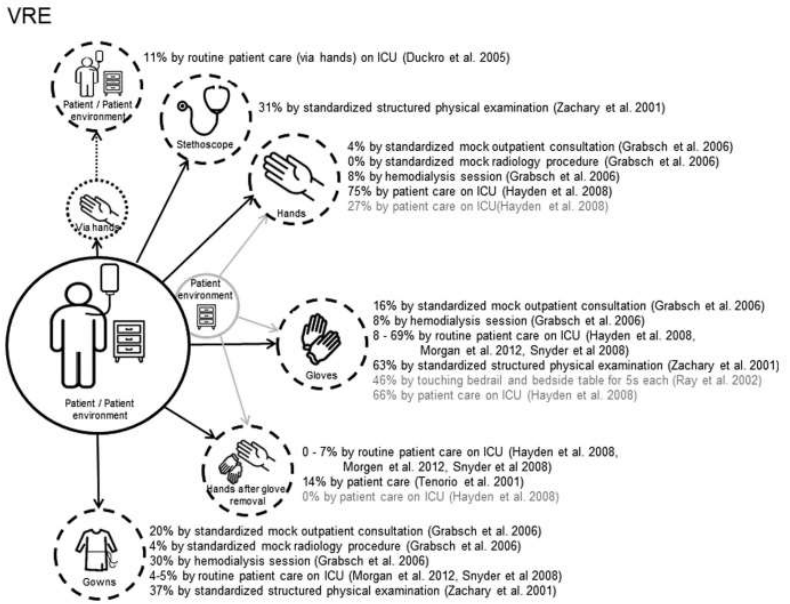


Fig. 2. Transfer frequency of VRE. Abbreviations: ICU, intensive care unit; VRE, vancomycin resistant enterococci; black circle, surface of origin, patient, and the patient environment; grey circle, surface of origin, patient environment, or inanimate objects; dotted circle, transfer surface; dashed circle, destination surface. Percentage is the transfer frequency or percentage of destination sites colonized or contaminated with corresponding microbe.

Wolfensberger A, et al. ICHE 2018;39:1093-1107

A Prospective Study of Transmission of MDROs Between Environmental Sites and Hospitalized Patients

- Goal: Assess MDRO transmission between the environment and patients using standard microbiological and molecular techniques.
- Methods: Prospective cohort study at 2 academic medical centers
- Results: Study enrolled 80 patient–room admissions; 9 of these patients (11.3%) were asymptomatically colonized with MDROs at study entry. Hospital room surfaces were contaminated with MDROs despite terminal disinfection in 44 cases (55%). Microbiological Bacterial Transfer events either to the patient, the environment, or both occurred in 12 patient encounters (18.5%) from the microbiologically evaluable cohort.

Description of 12 Cases of Potential Microbiological Bacterial Transfer Events[a]

Patient	Target MDRO	Terminal Clean Protocol	Patient-Environment	Environment-Patient	Indeterminate	Presence of Molecularly Related Isolates	Presence of Molecularly Discordant MDRO Isolates[b]
A	MRSA	Bleach	X			X	
B	MRSA	Bleach			X	X	X
C	VRE	Quat.	X				X
D	VRE[c]	Bleach + UV		X			
E	VRE[c]	Bleach + UV			X		
F	VRE[c]	Bleach + UV			X		
G	VRE	Bleach			X	X	
H	CDI	Bleach	X			X	X
I	CDI	Bleach		X			X
J	CDI	Quat.		X		X	X
K	CDI	Quat.		X		X	X
L	CDI	Quat. + UV	X				X
	Total	12	4 (33%)	4 (33%)	4 (33%)	6 (50%)	7(58%)

Chen LF, et al. ICHE 2019;40:47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"The patient in the next bed is highly infectious. Thank God for these curtains."

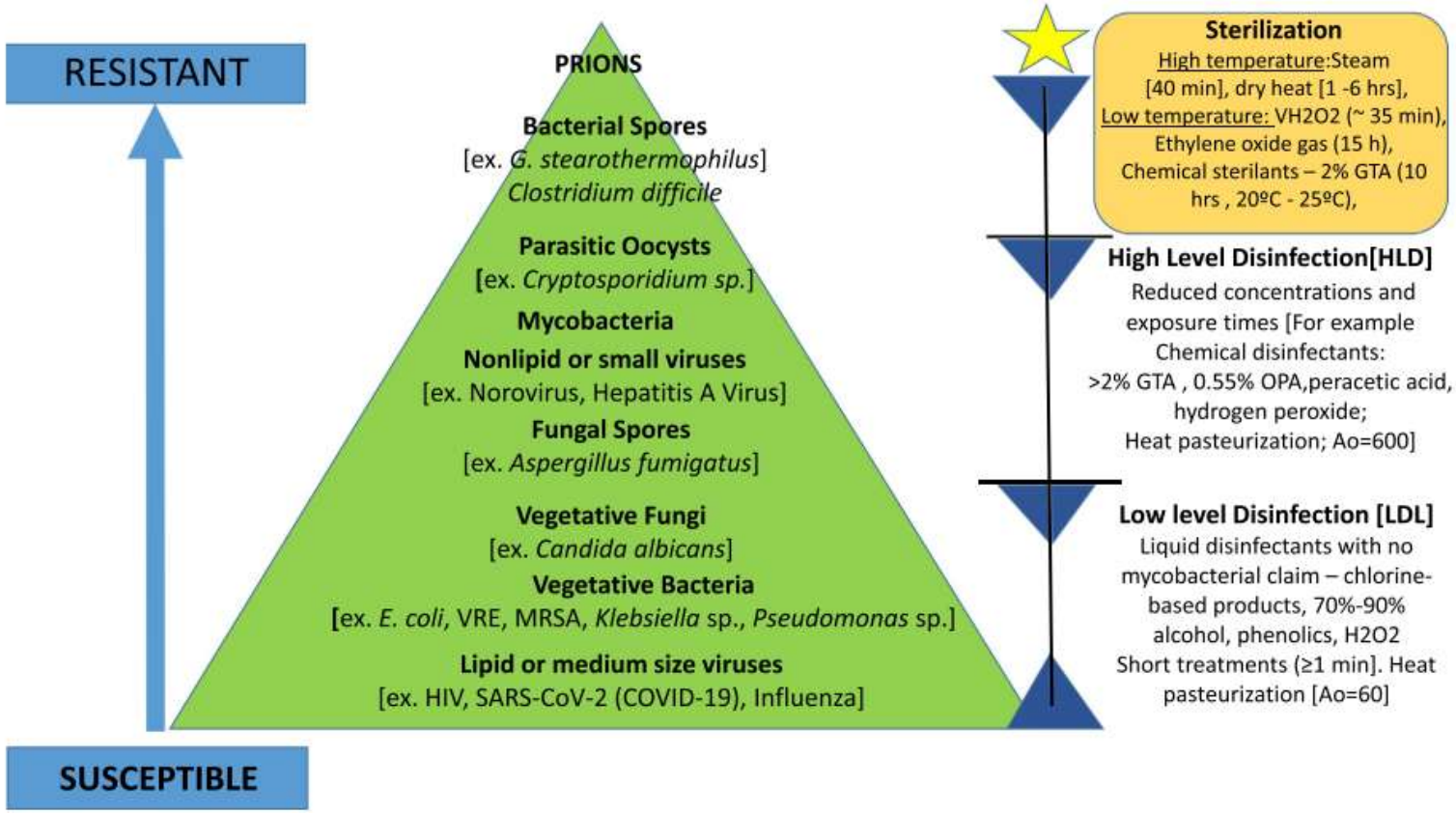

Fig. 1. Pyramid of increasing microbial resistance to disinfectants and sterilants [Noting, this is a guide as the actual levels of resistance depend on the type of disinfection/ sterilization process].

Rowan NJ, et al. Science of Total Environment 2023;878:162976

Fig. 5. Role of medical device cleaning, disinfection and sterilization in breaking the chain of infections.

Impacted By Hospital Design

Goal of hospital design; reduce or eliminate

1. **Microbial reservoirs**
2. **Microbial sources**
3. **Infectious disease transmission routes via patients, HCP and environment**

IMPLEMENTATION OF THE SPAULDING SYSTEM

Process	Level of microbial inactivation	Method	Examples (with processing times)	Health care application (examples)
Sterilization[†]	Destroys all microorganisms, including bacterial spores	High temperature Low temperature Liquid immersion	Steam (~40 min), dry heat (1-6 h, depending on temperature) Ethylene oxide gas (~15 h), HP gas plasma (28-38 min, NX), HP and ozone (46-70 min, VP4), HP vapor (28-55 min, V-PRO maX) Chemical sterilants[‡]: >2% glut (~10 h at 20°C-25°C), 1.12% glut with 1.93% phenol (12 h at 25°C), 7.35% HP with 0.23% PA (3 h at 20°C), 7.5% HP (6 h at 20°C), 1.0% HP with 0.08% PA (8 h at 20°C), ~0.2% PA (12 min at 50°C-56°C)	Heat-tolerant critical (surgical instruments) and semicritical patient care items Heat-sensitive critical and semicritical patient care items Heat-sensitive critical and semicritical patient care items that can be immersed
High-level disinfection	Destroys all microorganisms except some bacterial spores	Heat-automated Liquid immersion	Pasteurization (65°C-77°C, 30 min) Chemical sterilants/HLDs[‡]: >2% glut (20-90 min at 20°C-25°C), >2% glut (5 min at 35°C), 0.55% OPA (12 min at 20°C), 1.12% glut with 1.93% phenol (20 min at 25°C), 7.35% HP with 0.23% PA (15 min at 20°C), 7.5% HP (30 min at 20°C), 1.0% HP with 0.08% PA (25 min at 20°C), 650-675 free chlorine (10 min at 25°C), 2.0% HP (8 min at 20°C), 3.4% glut with 20.1% isopropanol (5 min at 25°C)	Heat-sensitive semicritical items (eg, respiratory therapy equipment) Heat-sensitive semicritical items (eg, GI endoscopes, bronchoscopes, endocavitary probes)
Low-level disinfection	Destroys vegetative bacteria and some fungi and viruses, but not mycobacteria or spores	Liquid contact	EPA-registered hospital disinfectant with no tuberculocidal claim (eg, chlorine-based products, phenolics, improved HP, HP plus PA, quats, quats plus alcohol, or 70%-90% alcohol. Exposure time >1 min)	Noncritical patient care items (eg, blood pressure cuffs) or surfaces (eg, bedside tables) with no visible blood

Rutala WA, Weber DJ. AJIC 2019;47:A3-A9

See later slides for more up-to-date list of sterilants and disinfectants

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HAIs IN NURING HOMES: SUMMARY OF THE PROBLEM

- In the United States, NHs host more than 1.7 million residents, which is more than the total number of beds occupied in all acute care hospitals and centers.
- Up to 15% of nursing home residents may acquire an infection while staying in these facilities (1.8–13.5 infections per 1000 patient-care days). A mix of patient vulnerability and a high number of daily interaction opportunities with healthcare personnel (HCP), other patients, and visitors accounts for a high likelihood of epidemics, as exemplified by the numerous deadly outbreaks in NHs during the currently ongoing COVID-19 pandemic.
- Infections are among the top 5 causes of death in NHs and rank even higher among preventable causes.
- It is no surprise then that NH residents are more likely to be prescribed antimicrobial therapy than any other drug class, even though they are responsible for more than one-fifth of all adverse drug reactions.
- Every year there are more than 2 million discharges from NHs, including planned and unplanned transfers to hospitals, and these numbers will likely grow. Most discharged patients are likely to use several different health care settings in the near future, including NHs. This frequent movement of patients across various health care facilities is a major driver of transmission of pathogens in NHs.
- Importantly, NH residents may be persistently colonized by antimicrobial-resistant organisms (MDROs), such as MRSA, and VRE, CRE and *C. auris*.

Sturm L, et al. Infect Dis Clinics NA 2021;35:803-825

Prevalence and Risk Factors for MDRO Colonization in Long-Term Care Facilities Around the World: A Review

- Methods: Search in PubMed and Scopus for studies examining the prevalence of MDROs and/or risk factors for the acquisition of MDROs in LTCF. One hundred and thirty-four studies published from 1987 to 2020 were included.
- Oceania: Prevalence in LTCFs: ESBL *Enterobacterales*, 6.0; ESBL, *E. coli*, 10.4; CRE *Enterobacterales*, 0.4; MDR *A. baumannii*, 6.0; MRSA, 10; VRE, 3.1

Table 3. Risk factors for multidrug-resistant organism colonization in long-term care facilities in the studies. Common characteristics and limitations.

Risk Factors for MDRO Colonization	Limitations and Common Characteristics
Age	An increase entails higher risk. There is not a cut-off established for colonization by MDROs.
Male sex	Confirmed in many studies by multivariate analysis
Dementia	An increase entails higher risk. There is not a cut-off established for colonization by MDROs.
Diabetes	Controversial results. Differences by MDRO type.
Cancer	Controversial results. Differences by MDRO type.
Chronic wound	Confirmed in many studies by multivariate analysis
Dependence	An increase entails higher risk. There is not a cut-off established for colonization by MDROs.
Medical devices	Confirmed in many studies by multivariate analysis
Previous antibiotic use	Confirmed in many studies by multivariate analysis
Previous hospitalization	Whether the risk could be increased by days of hospitalization is unknown.
Previous MDRO colonization	Controversial results. Differences by MDRO type.

MDRO: multidrug-resistant organism.

Rodriquez-Villodres A, et al. Antibiotics 2021;10, 680

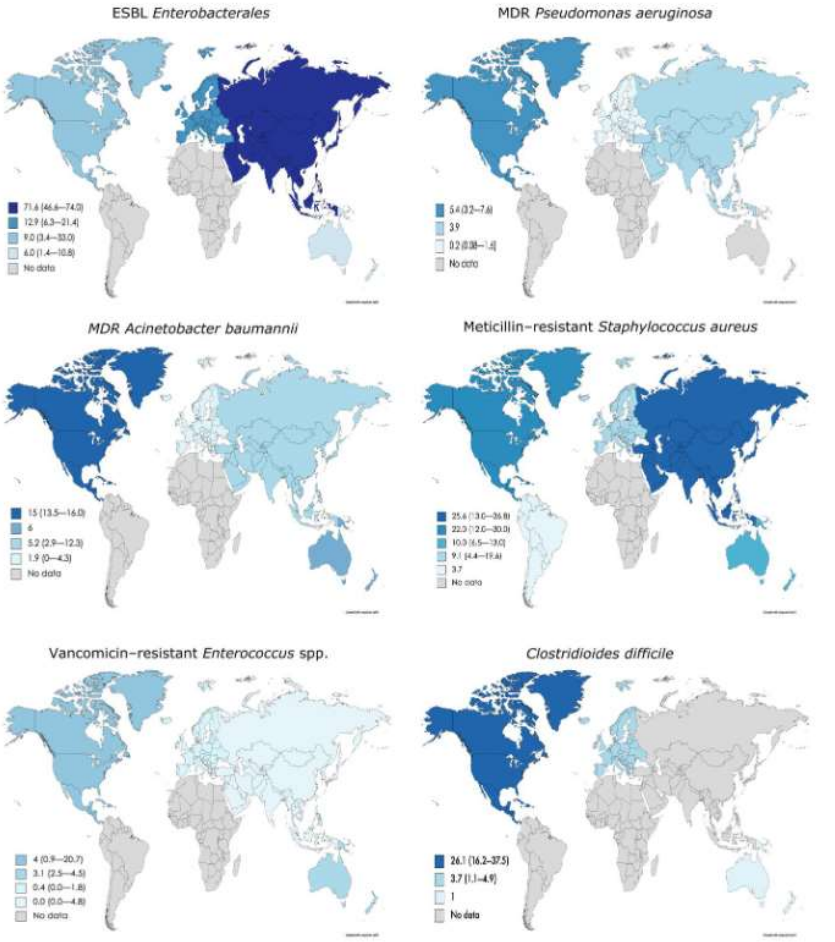


Figure 2. Prevalence of different MDRO in LTCF around the world. Maps were created through the online tool Mapchart.net (https://mapchart.net/world.html, accessed on 23 November 2020). ESBL, extended-spectrum ß-lactamase; MDR, multidrug-resistant.

RISK FACTORS FOR CRE ACQUISITION IN LTCFs

Types of factors	Odds ratio or relative risks documented in studies
Patient characteristics	Fecal incontinence (OR 5.78) (Mills et al., 2016)
	Solid organ or stem cell transplantation (OR 5.05) (Mills et al., 2016)
	Immunosuppressive status (OR 3.92) (Bhargava et al., 2014)
	Comorbidities (Charlson's score > 3; OR 4.85) (Bhargava et al., 2014)
	Strokes (Le et al., 2020), Dementia (Lee et al., 2017), Dependent functional status (Hagiya et al., 2018; Hayakawa et al., 2020)
Environmental factors	Usage of gastrointestinal devices (OR 19.7) (Cunha et al., 2016; Mckinnell et al., 2019)
	Indwelling devices (e.g. CVC or urinary catheters) (OR 5.21) (Lin et al., 2013)
	Mechanical ventilation (OR 3.56) (Mills et al., 2016)
	LTAC facility subtypes, esp. high-acuity facility with mechanical ventilation (Lin et al., 2013)
	Prolonged length of stay (Ben-David et al., 2011; Lin et al., 2013)
	Sharing a room with known carriers or increased prevalence of known carriers in the same ward (Chitnis et al., 2012)
Microbiology status	Prior antibiotic exposures (OR 3.89) (Chitnis et al., 2012; Bhargava et al., 2014; Brennan et al., 2014)
	Previous culture growing CRKP within 90 days (Chitnis et al., 2012)
	Recent *Clostridium difficile* infection (Prasad et al., 2016)

CVC, central venous catheter; CRKP, carbapenem-resistant Klebsiella pneumoniae; LTAC, long-term acute care hospitals; OR, odds ratio.

Chen H-Y, et al. Frontiers in Cellular and Infection Microbiol 2021;11:article 601968

UNC SCHOOL OF MEDICINE

High Prevalence of Multidrug-Resistant Organism Colonization in 28 Nursing Homes: An "Iceberg Effect"

- Goal: Assess the prevalence MRSA, VRE, ESBLs, and CRE among residents and in the environment of NHs.
- Methods: Point prevalence sampling of 28 NHs, 2016-17. 50 randomly selected residents per NH, 20 objects in common room or patient room.
- Results: 2797 swabs were obtained from 1400 residents in 28 NHs. Median prevalence of multidrug-resistant organism (MDRO) carriage per NH was 50% (range: 24%–70%). Median prevalence of specific MDROs were as follows: MRSA, 36% (range: 20%–54%); ESBL, 16% (range: 2%–34%); VRE, 5% (range: 0%–30%); and CRE, 0% (range: 0%–8%). A median of 45% of residents (range: 24%–67%) harbored an MDRO without a known MDRO history.
- Environmental MDRO contamination was found in 74% of resident rooms and 93% of common areas.

McKinnell JA, et al. J Am Med Dis Assoc. 2020;21:1937-43

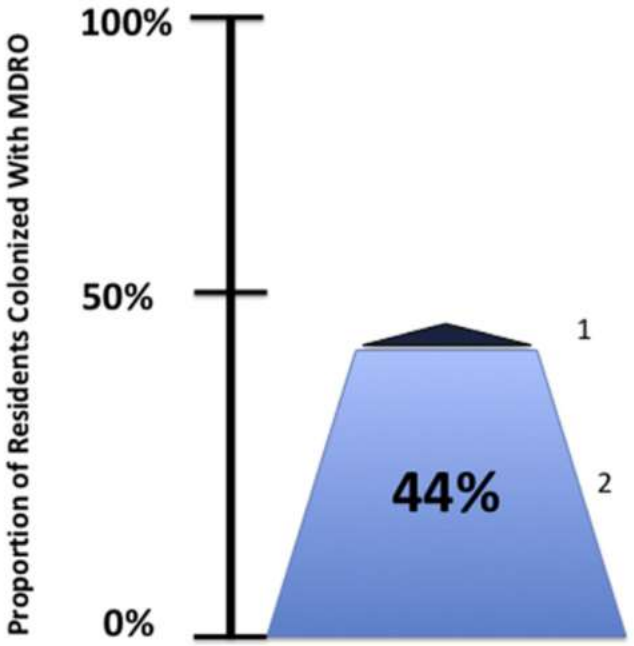


Fig. 1.
The iceberg of MDRO colonization in skilled nursing facilities. (1) Nearly half (48%) of nursing home residents are colonized with MDRO. The top "exposed" portion of the iceberg represents the (4%) of patients for whom point prevalence survey confirmed previously known colonization status (n = 53 residents). (2) Most of the MDRO colonization is unknown to the facility, with 45% of residents representing the unknown submerged iceberg population of previously unknown MDRO colonization. Of the NH population, 39% (n = 552 residents) had no history of MDRO, but point prevalence survey identified MDRO Carriage. In addition, 5% of the NH population (n = 75 residents) had a history of an MDRO, but point prevalence survey identified an additional MDRO unknown to the facility.

Patient Hand Contamination: Risk Factors and Implications

Population

6 post-acute care facilities

650 patients

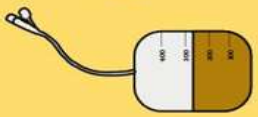
1,607 visits, hand swabs

14,689 environmental swabs

Risk Ratios

1.10 $p<0.001$

1.62 $p<0.001$



1.79 $p=0.014$

2.24 $p<0.001$

5.01 $p<0.001$

Implications

MDROs on patient hands

MDROs in environment

MDRO	Pt Hands (+) = Environ (+)	Pt Hands (-) = Environ (-)
MRSA*	83%	80%
VRE*	93%	62%
R-GNB**	63%	71%

*$p < 0.001$, **$p < 0.01$

Patel P, Mantey J, Mody L. Infect Control Hosp Epidemiol., July 2017.
Funded by CDC BAA

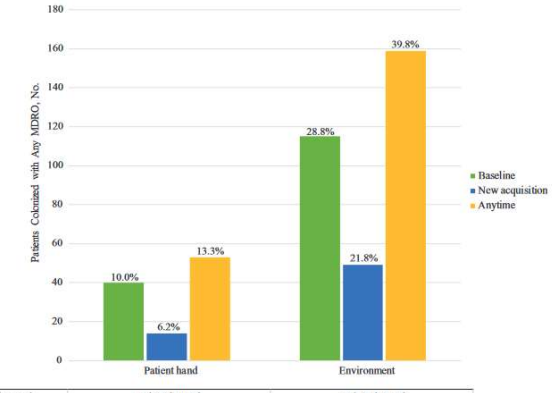
MICHIGAN MEDICINE
UNIVERSITY OF MICHIGAN

Slide provided by Dr. Lona Mody

MDROs in Hospitals: What Is on Patient Hands and in Their Rooms?

- Goal: Assess patient hand and environmental contamination (MRSA, VRE, R-GNB); 2 acute care hospitals
- Methods: Patients prospectively followed from admission
- Results: A total of 399 patients (mean age, 60.8 years; 49% male) were enrolled and followed for 710 visits. Fourteen percent (n = 56/399) of patients were colonized with an MDRO at baseline; 10% (40/399) had an MDRO on their hands. Twenty-nine per cent of rooms harbored an MDRO. Six percent (14/225 patients with at least 2 visits) newly acquired an MDRO on their hands during their stay. New MDRO acquisition in patients occurred at a rate of 24.6/1000 patient-days, and in rooms at a rate of 58.6/1000 patient-days. Typing demonstrated a high correlation between MRSA on patient hands and room surfaces.
- Conclusion: Patient hand contamination with MDROs is common and correlates with contamination on high-touch room surfaces.

Study discussed because of relevance to nursing homes – mechanism for contamination of common areas; Mody L, et al. Clin Infect Dis 2019;69:1837-44



Baseline (n = 399)	40/399 (10.0%)	115/399 (28.8%)
New acquisition* (n = 225 with at least one follow-up visit)	14/225 (6.2%)	49/225 (21.8%)
Anytime during hospital stay (n = 399)	53/399 (13.3%)	159/399 (39.8%)

Figure 1. Percentage of patient hand contamination and room surface contamination with multidrug-resistant organisms (MDROs). Patient hand contamination (left 3 columns) and patient room contamination (right 3 columns) were calculated at baseline, follow-up visits, and any time during follow-up. The table underneath indicates the raw numbers represented in the figure. *A patient can be colonized with 1 MDRO at baseline and be at risk to acquire another MDRO.

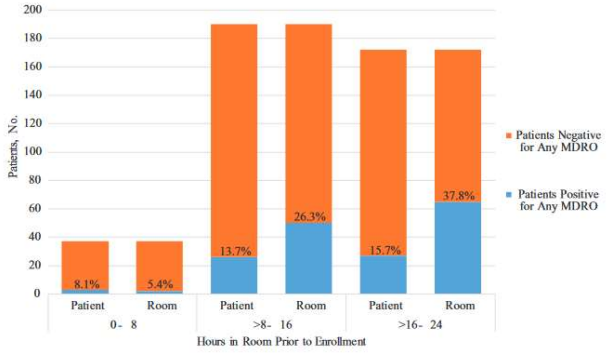


Figure 2. Multidrug-resistant organisms (MDROs) on patients and room surfaces by time in room prior to enrollment. Number of patients enrolled and cultured within 0–8 hours in the room, >8 to 16 hours in the room, and >16 to 24 hours in the room and proportion of patient and rooms colonized with MDROs.

Potential for Transmission of *C. difficile* by Asymptomatic Acute Care Patients and Long-Term Care Facility Residents with Prior *C. difficile* Infection

- Goal: Assess *C. difficile* shedding in an acute care hospital and long term care facility
- Results: Patients with active CDI (N = 35) had high frequencies of positive stool, skin, and environmental cultures (100%, 63%, and 51%, respectively). Among the 46 patients with resolved CDI, the frequency of positive stool, skin, and environmental cultures was significantly higher for the 24 patients cultured during the month after completion of treatment versus the 22 cultured more than 1 month after treatment (50%, 46%, and 29% vs 18%, 5%, and 5%, respectively; P< 0.01 for each comparison). None of the 12 patients whose CDI had resolved 6-24 months after completion of treatment had positive skin or environmental cultures.
- Our data suggest that contact precautions could be extended for 1 month after completion of therapy rather than until discharge.

Jinno S,…Donskey C, et al. ICHE 2012;33:638

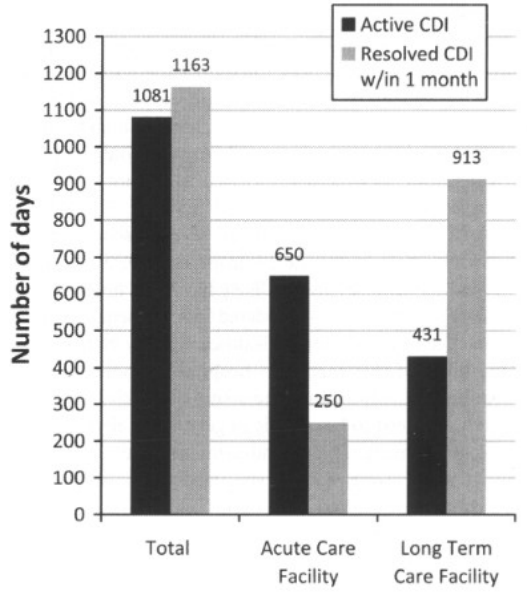


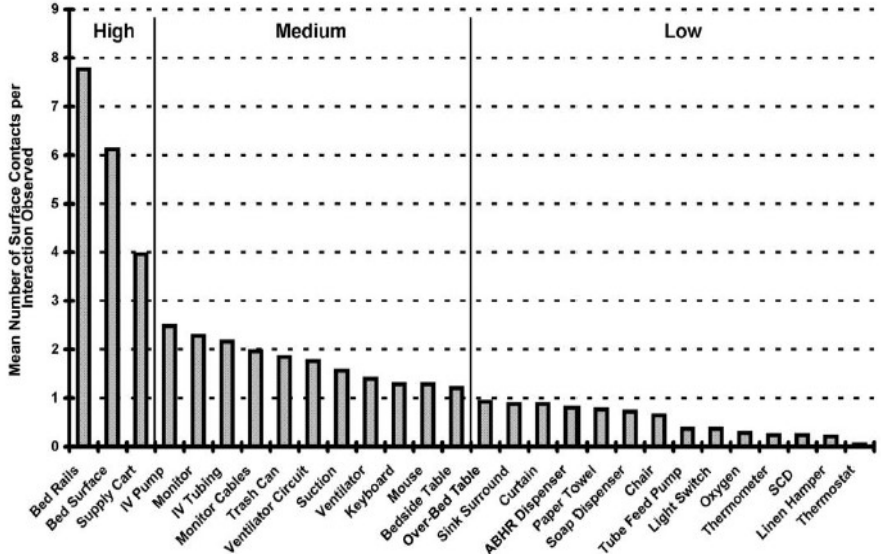
FIGURE 1. Days of care during a 6-month period for patients with active *Clostridium difficile* infection (CDI) and with resolved CDI within the past month, stratified by acute care facility and long-term care facility. Active CDI was defined as the time from diagnosis until completion of CDI treatment or until completion of 14 days of treatment in patients receiving prolonged tapering courses of vancomycin. Resolved CDI within the past month was defined as the time from end of therapy to 1 month after completion of therapy.

ALL “TOUCHABLE” (HAND CONTACT) SURFACES SHOULD BE WIPED WITH DISINFECTANT

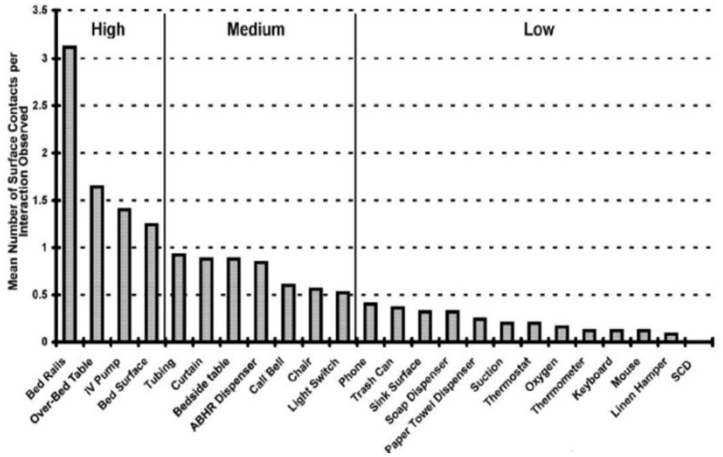
“High touch” objects only recently defined (no significant differences in microbial contamination of different surfaces) and “high risk” objects not epidemiologically defined. Cleaning and disinfecting is one-step with disinfectant-detergent. No pre-cleaning necessary unless spill or gross contamination.

DEFINING HIGH TOUCH SURFACES

ICU



NON-ICU



Huslage K, Rutala WA, Sickbert-Bennett E, Weber DJ. ICHE 2010;31:850-853

EVIDENCE THAT ALL TOUCHABLE ROOM SURFACES ARE EQUALLY CONTAMINATED

TABLE 1. Precleaning and Postcleaning Bacterial Load Measurements for High-, Medium-, and Low-Touch Surfaces

	Mean CFUs/RODAC (95% CI)	
Surface (no. of samples)	Precleaning	Postcleaning
High (n = 40)	71.9 (46.5–97.3)	9.6 (3.8–15.4)
Medium (n = 42)	44.2 (28.1–60.2)	9.3 (1.2–17.5)
Low (n = 37)	56.7 (34.2–79.2)	5.7 (2.01–9.4)

NOTE. CFU, colony-forming unit; CI, confidence interval.

Huslage K, Rutala W, Gergen M, Sickbert-Bennett S, Weber D
ICHE 2013;34:211-2

Number of culture sites and prevalence of contamination with nosocomial pathogens in intensive care units (N=523)

Ward	Culture sites[a]			
	HCWs' hands	Surfaces distant from patients	Surfaces close to patients	Prevalence of contamination
A	3/10 (30%)	0/22 (0%)	6/25 (24.0%)	9/57 (15.8%)
B	2/9 (22.2%)	4/19 (21.1%)	5/48 (10.4%)	11/76 (14.5%)
C	2/10 (20%)	2/26 (7.7%)	7/49 (14.3%)	11/85 (12.9%)
D	1/9 (11.1%)	2/24 (18.2%)	7/45 (15.6%)	10/78 (12.8%)
E	0/5 (0%)	4/22 (18.2%)	3/30 (10%)	7/57 (12.3%)
F	1/10 (10%)	0/11 (0%)	4/31 (12.9%)	5/52 (9.6%)
G	0/3 (0%)	2/14 (14.3%)	0/20 (0%)	2/37 (5.4%)
H	1/10 (10%)	0/16 (0%)	1/55 (1.8%)	2/81 (2.5%)
Total	10/66 (15.2%)	14/154 (9.1%)	33/303 (10.9%)	57/523 (10.9%)

HCW, healthcare worker.
[a] Number of contaminated samples/number of samples obtained.

Willi I, Mayre A, Kreidl P, et al.
JHI 2018;98:90-95

Evaluating hygienic cleaning in health care settings: What you do not know can harm your patients

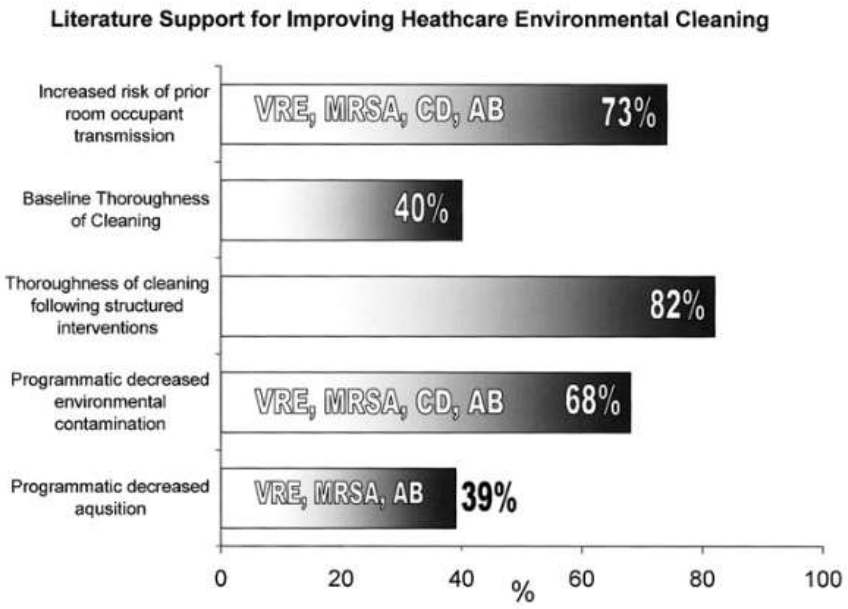


Fig 1. Summary of studies that provide support for improving heath care environmental cleaning practice.

Approaches to Programmatic Environmental Cleaning Monitoring

Conventional Program	Enhanced Program
• Subjective visual assessment	• Objective quantitative assessment
• Deficiency oriented	• Performance oriented
• Episodic evaluation	• Ongoing cyclic monitoring
• Problem detection feedback	• Objective performance feedback
• Open definition of correctable interventions	• Goal oriented structured Process Improvement model

Fig 2. A comparison of the elements of conventional hygienic monitoring with enhanced programs.

Carling PC, Bartley JM. AJIC 2010;38:S41-50

Justification for Using a Disinfectant for Non-Critical Surfaces

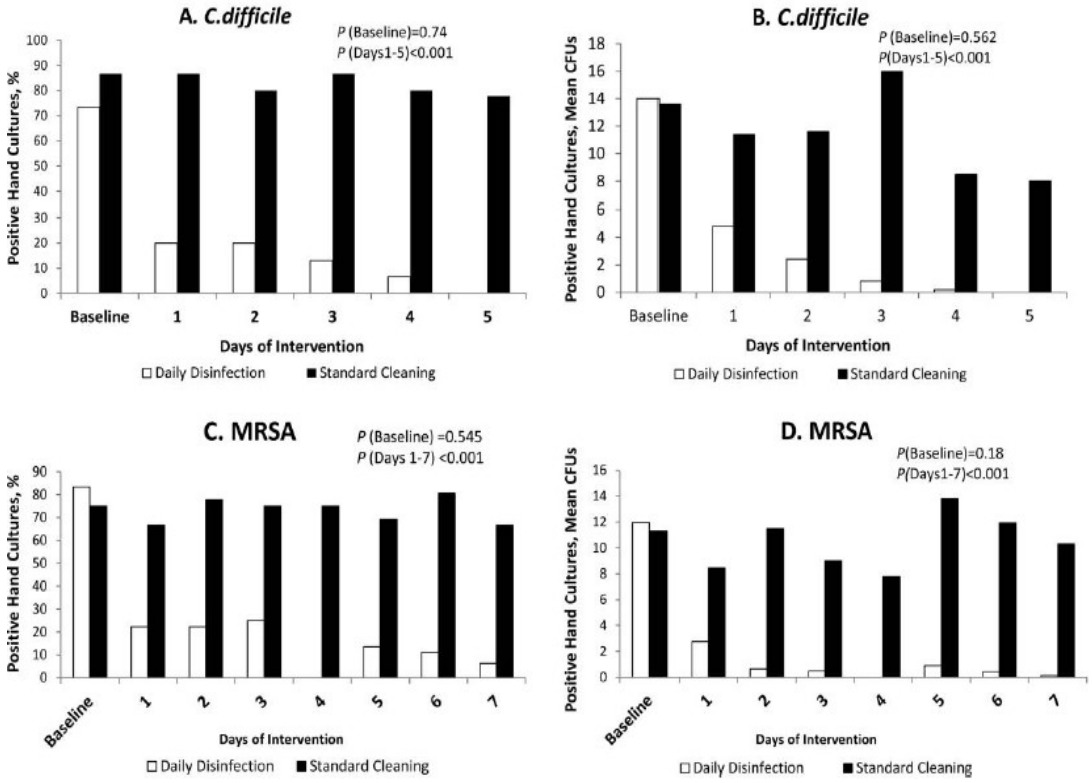
- Surfaces may contribute to transmission of epidemiologically-important pathogens such as MRSA, VRE, *C. difficile*, norovirus, and *C. auris*
- Disinfectants prevent HAIs
- Disinfectants are more effective than detergents in reducing contamination on surfaces
- Detergents become contaminated and result in seeding the patient's environment with bacteria
- Disinfection of non-critical patient care items and equipment is recommended for patients on isolation
- Disinfectants may have persistent antimicrobial activity

Studies involving interventions to improve effectiveness of cleaning and disinfection

Ref	Setting and organism	Design	Intervention	Monitoring of disinfection	Effect
38	Burn ICU VRE	Quasiexperimental	Twice-daily cleaning of all rooms, training of housekeepers, dedicated housekeeper for the unit, and use of checklists to guide cleaning	Decreased environmental contamination	Outbreak ended
11	Medical ICU VRE	Quasiexperimental	Education plus monitoring and feedback to improve daily and terminal cleaning	Decreased environmental contamination (10% to 3%-4% sites positive) and hand contamination (55% to 10%-11%)	Decreased VRE acquisition (hazard ratio, 0.36)
39	10 ICUs VRE & MRSA	Quasiexperimental	Feedback using fluorescent markers and bucket cleaning method with focus on terminal cleaning	Decreased contamination with MRSA or VRE after cleaning (27% vs 45% of rooms after cleaning)	Decreased acquisition of MRSA by 49% and VRE by 29%
40	ICU *A baumanii*	Quasiexperimental	Product substitution (hypochlorite [1,000 ppm replaced detergent]), new cleaning protocols, additional cleaning staff	Decreased environmental contamination	Outbreak ended
41	Surgical ward MRSA	Quasiexperimental	Entire ward disinfected, increased cleaning 57 hours per week including shared equipment and removal of dust, new protocols	Decreased environmental contamination from 11% to 0.7%	Decreased MRSA acquisition
42	2 Surgical wards MRSA	Ward-level crossover design	One additional cleaner disinfected high-touch surfaces in patient rooms 2-3 times/day and portable equipment and the nurse's station	Decreased aerobic microbial contamination by 33%, but no decrease in environmental MRSA	Decreased MRSA acquisition by 27%
43	Hospital *C difficile*	Quasiexperimental	Education; product substitutions (1st: hypochlorite; 2nd: 7% accelerated hydrogen peroxide); comprehensive ward disinfection when ≥3 nosocomial CDI cases	No	No decrease in CDI incidence
22	2 ICUs MRSA	1 Year randomized crossover study	Twice-daily enhanced cleaning of high-touch surfaces with ultramicrofiber cloths and a copper-based biocide; addition of a team of trained hygiene technicians	Decreased MRSA contamination in environment (15% vs 9%) and physician hands (3% vs 0.7%)	No decrease in MRSA acquisition (adjusted odds ratio, 0.98)
44	Hospital VRE	Quasiexperimental	Product substitution (hypochlorite 1,000 ppm), daily disinfection of all rooms, employment of cleaning supervisors, formal training plus monitoring and feedback, and 3-times yearly "super-clean-disinfection" of high-risk wards	Decreased VRE contamination by 66%	Decreased newly recognized VRE colonization by 25% and VRE bacteremia by 83%

Donskey CJ. AJIC 2013;41:S12-S19

EFFECT OF DAILY DISINFECTION VERSUS STANDARD CLEANING ON CONTAMINATION OF HCP HANDS



Kundrapu S, et al. ICHE 2012;33:1039-1042

UNC SCHOOL OF MEDICINE

An environmental cleaning bundle and health-care-associated infections in hospitals (REACH): a multicentre, randomised trial

Goal: We aimed to evaluate the effectiveness of an environmental cleaning bundle to reduce health care-associated infections in hospitals.

Results: Between May 9, 2016, and July 30, 2017, we implemented the cleaning bundle in 11 hospitals. In the pre-intervention phase, there were 230 cases of VRE infection, 362 of *S aureus* bacteremia, and 968 *C difficile* infections, for 3534439 occupied bed-days. During intervention, there were 50 cases of VRE infection, 109 of *S aureus* bacteremia, and 278 *C difficile* infections, for 1267134 occupied bed-days. After the intervention, VRE infections reduced from 0·35 to 0·22 per 10000 occupied bed-days (relative risk 0·63, 95% CI 0·41–0·97, p=0·0340). The incidences of *S aureus* bacteremia (0·97 to 0·80 per 10000 occupied bed-days; 0·82, 0·60–1·12, p=0·2180) and *C difficile* infections (2·34 to 2·52 per 10000 occupied bed-days; 1·07, 0·88–1·30, p=0·4655) did not change significantly. The intervention increased the percentage of frequent touch points cleaned in bathrooms from 55% to 76% (odds ratio 2·07, 1·83–2·34, p<0·0001) and bedrooms from 64% to 86% (1·87, 1·68–2·09, p<0·0001).

Product = This required use of a disinfectant for all discharge cleans and for daily cleans of high risk/ precautions rooms; use of detergent for routine cleans; use of point-of-care wipes for medical equipment (Hall L, et al. Antimicrob Resist & Infect Control 2020;9:35)

	Estimate (95% CI)	p value
No intervention		
Clostridium difficile infections	−28·8 (−45·9 to −6·4)	0·0163
Staphylococcus aureus bacteraemia*	5·1 (−33·0 to 65·0)	0·8280
Vancomycin-resistant enterococcus clinical isolates	−15·6 (−53·1 to 51·9)	0·5653
With intervention		
Clostridium difficile infections	7·3 (−11·8 to 30·5)	0·4655
S aureus bacteraemia*	−18·1 (−40·2 to 12·0)	0·2180
Vancomycin-resistant enterococcus	−36·9 (−59·0 to −2·8)	0·0340
All infections	−5·8 (−19·8 to 9·4)	0·4246

Per-protocol adjusted results, calculated using a linear trend and a binary switch with a 4-week intervention lag.
*Includes both meticillin-resistant and meticillin-sensitive *S aureus*.

Table 2: **Percentage changes in infection rates, by intervention**

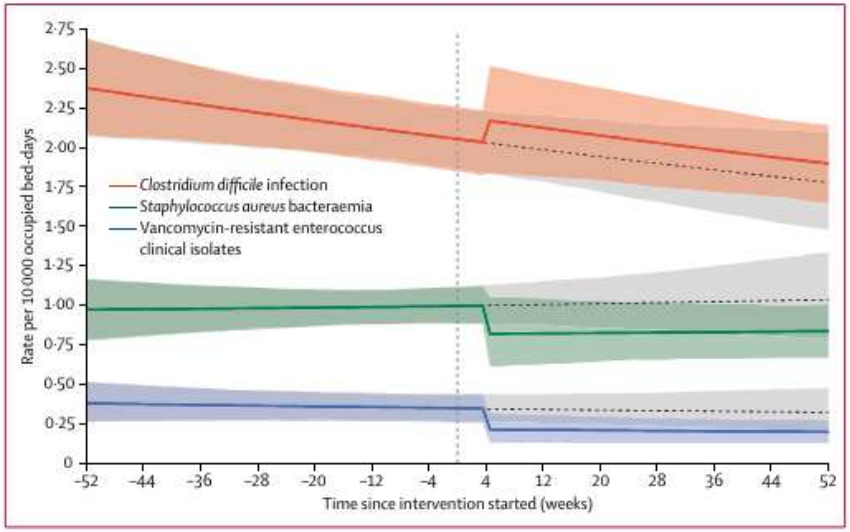


Figure 3: **Estimated changes in health care associated infection rates before and after the intervention**
Ribbons are 95% prediction intervals. Grey shading shows expected infection rates with no intervention.

Mitchell BG, et al. Lancet ID 2019;19:410-418

Mitigating hospital-onset *C. difficile*: The impact of an optimized environmental hygiene program in 8 hospitals

Goal: To evaluate the impact of a standardized, process-validated intervention utilizing daily hospital-wide patient-zone sporicidal disinfectant cleaning on incidence density of healthcare-onset *C. difficile* infection (HO-CDI) standardized infection ratios (SIRs).

Setting: Study was conducted across 8 acute-care hospitals in 6 states with stable endemic HO-CDI SIRs

Results: Following the wash-in period, the thoroughness of disinfection cleaning (TDC) improved steadily for all sites and by 18 months was 93.6% for the group. The mean HO-CDI SIRs decreased from 1.03 to 0.6 (95% CI, 0.13–0.75; P = .009). In the adjusted difference-in-differences analysis in comparison to controls, there was a 0.55 reduction (95% CI, −0.77 to −0.32) in HO-CDI (P < .001) or a 50% relative decrease from baseline.

1. At the time of hospitalization 10.6% of patients (range 2.8 – 21%) are CD carriers.	Ref: 47-59
2. During hospitalization 12.5% of patients (range 2.9-21%) are CD carriers.	Ref: 47,60-65
3. Transmission of CD spores to environmental surfaces is associated with: Patients with acute infection Patients recovering from acute infection Asymptomatic CD colonized patients	Ref: 70-72
4. Treatment does not decrease ongoing environmental spore contamination for more than a month.	Ref: 73
5. Wide spread surface contamination far from known CD infected patients	Ref: 46.59
6. Increased Cleaning and disinfection result in: Decreased surface and hand contamination Decreased CD acquisition	Ref: 46.69,70,75
7. Genomic confirmation of the role of asymptomatic CD carriers in transmission	Ref: 61,66-69
8. Acquisition of CD from a prior room occupant is significantly dependent on the prior room occupant receiving antibiotics	Ref: 74

Elements of *C. difficile* environmental epidemiology

Carling PC, et al. ICHE 2023:44;440-446

Mitigating hospital-onset *C. difficile*: The impact of an optimized environmental hygiene program in 8 hospitals

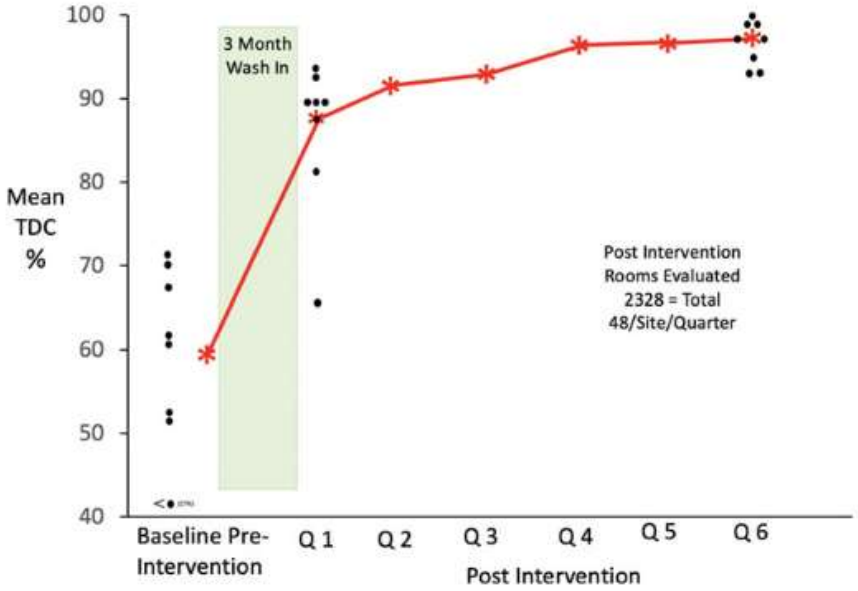


Fig. 2A . Thoroughness of cleaning in 8 intervention hospitals.

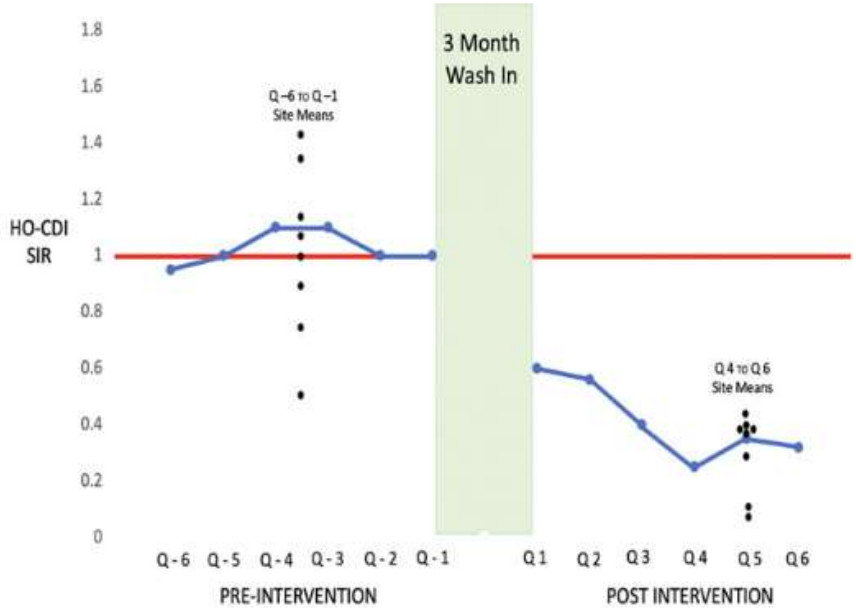


Fig. 2B. Endemic HO-SIRs in 8 intervention hospitals.

Carling PC, et al. ICHE 2023:44;440-446

IMPORTANCE OF BIOFILMS IN INFECTION PREVENTION

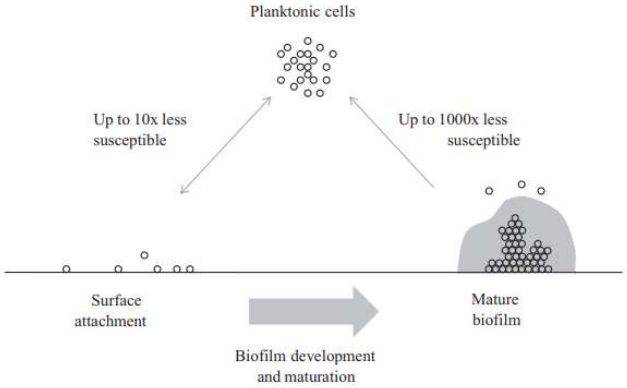


Figure 1. Schematic of surface attachment, biofilm formation and biocide susceptibility. This illustrates bacterial attachment to surfaces, development and maturation of biofilms, and implications for microbial susceptibility. The grey shading around the mature biofilms illustrates EPS. The biofilm development and maturation process is a complex step-wise process, simplified here as a single step.[2,3] Whilst the reduced biocide susceptibility associated with surface attachment and biofilms will be determined by a number of factors, not least the biocide, microbe and testing conditions, bacteria in mature biofilms are consistently less susceptible than biofilms attached to surfaces, often by several orders of magnitude.[18–20]

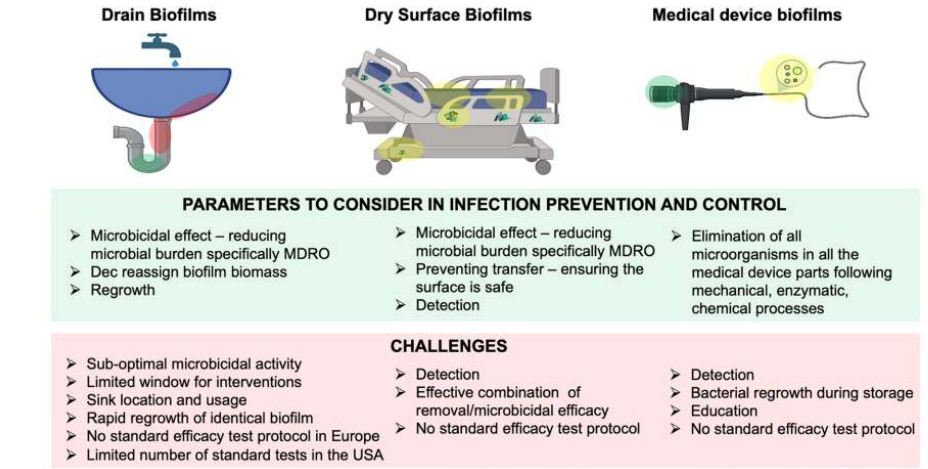


Fig. 2 Biofilm type and location and associated challenges. Hydrated biofilms; dry surface biofilms; Semi-hydrated biofilm. Semi-hydrated biofilms are subjected to serial wet and dry phases, for example during device reprocessing

KEY POINTS

- Dry surface biofilms are widespread on dry environmental surfaces in healthcare settings (as high as 95% of surfaces).
- Dry surface biofilms can harbour bacterial pathogens including multidrug-resistant organisms.
- Dry surface biofilms cannot be detected by routine wet swabbing.
- Dry surface biofilms are less susceptible to disinfection.
- Bacterial pathogens in dry surface biofilms are transferable by direct and indirect contact (gloves) following cleaning and disinfection.

Otter JA, et al. JHI 2015;89:16-27; Ledwock K, et al. Br J Hosp Med 2022;83:No 8; Maillard J-V, Centeleghe I. Antimicrob Resist & Infect Control 2023;12:95;

Efficacy of Different Cleaning and Disinfection Methods against *C. difficile* Spores: Importance of Physical Removal versus Sporicidal Inactivation

We tested the effectiveness of disinfectants and wipe methods against *C. difficile* spores. Wiping with nonsporicidal agents (physical removal) was effective in removing more than 2.9 $\log_{10}$ *C. difficile* spores. Wiping with sporicidal agents eliminated more than 3.90 $\log_{10}$ *C. difficile* spores (physical removal and/or inactivation). Spraying with a sporicide eliminated more than 3.44 $\log_{10}$ C. difficile spores but would not remove debris

TABLE 2. Effectiveness of Different Wipe and Spray Methods as Measured by Reduction in Bacterial Count and Drying Time

	Wipe and/or spray method					
Product	Saturated cloth[a]	Spray (10 s) and wipe	Spray, wipe, spray (1 min), wipe	Disposable pop-up wipes	Spray, wipe, spray, air dry	Spray and air dry
Ecolab QC-53, detergent						
Reduction	3.38 (1.61–5.16)	3.28 (2.18–4.38)	4.02 (3.68–4.35)	NT	2.90 (1.34–4.45)	<2.00 (1.78–2.21)
Drying time, min:s	2:09	4:18	3:34	NT	24:26	28:11
Ecolab A456-II						
Reduction	3.14 (2.01–4.27)	2.98 (1.92–4.04)	4.18 (3.46–4.90)	NT	2.90 (1.52–4.27)	<2.00 (1.78–2.21)
Drying time, min:s	2:26	6:18	4:44	NT	24:00	30:14
1 : 10 Bleach						
Reduction	3.90 (2.87–4.92)	4.48 (4.26–4.69)	4.48 (4.26–4.69)	NT	4.48 (4.26–4.69)	3.44 (1.65–5.22)
Drying time, min:s	1:45	5:18	5:21	NT	51:08	39:40
Kimtech One-Step Germicidal Wipe						
Reduction	NT	NT	NT	4.18 (4.18–4.18)	NT	NT
Drying time, min:s	NT	NT	NT	4:06	NT	NT
Clorox Germicidal Wipe						
Reduction	NT	NT	NT	3.98 (3.23–4.72)	NT	NT
Drying time, min:s	NT	NT	NT	1:47	NT	NT
Clorox #9255–41–1 and 3						
Reduction	NT	6.14 (6.14–6.14)	NT	NT	NT	5.96 (5.22–6.70)
Drying time, min:s	NT	2:49	NT	NT	NT	40:14

NOTE. Data are mean $\log_{10}$ reduction in bacterial count (95% confidence interval [CI]) unless otherwise indication. Nonoverlapping 95% CIs between any two products or wipe and/or spray methods indicates a significant difference ($P < .05$). Drying time represents the time required to achieve a completely dry Formica surface. NT, not tested.

[a] Kimberly Clark Nonwoven Spunlace Wiper #6411 squeezed until not dripping.

Rutala WA, Gergen MF, Weber DJ.
ICHE 2012;33:1255-1258

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DISPOSABLE DISINFECTANT WIPES AND DRY BIOFILMS

Advantages of "ready to use" (RTU) disinfectant wipes compared to reusable wipes: 1) Disposable RTU wipes have the advantage of not requiring manual or automated dilution of disinfectants, which can avoid improper dilution of disinfectants. 2) Use of RTU wipes can also avoid other human errors associated with using disinfectants in reusable buckets, such as choosing an inappropriate type of wipe, "double-dipping of cloths in disinfectant, and failure to moisten cloths or wipes with an adequate amount of disinfectant. In contrast, RTU wipe products generally have a consistent disinfectant/wipe ratio if the wipe container lid is kept on, and match the type of wipe material to the disinfectant employed. 3) Compared to wipes used in reusable buckets, RTU wipes are probably at lower risk of becoming contaminated prior to use as long as the container is kept closed as recommended. 4) Unlike reusable wipes, there are no laundering or replacement costs associated with RTU wipes, which may help offset the increased costs associated with purchasing RTU wipes.*

RTU wipes versus sprays: Spraying disinfectants has on occasion caused eye irritation or respiratory symptoms. For this reason, application of disinfectants by aerosol or trigger sprays is not recommended in Canada.*

Efficacy against dry surface biofilms: Studies demonstrate that combining disinfectants effective against target pathogens with the appropriate wipe material is needed to obtain optimal removal of pathogens from surfaces and prevent transfer of microorganisms from one surface to another by wipes*

Dry surface biofilms (DSB): "For DSB, mechanical removal together with disinfection have been shown to be efficacious."^

Wipes: "The reference method for the treatment of hospital inert surfaces is wiping. This recommended technique ensures a mechanical removal of adherent cells, potentiates the action of the detergent, if any, and completes the action of the disinfectant."#

*Boyce JM. AJIC 2021;49:104-114; ^Maillard J-V, Centeleghe I. Antimicrob Resist & Infect Control 2023;12:95; # Schapira A-J, et al. JHI 2024;144:94-110

Use of germicides in health care settings; is there a relationship between germicide use and antimicrobial resistance

Despite the widespread use of disinfectants and antiseptics in hospitals, acquired resistance to current disinfectants has rarely been reported. Germicides, as with medications, should only be used when their benefit as demonstrated by scientific studies exceeds possible risks to human health or the environment.*

Similarities and differences between antibiotic and germicide resistance

Similarities
Intrinsic resistance (eg, spores are resistant to alcohols) and extrinsic resistance (eg, efflux pumps for heavy metals) are well described.
Acquired mechanisms of resistance are similar (eg, impermeability, efflux pumps).
Biofilms impair inactivation/killing.
Inactivation is dependent on the concentration and duration of contact with the antibiotic or germicide.
Differences
Most antibiotics inhibit a specific target in a biosynthetic process.
Most biocides have multiple concentration-dependent targets, with subtle effects occurring at low concentrations and more damaging ones at higher concentrations.

Summary of the relationship between germicide use and antibiotic resistance

Question	Answer
Does the use of disinfectants or antiseptics result in disinfectant and/or antiseptic resistance to the recommended concentrations of the antiseptics or disinfectants?	No
Do antibiotic-resistant bacteria exhibit resistance to the recommended concentrations of antiseptics or disinfectants?	No
Does the use of currently recommended hospital disinfectants and/or antiseptics precipitate antibiotic resistance?	No
Does the recommended use of antiseptics and disinfectants in hospitals decrease the burden of health care–associated infections?	Yes
Conclusion: Regarding the continued use of antiseptics and disinfectants as currently recommended, the benefits overwhelming exceed the risks.	

Laboratory studies have identified multiple mechanisms by which bacteria can develop tolerance or resistance to quaternary ammonium disinfectants and antibiotics. De novo development of tolerance or resistance in real-world settings is uncommon.^

*Weber DJ, et al. AJIC 2019;47S;A106-109; ^Boyce JM. Antimicrob Resist & Infect Control 2023;12:32.

"NO TOUCH" ROOM DISINFECTION TECHNOLOGIES

- Entire room (terminal disinfection)
  - UV devices
    - Stationary (UV-C, UV-pulsed Zenon)
    - Mobile (UV-C)
  - Hydrogen peroxide systems
    - Hydrogen peroxide vapor (30-35% H2O2)
    - Aerosolized hydrogen peroxide systems (5-6% HsO2 plus silver)
- Room surfaces (daily and terminal disinfection)
  - Handheld UV devices
  - Handheld lectrostatic sprayers
- Continuous room disinfection technologies
  - Dilute hydrogen peroxide; hydroxyl radicals; free reactive oxygen
  - Far UV (207-222 nm)
  - UV-A (365 nm)
  - Visible light (i.e., "blue light," 400-470 nm)
  - Miscellaneous: Bipolar ionization, multi-jet cold air plasma
- Self-disinfecting surfaces
  - Heavy metals (e.g., copper, silver)
  - Surface chemical disinfectants with persistence
    - Quaternary ammonium compound-based agents
    - Organosilane compounds
- Others
  - Altered topography
  - Antimicrobial peptides bound to surfaces
  - Photoactivated surfaces (eg, TiO_2 , toluidine blue O, rose bengal)
  - Anti-adhesive surfaces (e.g., super hydrophobic surfaces; zwotterionic materials such as carboxybetaine or sufobetaine)
  - Attachment of bacteriophages to surfaces
  - Surface coating with carbon nanotubes, graphene, or diamond-like carbon
  - Use of probiotics to disrupt biofilms

Topics to be covered in lecture, highlighted in red

Weber DJ, et al. AJIC 2023;51:A134-A143

Enhanced terminal room disinfection and acquisition and infection caused by multidrug-resistant organisms and *C. difficile* (the Benefits of Enhanced Terminal Room Disinfection study): a cluster-randomized, multicentre, crossover study

Goal: Pragmatic, cluster-randomized, crossover trial at nine hospitals in the southeastern USA.

Results: The incidence of target organisms among exposed patients was significantly lower after adding UV to standard cleaning strategies (n=76; 33·9 cases per 10 000 exposure days; relative risk [RR] 0·70, 95% CI 0·50–0·98; p=0·036). The incidence of *C difficile* infection among exposed patients was not changed after adding UV to cleaning with bleach (n=38 vs 36; 30·4 cases vs 31·6 cases per 10 000 exposure days; RR 1·0, 95% CI 0·57–1·75; p=0·997).

Anderson DJ, et al.Lancet 2017;389:805

Results of per-protocol analysis

	Reference group	UV group	Bleach group	Bleach and UV group
All target organisms				
Exposed patients	4916	2848	5438	3701
Incident cases (%)	115 (2·3%)	46 (1·6%)	101 (1·9%)	93 (2·5%)
Exposure days	22 426	12 299	24 261	17 354
Rate (per 10 000 exposure-days)	51·3	37·4	41·6	53·6
Risk reduction (95% CI)	Reference	13·9 (−0·1 to 27·9)	9·7 (−2·7 to 22·0)	−2·3 (−15·7 to 11·1)
RR (95% CI); p value	Reference	0·69 (0·50 to 0·95); 0·025	0·74 (0·61 to 0·91); 0·004	1·0 (0·81 to 1·23); 1·00
Clostridium difficile *				
Exposed patients	..	..	2499	1712
Incident cases (%)	..	..	36 (1·4%)	30 (1·8%)
Exposure days	..	..	11 385	8015
Rate (per 10 000 exposure-days)	..	..	31·6	37·4
Risk reduction (95% CI)	..	..	Reference	−5·8 (−17·1 to 5·5)
RR (95% CI); p value	..	..	Reference	1·22 (0·68 to 2·17); 0·511
Meticillin-resistant *Staphylococcus aureus*				
Exposed patients	3300	1872	3631	2425
Incident cases (%)	73 (2·2%)	28 (1·5%)	74 (2·0%)	63 (2·6%)
Exposure days	14 525	7934	15 343	10 681
Rate (per 10 000 exposure-days)	50·3	35·3	48·2	59·0
Risk reduction (95% CI)	Reference	15·0 (−0·6 to 30·6)	2·1 (−13·8 to 17·8)	−8·7 (−18·0 to 0·5)
RR (95% CI); p value	Reference	0·67 (0·48 to 0·94); 0·019	0·89 (0·72 to 1·09); 0·260	1·09 (0·85 to 1·39); 0·503
Vancomycin-resistant enterococci				
Exposed patients	1055	659	1468	1134
Incident cases (%)	37 (3·5%)	13 (2·0%)	24 (1·6%)	24 (2·1%)
Exposure days	5838	3265	7522	6237
Rate (per 10 000 exposure-days)	63·4	39·8	31·9	38·5
Risk reduction (95% CI)	Reference	23·6 (−6·1 to 53·2)	31·5 (12·7 to 50·2)	24·9 (−0·6 to 50·4)
RR (95% CI); p value	Reference	0·56 (0·21 to 1·50); 0·248	0·35 (0·16 to 0·78); 0·010	0·41 (0·22 to 0·77); 0·006

Effectiveness of targeted enhanced terminal room disinfection on hospital-wide acquisition and infection with multidrug-resistant organisms and *C. difficile*: a secondary analysis of a multicenter cluster randomized controlled trial with crossover design (BETR Disinfection)

Results: Between 4/2012, and 7/2014, there were 271 740 unique patients with 375918 admissions; 2681 incident cases of hospital-acquired infection or colonization occurred during the study. There was no significant difference in the hospital-wide risk of target organism acquisition between standard disinfection and the three enhanced terminal disinfection strategies for all target multidrug-resistant organisms (UV study period relative risk [RR] 0.89, 95% CI 0.79–1.00; p=0.052; bleach study period 0.92, 0.79–1.08; p=0.32; bleach and UV study period 0.99, 0.89–1.11; p=0.89). The decrease in risk in the UV study period was driven by decreases in risk of acquisition of *C difficile* (RR 0.89, 95% CI 0.80–0.99; p=0.031) and VRE (0.56, 0.31–0.996; p=0.048).

Conclusion: Enhanced terminal room disinfection with UV in a targeted subset of high-risk rooms led to a decrease in hospital-wide incidence of *C difficile* and VRE. Enhanced disinfection overcomes limitations of standard disinfection strategies and is a potential strategy to reduce the risk of acquisition of multidrug-resistant organisms and *C difficile*.

Anderson DJ, et al. Lancet ID 2018;18:845

Incidence of hospital acquisition of target multidrug-resistant organisms

	Standard disinfection period (reference group)	UV period	Bleach period	Bleach and UV period
All target organisms				
Exposed admissions	73 071	81 621	78 760	81 158
Incident cases (%)	626 (0.86%)	683 (0.84%)	671 (0.85%)	701 (0.86%)
Patient days	345 484	397 222	382 388	401 822
Incidence (per 10000 patient days)	18.1	17.2	17.5	17.4
Risk difference (95% CI)	1 (ref)	0.93 (−0.83 to 2.68)	0.57 (−1.21 to 2.35)	0.67 (−1.12 to 2.46)
Relative risk (95% CI); p value	1 (ref)	0.89 (0.79 to 1.00); 0.052	0.92 (0.79 to 1.08); 0.32	0.99 (0.89 to 1.11); 0.89
Clostiidium difficile				
Exposed admissions	76 099	84 776	82 193	84 741
Incident cases (%)	375 (0.49%)	389 (0.46%)	362 (0.44%)	389 (0.46%)
Patient days	372 654	426 157	411 471	436 330
Incidence (per 10 000 patient days)	10.1	9.13	8.80	8.92
Risk difference (95% CI)	1 (ref)	0.93 (−0.31 to 2.18)	1.27 (0.005 to 2.53)	1.15 (−0.13 to 2.43)
Relative risk (95% CI); p value	1 (ref)	0.89 (0.80 to 0.99); 0031	0.91 (0.75 to 1.10); 0.32	0.97 (0.84 to 1.12); 0.68
Meticillin-resistant *Staphylococcus aureus*				
Exposed admissions	74 273	82 773	80 008	82 576
Incident cases (%)	204 (0.27%)	259 (0.31%)	234 (0.29%)	242 (0.29%)
Patient days	360 268	411 857	397 959	420 338
Incidence (per 10 000 patient days)	5.66	6.29	5.88	5.76
Risk difference (95% CI)	1 (ref)	−0.63 (−1.63 to 0.37)	−0.22 (−1.21 to 0.77)	−0.10 (−1.08 to 0.89)
Relative risk (95% CI); p value	1 (ref)	1.08 (0.89 to 1.30); 0.42	0.97 (0.76 to 1.24); 0.82	1.00 (0.87 to 1.14); 0.97
Vancomycin-resistant enterococci				
Exposed admissions	76 125	84 733	81 910	84 466
Incident cases (%)	121 (0.16%)	138 (0.16%)	189 (0.23%)	194 (0.23%)
Patient days	373 306	427 099	409 366	432 599
Incidence (per 10 000 patient days)	3.24	3.23	4.62	4.48
Risk difference (95% CI)	1 (ref)	0.010 (−0.77 to 0.79)	−1.38 (−2.21 to −0.54)	−1.24 (−2.06 to −0.42)
Relative risk (95% CI); p value	1 (ref)	0.56 (0.31 to 0.996); 0.048	0.87 (0.65 to 1.17); 0.35	1.28 (0.94 to 1.73); 0.11

OTHER IMPORTANT SURFACES

Curtains frequently contaminated with MDROs. Possible solutions: disposable curtains, antimicrobial curtains, routine disinfection of grab area. Rutala WA, …Weber, DJ. AJIC 2014;42:426-8

Shared patient items may transmit MDROs. Possible solution: Assess cleaning (fluorescent dye, ATP) with feedback, UV-C disinfection. Donskey C. AJIC 2019;47S:A90

Floors contaminated with MDROs. May serve as source for contaminating socks and shoes leading to dissemination. Possible solutions: EVS education, use disinfectant on floors, UV-C. Donskey C. AJIC 2019;47S:A90

Fabric covered chairs may be contaminated with MDROs leading to transmission among patients. Possible solution: Use only non-porous furniture in hospital to facilitate cleaning & disinfection. Noskins GA, et al. AJIC 2000;28:311.

CLEEN STUDY
(CLEaning and Enhanced disiNfectoin)

Design: 1 hospital (500 beds), 10 wards (2 per cluster, 2 week time period, 9 months; comparison arm (standard care)

Intervention: 3 extra hours per weekday, dedicated for the cleaning of shared medical equipment only (dedicated staff); Training; 2 in 1 detergent and disinfectant wipes (Clinell Universal; Clinell sporicidal for commodes); Fortnightly auditing of the thoroughness of cleaning with feedback to staff

Outcome: Proportion of adult inpatients with a HAI (any HAI); subgroup analysis also conducted by type of HAI

2nd outcomes: Thoroughness of cleaning, florescent marker and UV light; Cost-effectiveness; Cleaning time; Cleaning staff interviews

Results: 5,005 patients were included in the study; 2,497 (49·9%) in the control, 2,508 (50·1%) in the intervention; 49.5% male

- **Unadjusted results**: Control 433 HAIs from 2,497 patients (17.3%, 95%CI 15.9-18.8); Intervention 301 HAIs from 2,508 patients (12.0%, 95%CI 10.7 to 13.3)
- **Primary outcome (All HAIs)**: Control 14.9% (10.4 to 19.4); Intervention 9.8% (6.1 to 14.1); **OR 0.62 (0.45 to 0.80), p<0.001;** Absolute difference -5.2 (-8.2 to -2.3) - Relative difference -34.5 (-50.3 to -17.5)

Brett Mitchell; Presented at ESCMID, Barcelona, 27-30 April, 2024

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CONCLUSIONS

- Hospital room surfaces are frequently contaminated with epidemiologically important pathogens (e.g., MRSA; VRE; *C. difficile*; norovirus, multidrug-resistant *P. aeruginosa* and *Acinetobacter* spp; and *C. auris*)
- Epidemiologically important pathogens (EIP) may survive in the environmental for extended periods of time
- The hands and/or gloves of healthcare personnel are frequently contaminated with pathogens
- Patients admitted to a hospital room where the previous patient was colonized or infected with an EIP have a substantial risk of acquisition of colonization or infection with the same pathogen
- New studies have documented the risk of transfer of EIP between patients and the environment and vice versa
- Improved cleaning/disinfection leads to a reduction of HAIs
- Dry surface biofilms likely play role in the persistence of pathogens on environmental surfaces
- Disposable wipes have many advantages over other methods of hospital surface disinfection as they provide physical removal plus chemical disinfection
- Current evidence does NOT suggest that surface disinfectants lead to clinically relevant antibiotic resistance

THANK YOU!

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Thank you for attending today's webinar!

Scan now to download the White Paper **"Do you need to worry about disinfectant resistance?"** co-authored by Karen Wares, Clinical and Scientific Director at GAMA Healthcare, and James Clarke, Head of R&D Science and Technology at GAMA Healthcare.

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