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Microbial Pathogens and Inanimate Surfaces

SE IPAC Hub & Spoke

Cleaning and Disinfection Day

April 14, 2026

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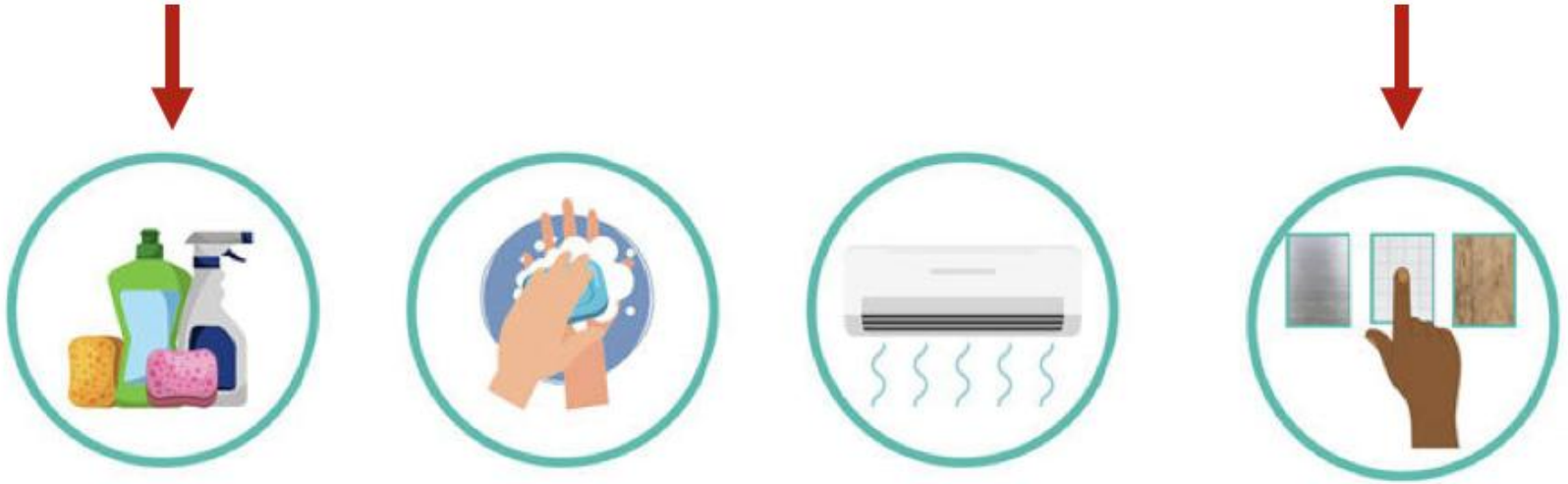
Outline: Microbial Pathogens and Inanimate Surfaces

- The role of surfaces in the transmission
- Environmental factors that influence replication of pathogens on surfaces
- Pathogen transmission routes from a contaminated surface
- How does the effectiveness of cleaning and disinfection impact transmission of pathogens
- Surface cleaning and disinfection impact on patient clinical outcomes

IPAC Measures to reduce HAI Transmission



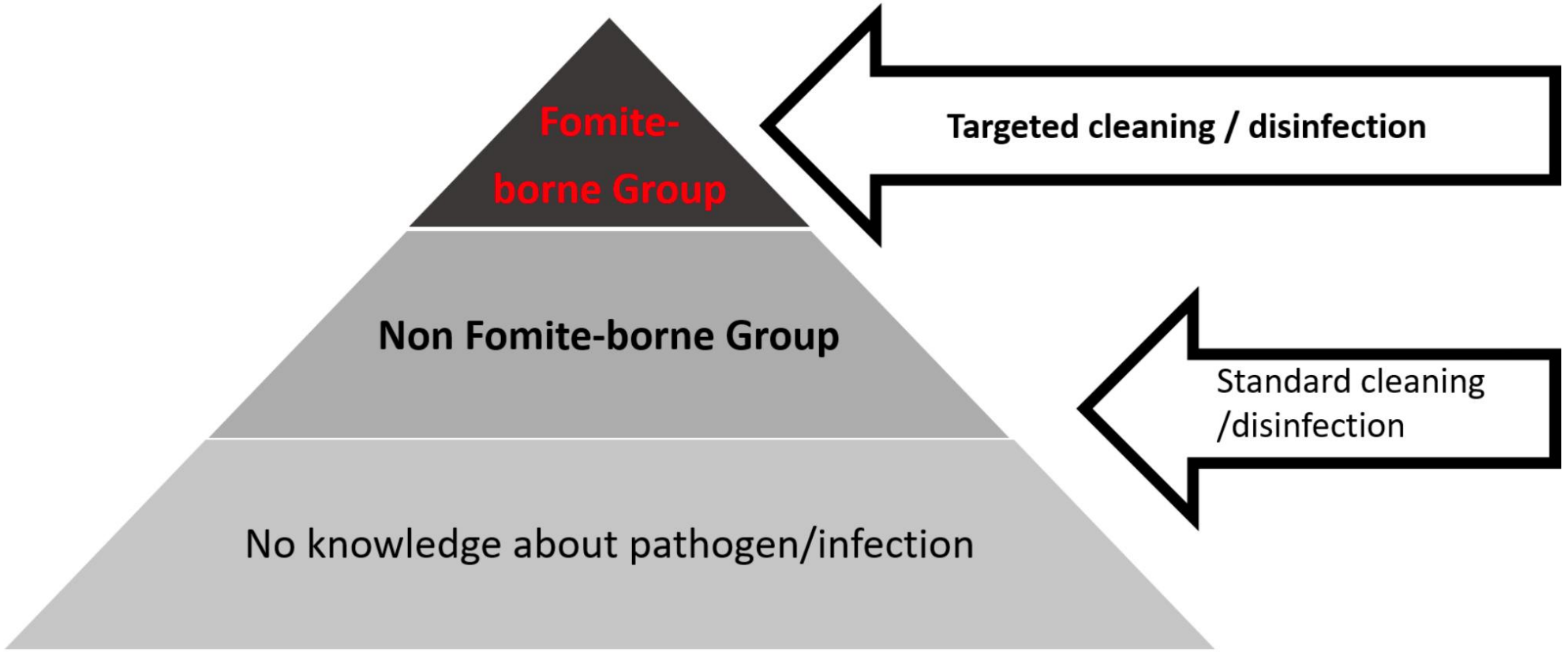
IPC measures, e.g. surface cleaning/disinfection, hand hygiene, environmental control and informed decision on surface materials

The role of surfaces in the transmission of pathogenic microorganisms causing healthcare-acquired infections

1. Microbial pathogens are shed from infected and/or colonized patients or staff into the hospital environment
2. Some pathogens, including *C. difficile* spores, VRE, and MRSA can survive for 4–5 months or more on dry surfaces
3. The levels of surface contamination by microorganisms in hospitals are low in comparison to the concentrations on patient skin or in biologic waste
   - However, the risk of transfer is also affected by the infectious dose, which for many nosocomial pathogens is low
4. Several studies show an increased risk of infection in patients admitted to side rooms previously occupied by other infected cases
5. The importance of surface contamination is also shown by the reduction in the rate of healthcare-associated infections when effective measures of environmental hygiene are implemented

Source: J Gebel et al GMS Hygiene and Infection Control 2013;8(1):1-12

Classification of pathogens with fomite-borne transmission potential and IPAC strategies



Source: A Kramer et al Clin Microbiol Rev 2024;37(4): 1-43 https://doi.org/10.1128/cmr.00186-23

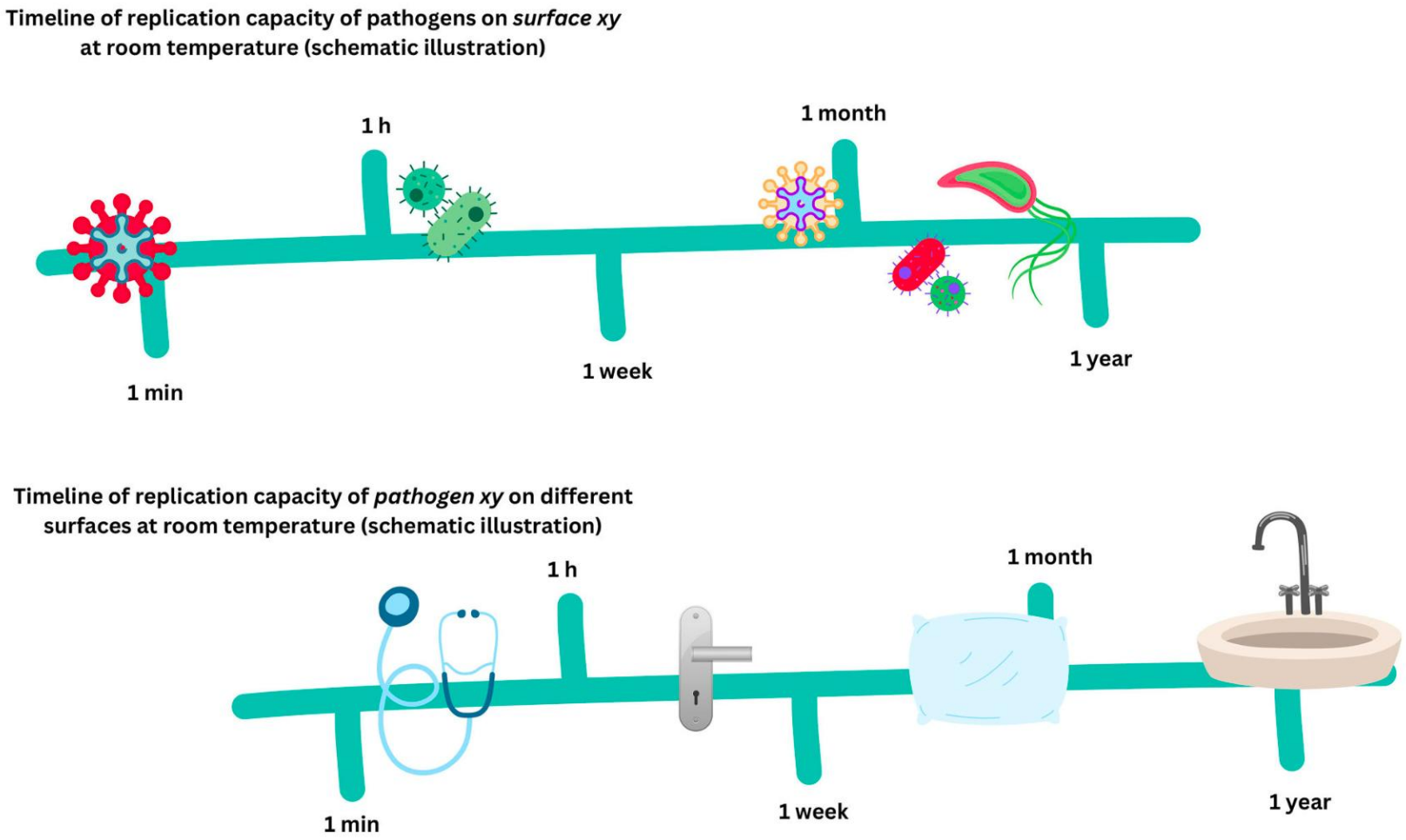
Minimal infectious dose of selected pathogens

TABLE 9 Minimal infectious dose of selected pathogens

Infectious dose	Application	Pathogen	Reference
1–100 virus particles, CFU resp. oocysts	Oral	Noro-, rotavirus, EHEC, ETEC, *C. difficile*, MRSA, *Cr. parvum*, *G. intestinalis*	(67, 311, 331, 370, 408–412)
6.6 virus particles	Inhalative	Adenovirus type 4	(331)
10–100 virus particles	Oral	HAV	(413)
30–40 $TCID_{50}$	Intranasal	RSV	(331)
6/71 $TCID_{50}$	Intranasal/oral	Coxsackievirus A21	(331)
0.03/>10^{1}–10^{4} $TCID_{50}$	Intranasal/inhalative	Rhinovirus, different serotypes	(331)
<10^{3} CFU	Oral	*Acinetobacter* spp., *C. jejuni*, *Klebsiella* spp., VRE	(67, 414)
≥10^{3} spores	Chorio-allantois-membrane hen egg (equivalent to eye contact)	*Lichtheimia corymbifera*	(415)
≥10^{3} CFU	Oral	*Salmonella enteritidis*	(416)
≥10^{3} $TCID_{50}$	Oral	Echovirus	(331)
>10^{3} $TCID_{50}$	Inhalative	Influenza A virus (H3N2)	(331)
>10^{3} LD_{50}	Intranasal	Congo Basin MPXV	(417)
≥10^{4} CFU	Conjunctival	*P. aeruginosa*	(418)
≥10^{4} to ≥10^{7} $TCID_{50}$	Inhalative	Influenza B virus	(331)
≥10^{4} spores		*Rhizopus* spp., *A. fumigatus*	(419, 420)
10^{5} $TCID_{50}$	Conjunctival	RSV	(331)
≥10^{5} CFU	Intravenous	*C. albicans*, *C. auris*	(421)
≥10^{5} spores	Parenteral	*Rhizomucor pusillus*	(419)
>10^{5} CFU	Oral	*E. coli*, *S. aureus*	(422)
>10^{5} LD_{50}	Intranasal	West African MPXV	(417)
>10^{6} $TCID_{50}$	Oral	Adenovirus	(331)
>10^{6} to >10^{7} $TCID_{50}$	Inhalative	Influenza A virus (H1N1)	
>10^{8} CFU/mL	Intraperitoneal	*P. aeruginosa*	(423)
>10^{10} CFU/mL		*S. aureus*	

Source: A Kramer et al Clin Microbiol Rev 2024;37(4): 1-43 https://doi.org/10.1128/cmr.00186-23

Different replication capacities depending on the pathogen and surface material



Source: A Kramer et al Clin Microbiol Rev 2024;37(4): 1-43 https://doi.org/10.1128/cmr.00186-23

Range of Survival by Pathogen

Table II
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.

Source: L Porter et al J Hosp Infect 2024;147:25e31 https://doi.org/10.1016/j.jhin.2024.01.023

Survival of Common Respiratory & GI viruses

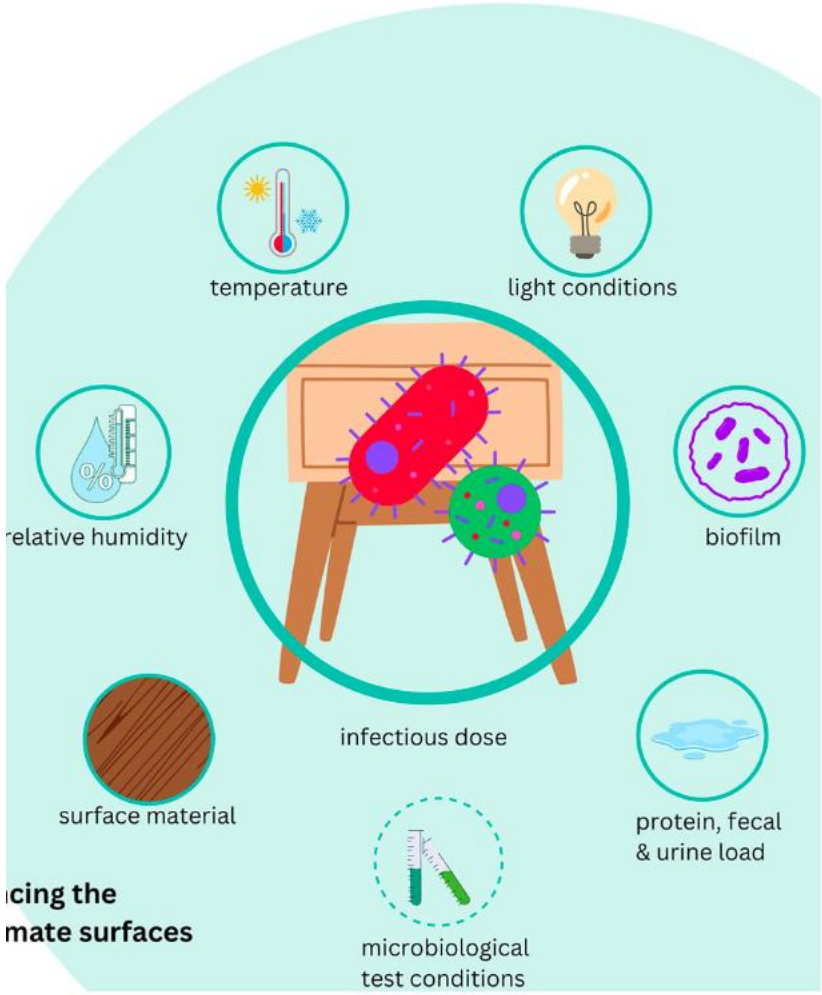
Table 2. Survival of RNA viruses.

Pathogen	Material (Cluster)	Survival (Range)	References
Influenza A-virus	Stainless steel	6 h- 2 weeks	[43–46]
	Plastics	<2 h–4 days	[23,43,44]
	Cloth	< 2 h–1 week	[43,46]
	Paper	12–24 h	[43]
	Wood	<2 h	[44]
Influenza B-virus	Stainless steel	24 h	[43]
	Plastic	24 h	[43]
	Cloth	6–8 h	[43]
	Paper	8 h	[43]
Parainfluenza virus	Stainless steel	2–>8 h	[47]
	Formica	0.5–>8 h	[47]
	Cloth	<0.5–>4 h	[47]
HCoV-OC43	Aluminum	2 h	[51]
	Sponge	<1 h	[51]
	Latex	<1 h	[51]
SARS-CoV-1 (incl. TGEV and MHV)	Plastic	72 h–9 days	[20,52,53]
	Paper	24 h	[54]
	Disposable gown	2 days	[54]
	Cloth	24 h	[54]
	Cardboard	8 h	[53]
	Copper	8 h	[53]
	Stainless steel	48 h	[53]
SARS-CoV-2	Steel	8–48 h	[56]
	Cardboard	24 h	[53]
	Copper	4 h	[53]
	Plastic	72 h–4 days	[53,57]
	Stainless steel	72 h–>8 days	[53,57,58]
	Paper	30 min–2 days	[57]
	Wood	1 day	[57]
	Glass	2 days	[57]
	Cloth	1 day	[57]
	Surgical masks	4–>7 days	[57]
Astrovirus	China	7–60 days	[59]
	Paper	7–90 days	[59]

Source: Wismann JE et al Microorganisms 2021;9:343 https://doi.org/10.3390/microorganisms9020343

Factors Influencing the Survival of Microorganisms in the Environment

1. Relative Humidity (RH)
2. Temperature
3. Biofilm
4. Light conditions
5. Biologic material
6. Surface nature
   - Porous
   - Non-porous



Source: A Kramer and O Assidian Chapter 2 Survival of Microorganisms on Inanimate Surfaces in G. Borkow (ed.), Use of Biocidal Surfaces for Reduction of Healthcare Acquired Infections, DOI 10.1007/978-3-319-08057-4_2,

Range of survival time by pathogen and surface type

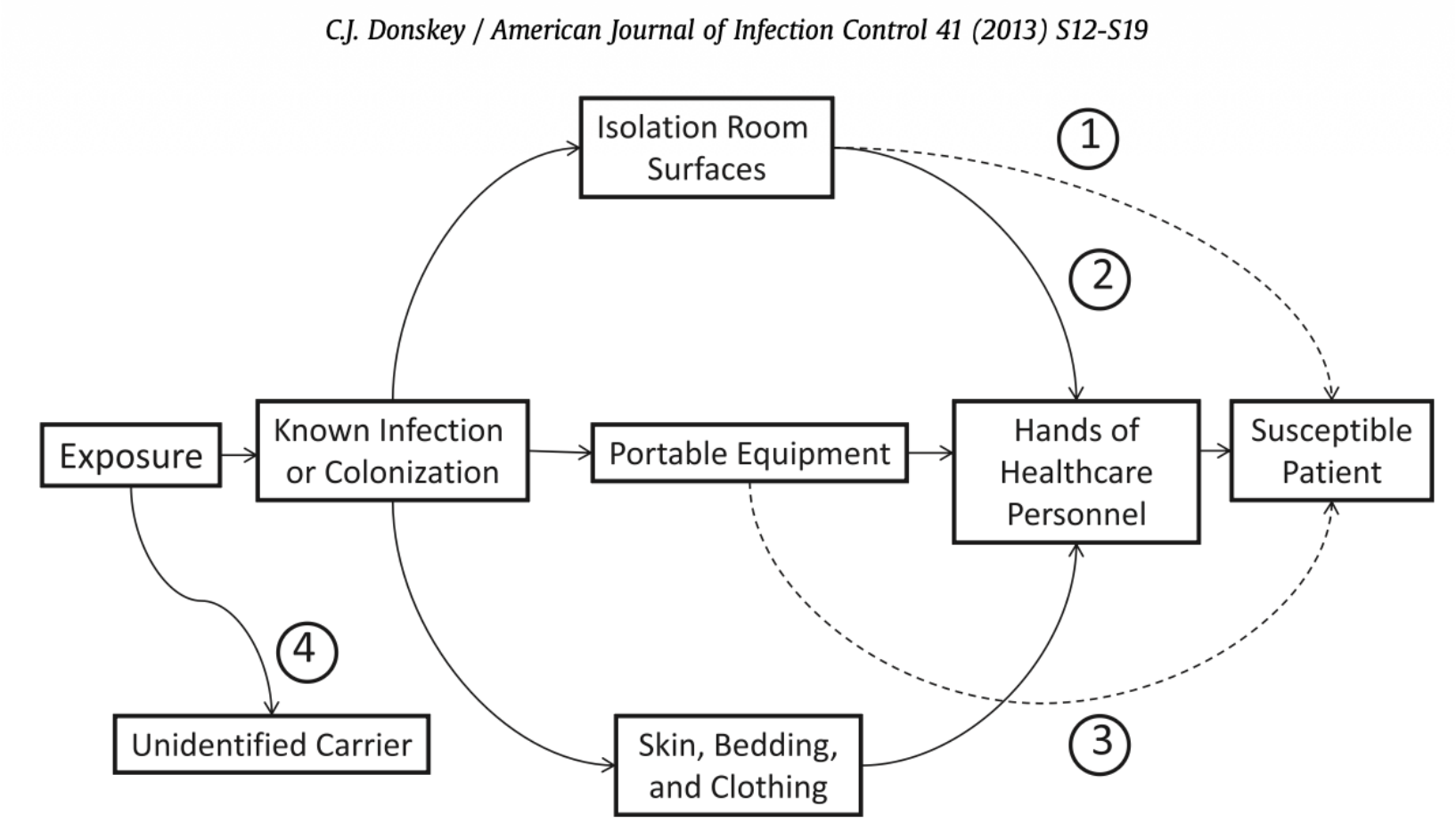
Table III
Range of survival time by pathogen and surface

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.

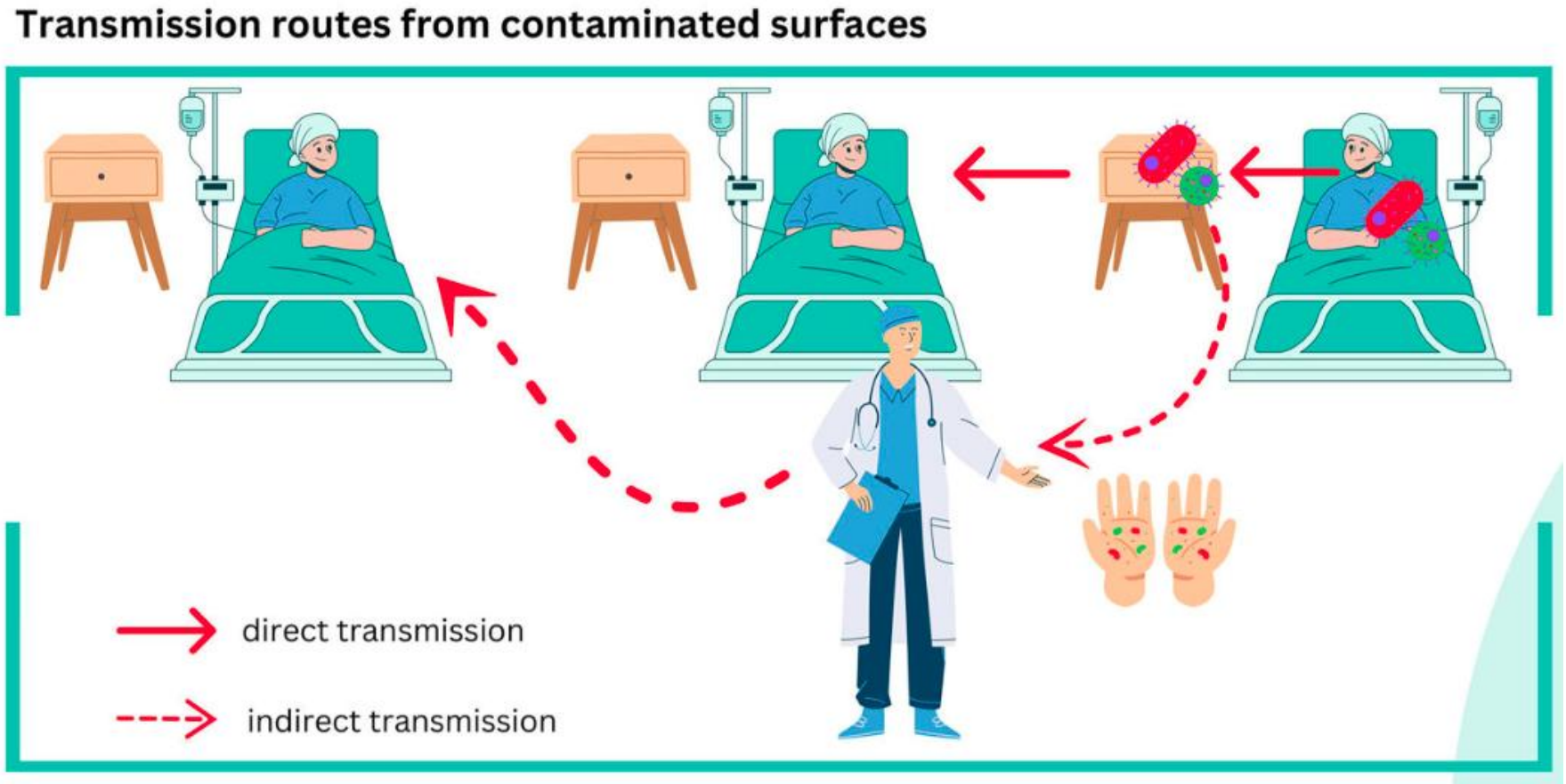
Source: L Porter et al J Hosp Infect 2024;147:25e31 https://doi.org/10.1016/j.jhin.2024.01.023

Common routes of transmission of health care-associated pathogens and potential environmental disinfection strategies



Source: CJ Donskey Am J Infect Control 2013;41:S12-S19 http://dx.doi.org/10.1016/j.ajic.2012.12.010

Transmission routes from contaminated inanimate surfaces and environmental influences



Source: A Kramer et al Clin Microbiol Rev 2024;37(4): 1-43 https://doi.org/10.1128/cmr.00186-23

Transfer of pathogens from surfaces to the hands of health care personnel

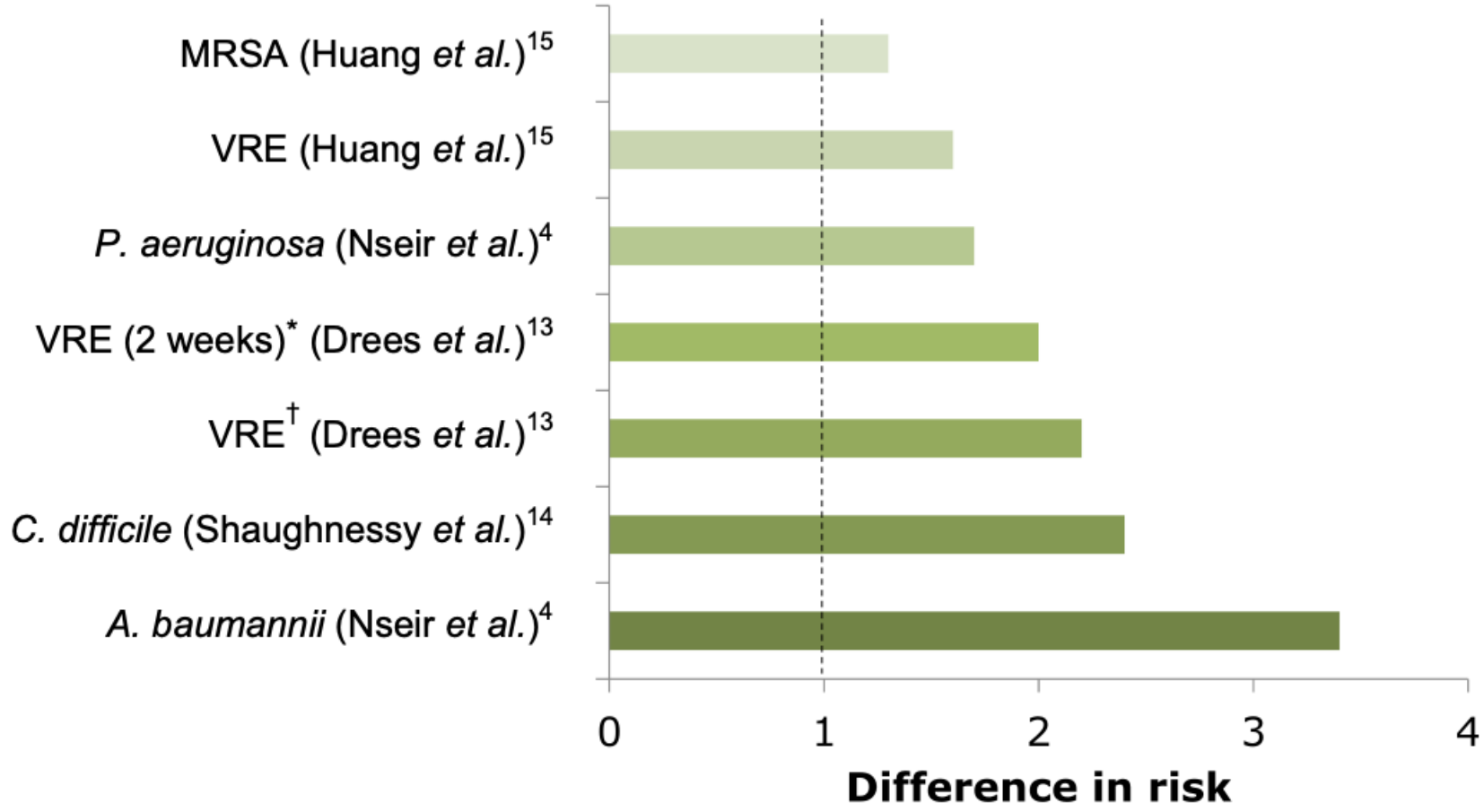
Table 2
Transfer of pathogens from surfaces to the hands of health care personnel

Direct patient contact	Contact with environmental surfaces only
	52% of 44 HCP acquired VRE on their hands or gloves[10]
45% of 50 HCP acquired MRSA on their gloved hands[39]	40% of 50 HCP acquired MRSA on their gloved hands[39]
50% of 30 HCP acquired *Clostridium difficile* on their gloved hands[40]	50% of 30 HCP acquired *C difficile* on their gloved hands[40]
Compliance with hand hygiene: 80%[41]	Compliance with hand hygiene: 50%[41]

HCP, Health care personnel.

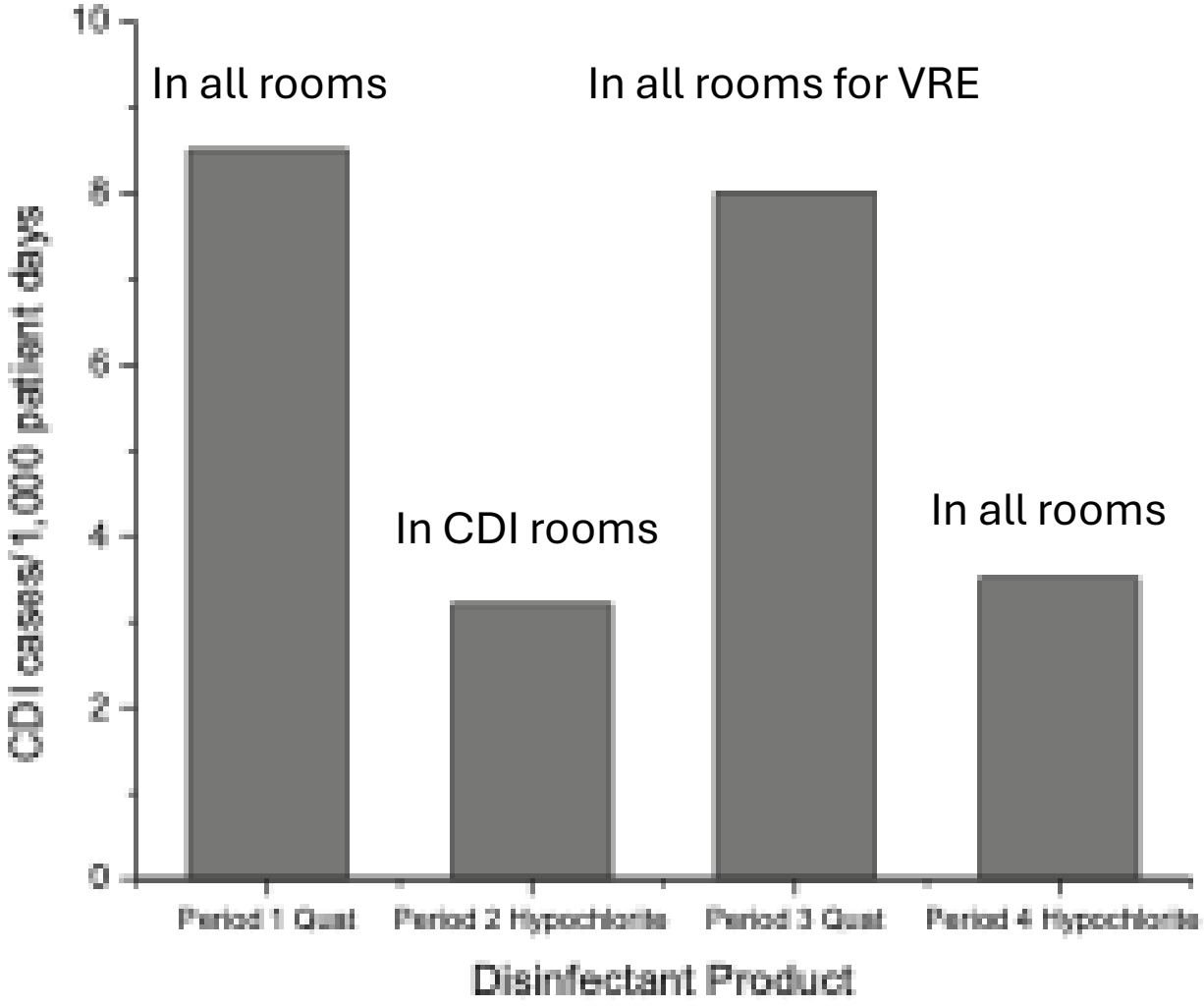
Source: J.A. Otter et al Amer J Infect Control 2013;41:S6-S11 http://dx.doi.org/10.1016/j.ajic.2012.12.004

The increased risk associated with the prior room occupant



Source: J.A. Otter et al Amer J Infect Control 2013;41:S6-S11 http://dx.doi.org/10.1016/j.ajic.2012.12.004

Incidence of CDI on a BMT unit during periods when different disinfectant products were used



Source: CJ Donskey Am J Infect Control 2013;41:S12-S19 http://dx.doi.org/10.1016/j.ajic.2012.12.010

Common cleaning and disinfection methods in healthcare

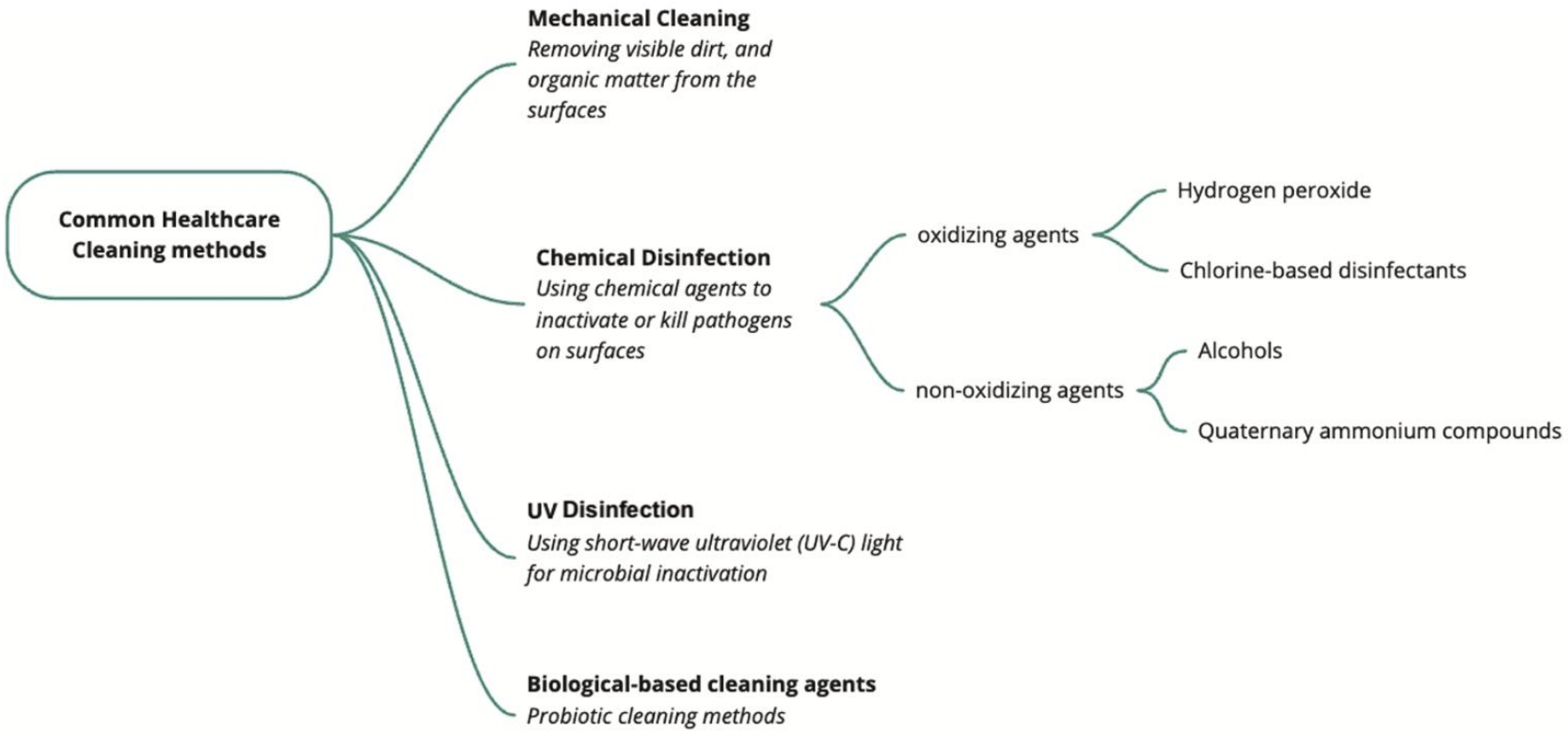


Fig. 5. Diagram of common cleaning and disinfection methods in healthcare.

Source: A Zeinali & L Sundahl Platt Building and Environment 2025;280:113179 https://doi.org/10.1016/j.buildenv.2025.113179

Studies of Cleaning Types

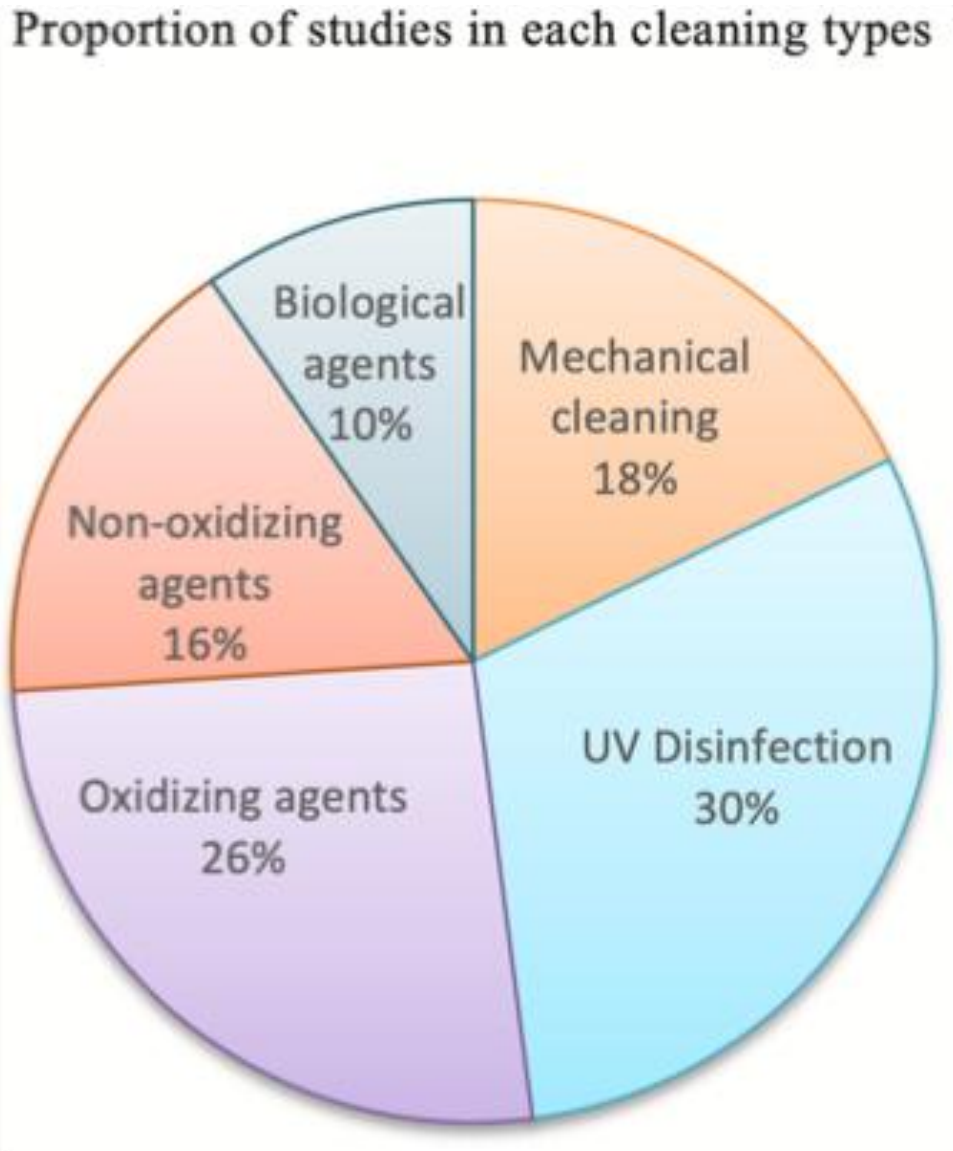


Fig. 3. Proportion of cleaning methods evaluated in included studies.

Source: A Zeinali & L Sundahl Platt Building and Environment 2025;280:113179 https://doi.org/10.1016/j.buildenv.2025.113179

Sankey diagram illustrating the frequency and diversity of tested surface materials, disinfectant types, and pathogens in the reviewed literature

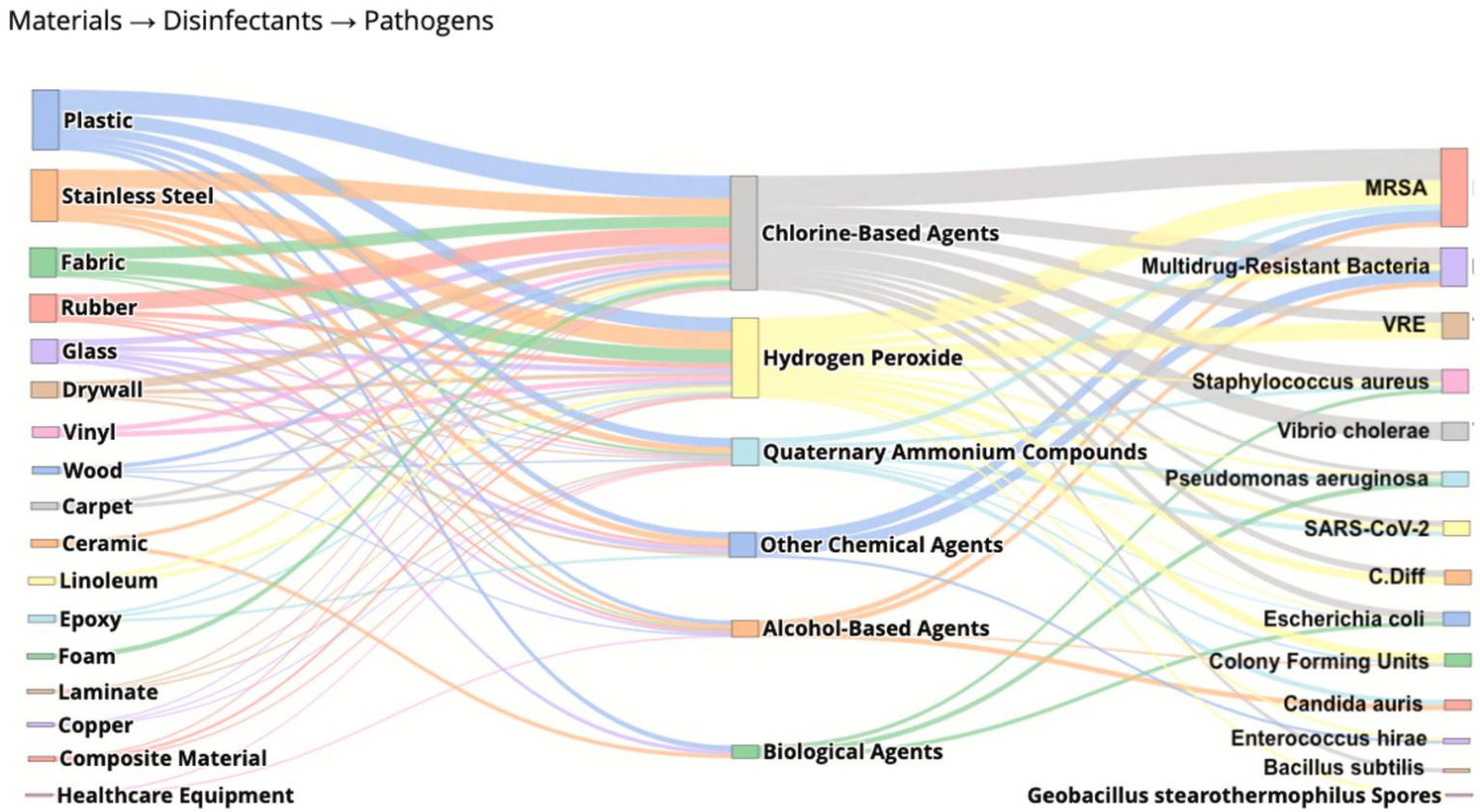


Fig. 4. Sankey diagram illustrating the frequency and diversity of tested surface materials, disinfectant types, and pathogens in the reviewed literature.

Source: A Zeinali & L Sundahl Platt Building and Environment 2025;280:113179 https://doi.org/10.1016/j.buildenv.2025.113179

Summary of cleaning methods in healthcare settings

Table 2
Summary of cleaning methods in healthcare settings.

Cleaning method	Mechanism of action	Common applications	Advantages	Limitations
Mechanical cleaning	Physically removes dirt, debris, and microorganisms through scrubbing or wiping.	General surface cleaning, and preparation before disinfection.	Simple, cost-effective, and enhances the effectiveness of subsequent disinfection.	Less effective on porous or rough surfaces and requires physical effort. Not sufficient for killing pathogens
Chemical disinfecting (oxidizing agents)	Destroys pathogens by oxidizing microbial cell walls, leading to cell death.	Disinfection of high-touch surfaces, terminal cleaning, and outbreak control.	Broad-spectrum efficacy, rapid action, effective on various pathogens.	Potential material degradation, harmful if misused, can be corrosive.
Chemical disinfecting (nonoxidizing agents)	Disrupts microbial cell membranes and proteins, leading to cell inactivation.	Routine disinfection, maintenance cleaning, high-touch surfaces.	Non-corrosive options available leave a persistent antimicrobial residue.	Reduced efficacy in the presence of organic matter, the potential for resistance development.
UV disinfection	Uses UV-C light to disrupt microbial DNA, preventing replication.	Terminal disinfection, supplement to manual cleaning in critical areas.	No chemical residues, broad antimicrobial action, effective on nonporous surfaces.	Less effective on porous/textured surfaces, risk of material degradation with prolonged exposure.
Probiotic cleaning	Uses beneficial microorganisms to outcompete harmful pathogens on surfaces.	Routine cleaning in low-risk areas, complementary to chemical cleaning.	Environmentally friendly, non-toxic, maintains beneficial surface microbiomes.	Variable efficacy depends on surface type, less effective in high-contamination areas.

Source: A Zeinali & L Sundahl Platt Building and Environment 2025;280:113179 https://doi.org/10.1016/j.buildenv.2025.113179

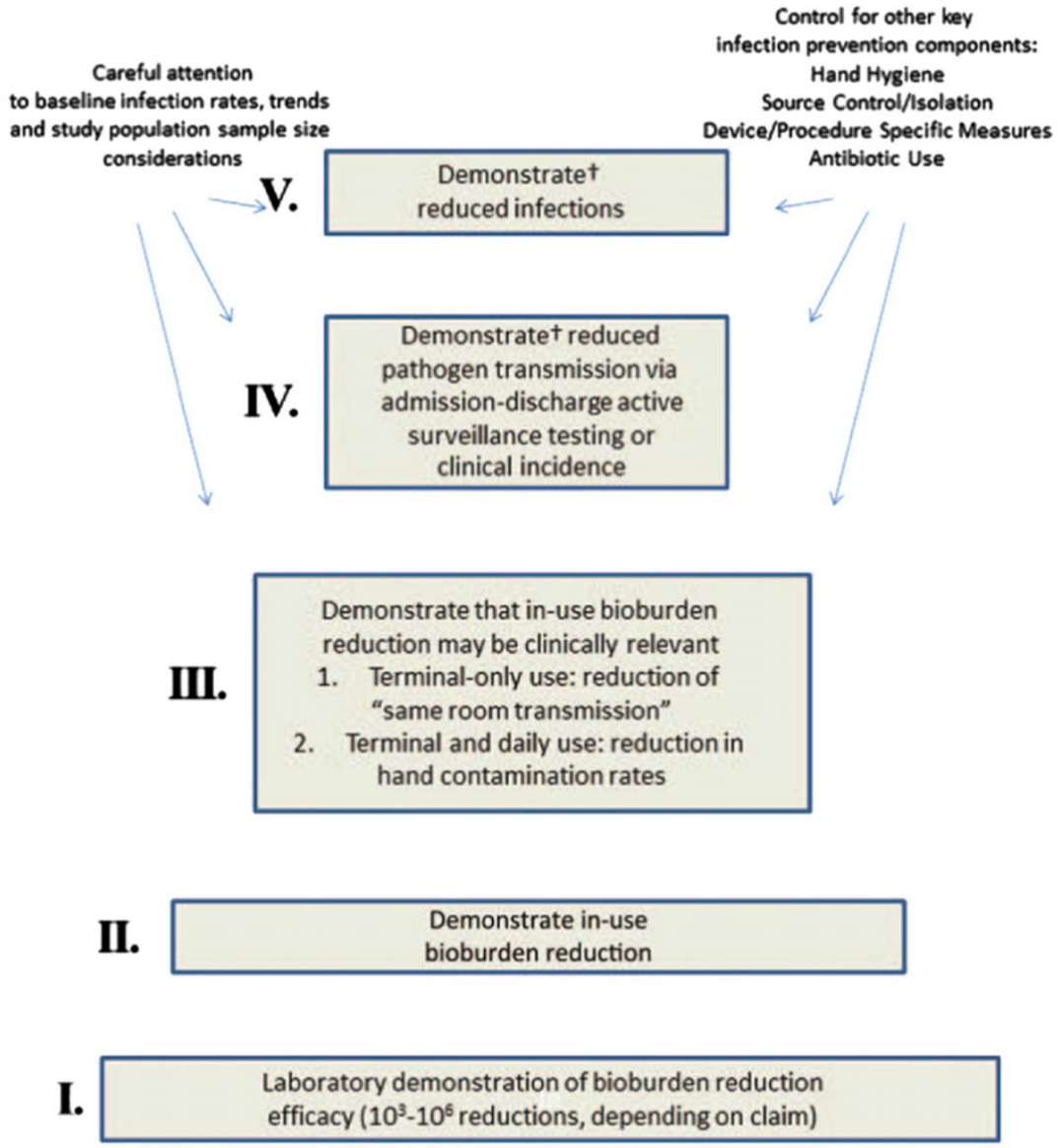
Challenges: Compatibility of surface materials with chemical disinfectants

Table 5
Compatibility of surface materials with chemical disinfectants.

Disinfectant type	Common uses	Compatible materials	Incompatible materials	Potential degradation effects
Hydrogen peroxide (H2O2)	High-touch surfaces, terminal cleaning, outbreak control	Stainless steel, glass, composite epoxy	Textiles, some plastics (e.g., ABS, PVC), wood	Weakens textiles, can cause discoloration on certain plastics
Sodium hypochlorite (bleach)	General disinfection, biofilm control, high-risk areas	Stainless steel, glass, low-density polyethylene	Metals (prone to corrosion), certain plastics	Corrosive to metals, can degrade some plastics over time
Quaternary ammonium compounds (QACs)	Routine surface cleaning, maintenance, nonporous materials	Glass, metals, treated plastics	Textiles, microfiber cloths (absorbs disinfectant)	Reduced efficacy on porous materials, potential resistance buildup
Alcohol-based solutions	Surface disinfection, equipment that cannot tolerate moisture	Glass, stainless steel, polished surfaces	Certain plastics, rubber, porous materials	Damages some plastics and rubber, less effective on organic debris

Source: A Zeinali & L Sundahl Platt Building and Environment 2025;280:113179 https://doi.org/10.1016/j.buildenv.2025.113179

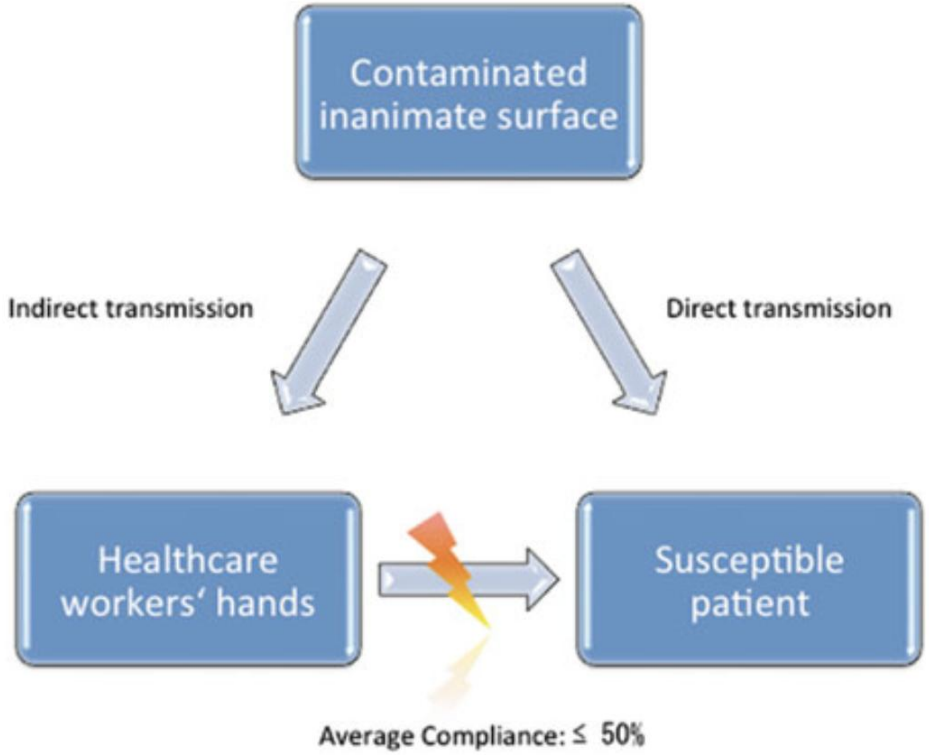
Evidence hierarchy for increasing patient safety through health care environmental surface cleaning and disinfection



Source: CJ Donskey Am J Infect Control 2013;41:S12-S19 http://dx.doi.org/10.1016/j.ajic.2012.12.010

Impact of Surface Disinfection on Patient Outcomes and Transmission

- There is reasoned evidence in the literature that environmental cleaning reduces adverse clinical outcomes (e.g., patient infections and outbreaks)
- Reduced recovery of pathogens from surfaces when cleaning is done correctly, shows less transmission of *C. difficile* and *VRE*, both of which are pathogens with a relevant environmental reservoir



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2. A Kramer and O Assidian Chapter 2 Survival of Microorganisms on Inanimate Surfaces in G. Borkow (ed.), Use of Biocidal Surfaces for Reduction of Healthcare Acquired Infections, DOI 10.1007/978-3-319-08057-4_2

Clinical Effect of Various Disinfection Practices

Table 1
Studies involving disinfectant product substitutions

Ref	Setting and organism	Product	Practice	Monitoring of disinfection	Effect
31	2 Hospital wards Nosocomial infections	Active oxygen-based compound	Daily cleaning of floors and furniture	Cultures: decreased bacterial load on surfaces	No reduction in bloodstream infections or MRSA colonization or infection
32	Medical ward *Clostridium difficile*	Hypochlorite 500 ppm	Terminal CDI rooms	Cultures: surface contamination decreased to 21% of initial levels	Outbreak ended
33	Bone marrow transplant (BMT) unit, Medical Ward, ICU *Clostridium difficile*	Hypochlorite 5,000 ppm	Terminal CDI rooms	No	Significant decrease on BMT unit but not on the other 2 wards
34	2 Medical wards (crossover study) *Clostridium difficile*	Hypochlorite 1,000 ppm	Terminal CDI rooms	Cultures: no decrease in the percentage of positive environmental cultures	Decreased on 1 of 2 wards
35	Medical and surgical ICUs *Clostridium difficile*	Hypochlorite 5,000 ppm	Ward 1: terminal CDI rooms; ward 2: all rooms	No	Decreased on both units
36	3 Hospitals *Clostridium difficile*	Hypochlorite 5,000 ppm	Terminal CDI rooms	No	48% decrease in prevalence density of CDI
25	2 Medical wards *Clostridium difficile*	Hypochlorite 5,500 ppm (wipes)	Terminal and daily CDI and non-CDI rooms	Yes (ATP bioluminescence)	85% decrease in hospital acquired CDI

ATP, Adenosine triphosphate; *BMT*, Bone marrow transplant; *CDI*, *C difficile* infection; *ICU*, intensive care unit; *PPM*, parts per million; *Ref*, reference number.
NOTE. 5,000 ppm = 1:10 dilution of household bleach.

Source: CJ Donskey Am J Infect Control 2013;41:S12-S19 http://dx.doi.org/10.1016/j.ajic.2012.12.010


N. Lotfinejad