
ROLE OF THE SURFACE ENVIRONMENT IN THE SPREAD OF HEALTHCARE-ASSOCIATED PATHOGENS

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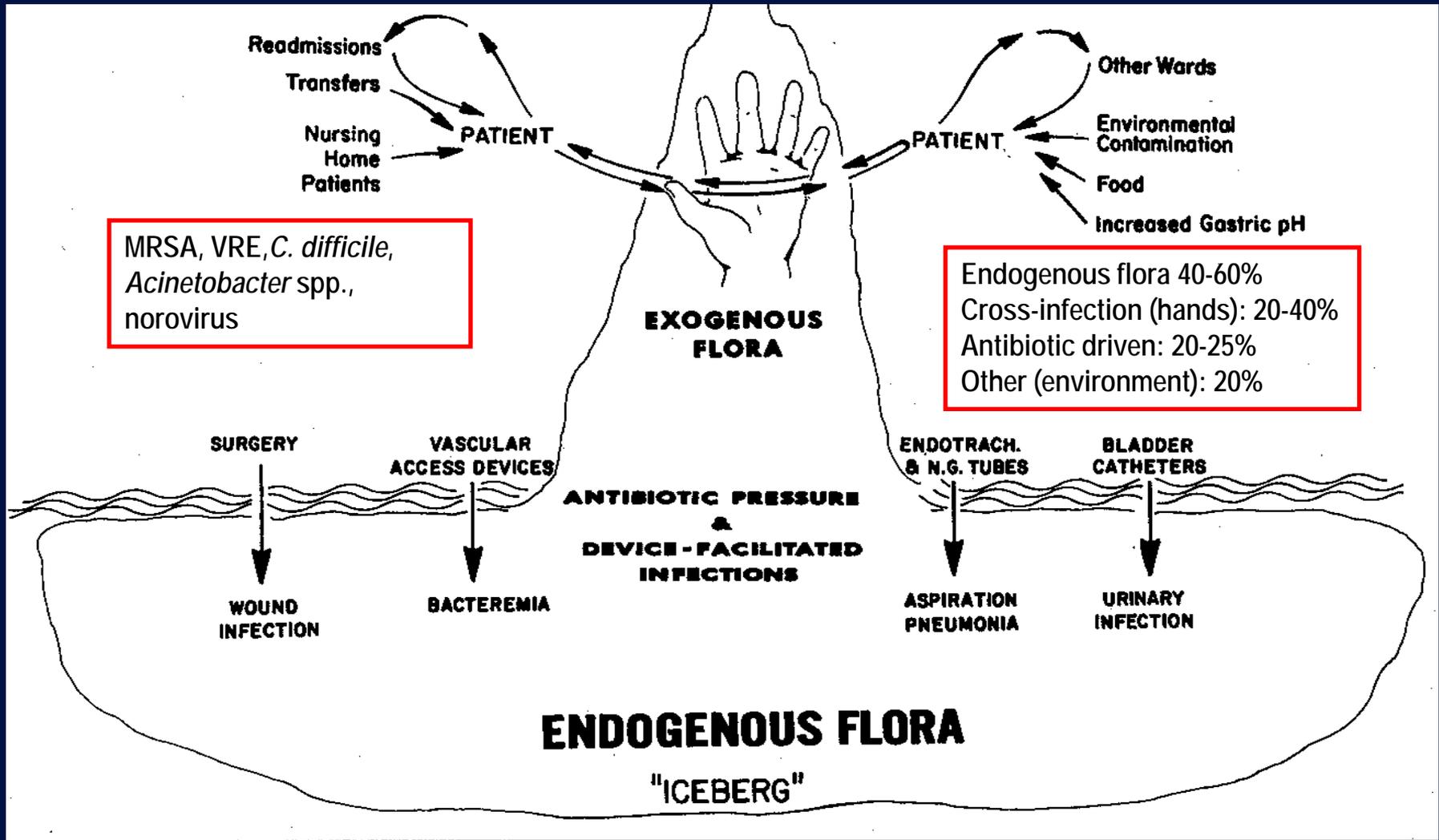
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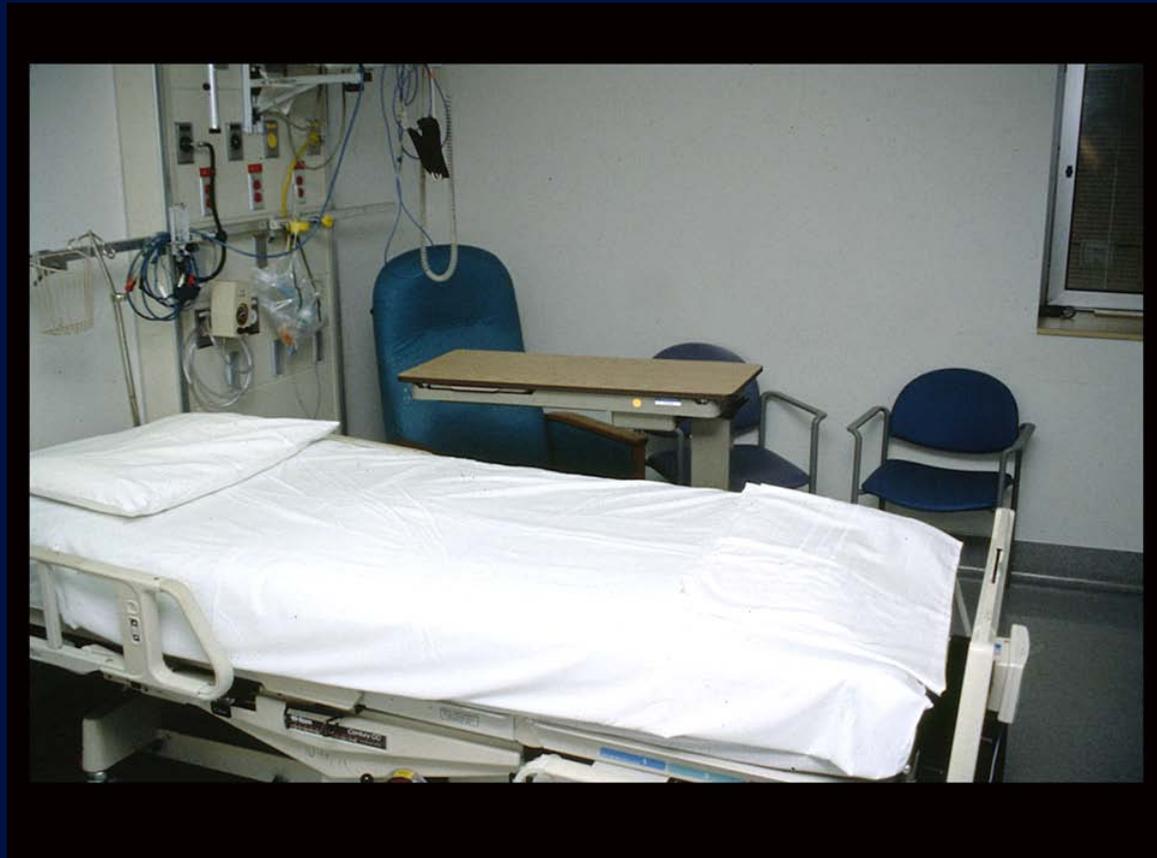
LECTURE OBJECTIVES

- Understand the pathogens for which contaminated hospital surfaces play a role in transmission
- Understand the characteristics of healthcare-associated pathogens associated with contaminated surfaces
- Understand how to prevent transmission of pathogens associated with contaminated surfaces

HAZARDS IN THE HOSPITAL



ROLE OF ENVIRONMENTAL CONTAMINATION IN TRANSMISSION OF HEALTHCARE-ASSOCIATED PATHOGENS



KEY PATHOGENS WHERE ENVIRONMENTAL SURFACES PLAY A ROLE IN TRANSMISSION

- MRSA
- VRE
- *Acinetobacter* spp.
- *Clostridium difficile*
- Norovirus
- Rotavirus
- SARS

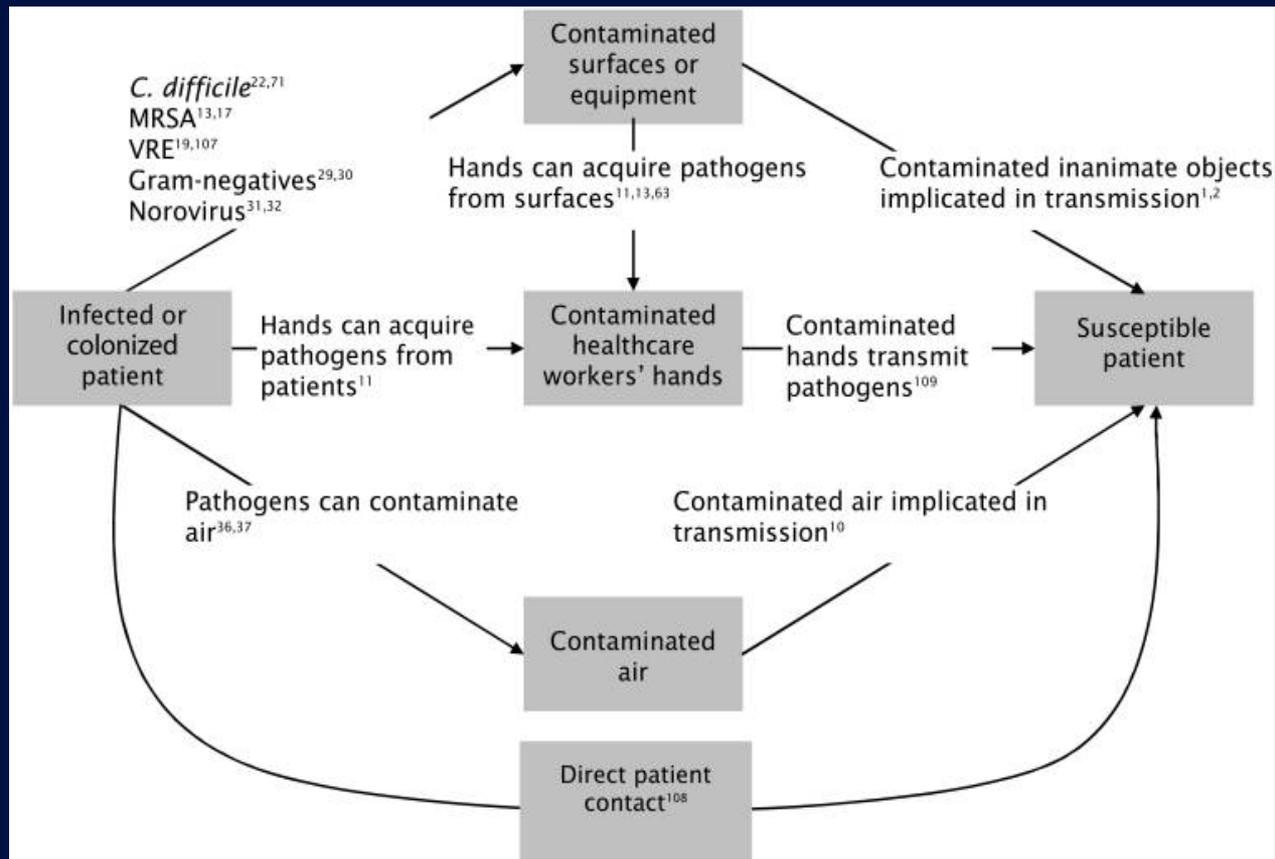
MICROBIAL FACTORS THAT FACILITATE ENVIRONMENTAL TRANSMISSION

- Ability to survive in the environment for hours to days
- Ability to remain virulent after environmental exposure
- Low inoculating dose
- Deposition on surfaces frequently touched by HCP must occur
- Ability to colonize patients
- Transmission directly or via the contaminated hands of HCP
- Relative resistance to antiseptics (norovirus, *C. difficile*)
- Relative resistance to disinfectants (norovirus, *C. difficile*)

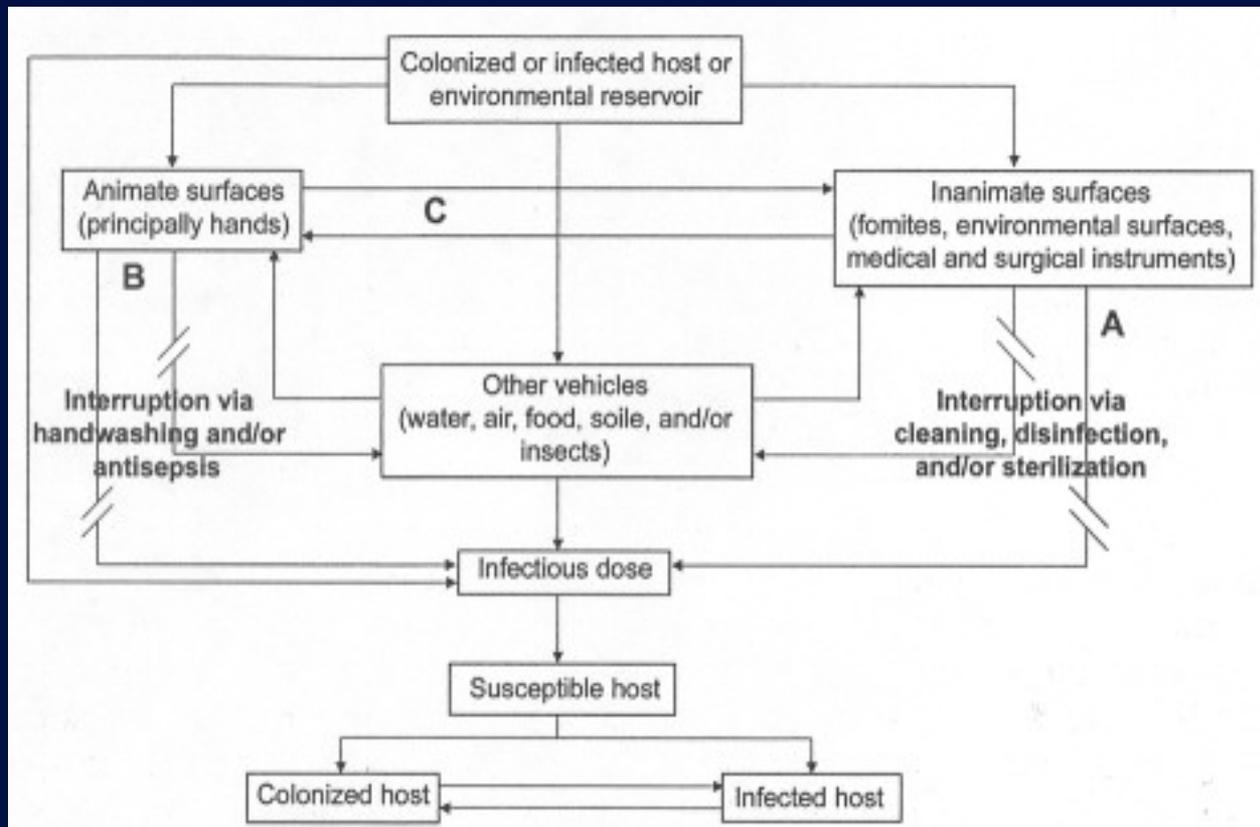
PROVING THAT ENVIRONMENTAL CONTAMINATION LEADS TO NOSOCOMIAL INFECTIONS

- Demonstration of microbial persistence in the environment: *In vitro* studies and environmental samples
- Demonstration of frequent environmental contamination
- Demonstration of HCW hand contamination
- Relationship between level of environmental contamination and hand contamination
- Demonstration of person-to-person transmission (molecular link)
- Demonstration that being housed in a room previously occupied by a patient with the pathogen of interest is a risk factor for disease
- Demonstration that improved surface cleaning/disinfection reduces disease incidence

TRANSMISSION MECHANISMS INVOLVING THE SURFACE ENVIRONMENT



TRANSMISSION MECHANISMS INVOLVING THE SURFACE ENVIRONMENT



Rutala WA, Weber DJ. In: "SHEA Practical Healthcare Epidemiology" (Lautenbach E, Woeltje KF, Malani PN, eds), 3rd ed, 2010.

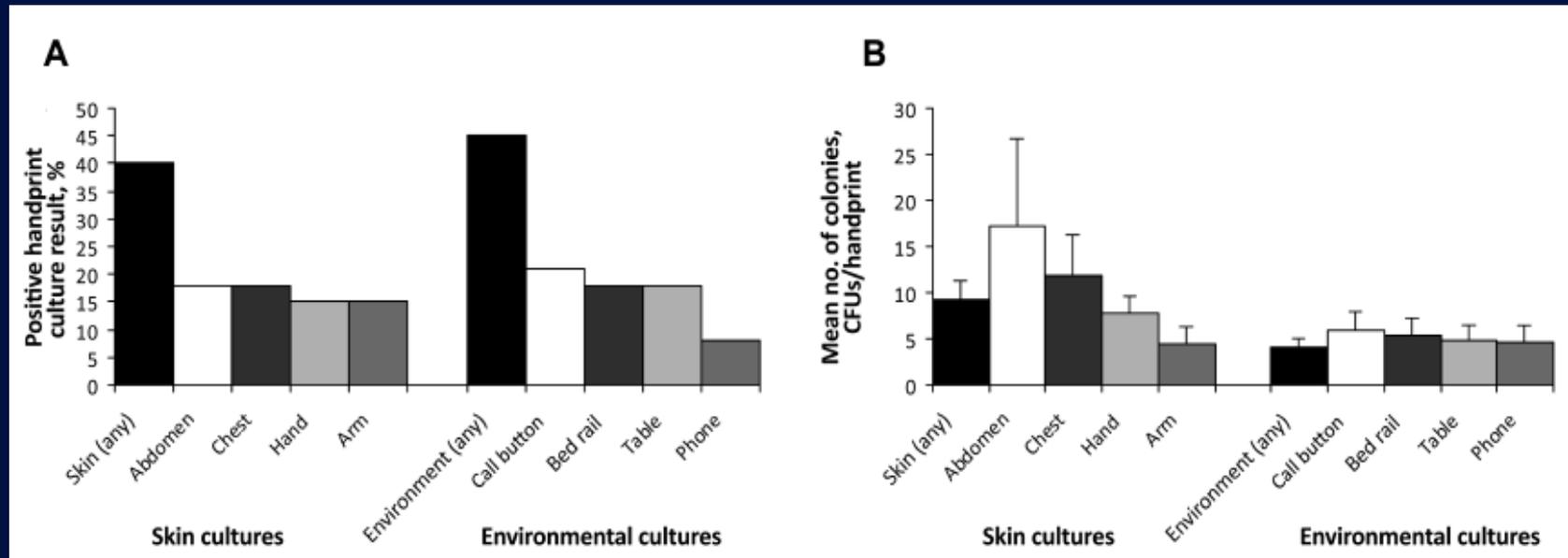
ENVIRONMENTAL SURVIVAL OF KEY PATHOGENS

Pathogen	Survival	Environmental Data
MRSA	Days to weeks	2-3+
VRE	Days to weeks	3+
<i>Acinetobacter</i>	Days to months	2-3+
<i>C. difficile</i>	Months (spores)	3+
Norovirus	Days to weeks	3+

Adapted from Hota B, et al. Clin Infect Dis 2004;39:1182-9 and
Kramer A, et al. BMC Infectious Diseases 2006;6:130

FREQUENCY OF ACQUISITION OF MRSA ON GLOVED HANDS AFTER CONTACT WITH SKIN AND ENVIRONMENTAL SITES

No significant difference on contamination rates of gloved hands after contact with skin or environmental surfaces (40% vs 45%; $p=0.59$)



Environmental Contamination

Endemic and Epidemic MRSA

	Outbreak	Endemic			Site estimated mean§	
	Rampling et al ^{27*}	Boyce et al ^{48*}	Sexton et al ^{51†}	Lemmen et al ^{50* ‡}		French et al ^{64*}
Floor	9%	50–55%	44–60%	24%	..	34.5%
Bed linen	..	38–54%	44%	34%	..	41%
Patient gown	..	40–53%	..	34%	..	40.5%
Overbed table	..	18–42%	64–67%	24%	..	40%
Blood pressure cuff	13%	25–33%	..	..	..	21%
Bed or siderails	5%	1–30%	44–60%	21%	43%	27%
Bathroom door handle	..	8–24%	..	12%¶	..	14%
Infusion pump button	13%	7–18%	..	30%	..	19%
Room door handle	11%	4–8%	..	23%	59%	21.5%||
Furniture	11%	..	44–59%	19%	..	27%
Flat surfaces	7%	..	32–38%	..	..	21.5%
Sink taps or basin fitting	..	..	..	14%	33%	23.5%
Average quoted**	11%	27%	49%	25%	74%	37%

Room Contamination

Post-Discharge Cleaning

Pathogen	% Contaminated After Discharge Cleaning
MRSA ¹	74% of surface cultures
MRSA ²	46% of rooms
MRSA ³	24% of rooms
VRE ³	22% of rooms
VRE ⁴	16% of rooms

¹ French GL et al. J Hosp Infect 2004;57:31-7

² Blythe D et al. J Hosp Infect 1998;38:67-70

³ Goodman ER et al. Infect Control Hosp Epidemiol 2008; 29:593-9

⁴ Byers KE. ICHE 1998;19:261-4.

Cross-Transmission

Pathogen	% Cross-Contamination	Transmission
VRE ¹	12% of all room cultures	41% of vent patients
VRE ²	12% of all room cultures	21 clonal cases
MRSA ³	40% of transmission from strains found in other patients	4%
MRSA ⁴	11% of all room cultures	69 clonal cases

¹ Bonten MJM et al. Lancet 1996;348:1615-19

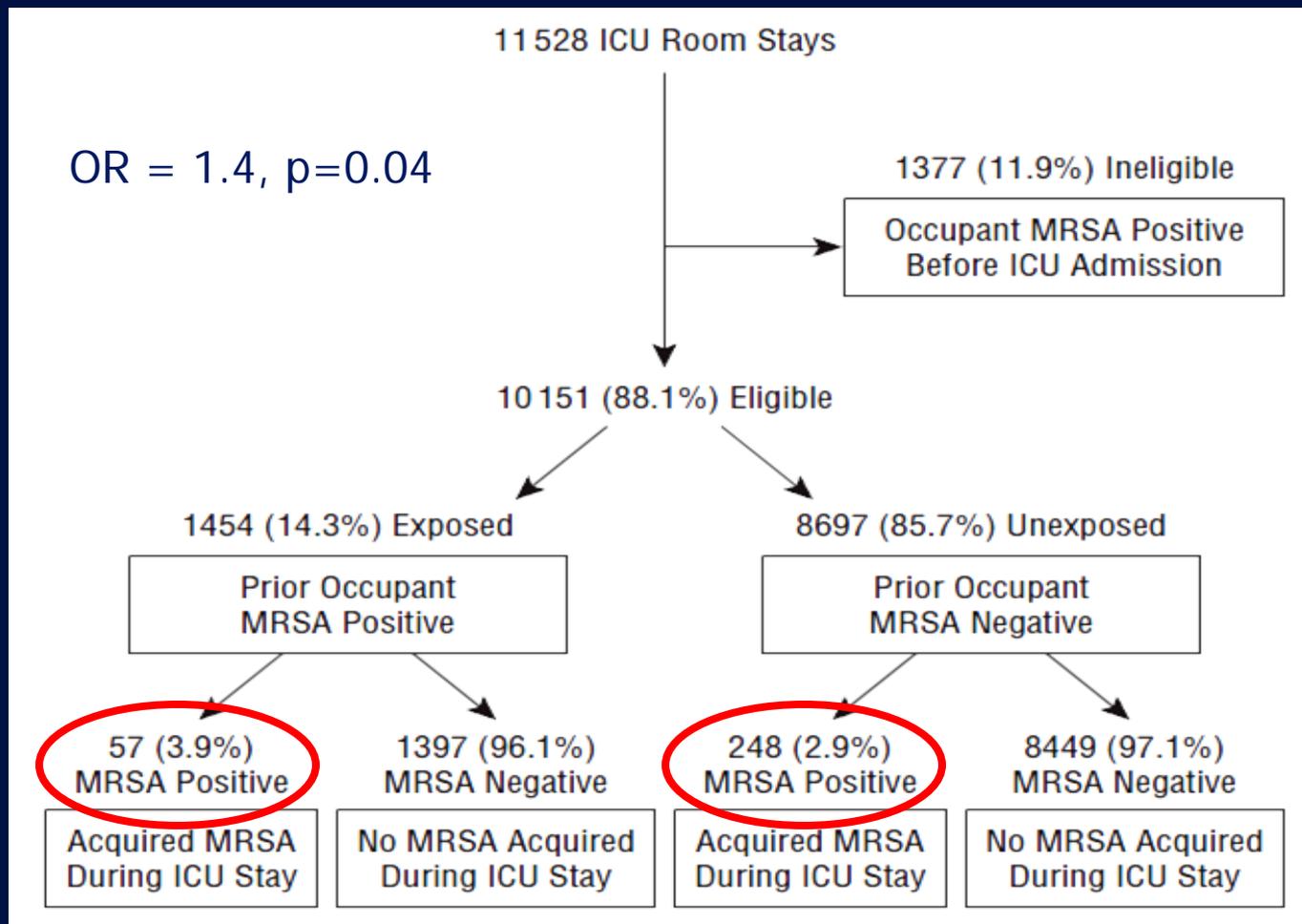
² Falk PS et al. ICHE 2000;21:575-82

³ Bloemendaal ALA et al. ICHE 2009;30(2):117-24

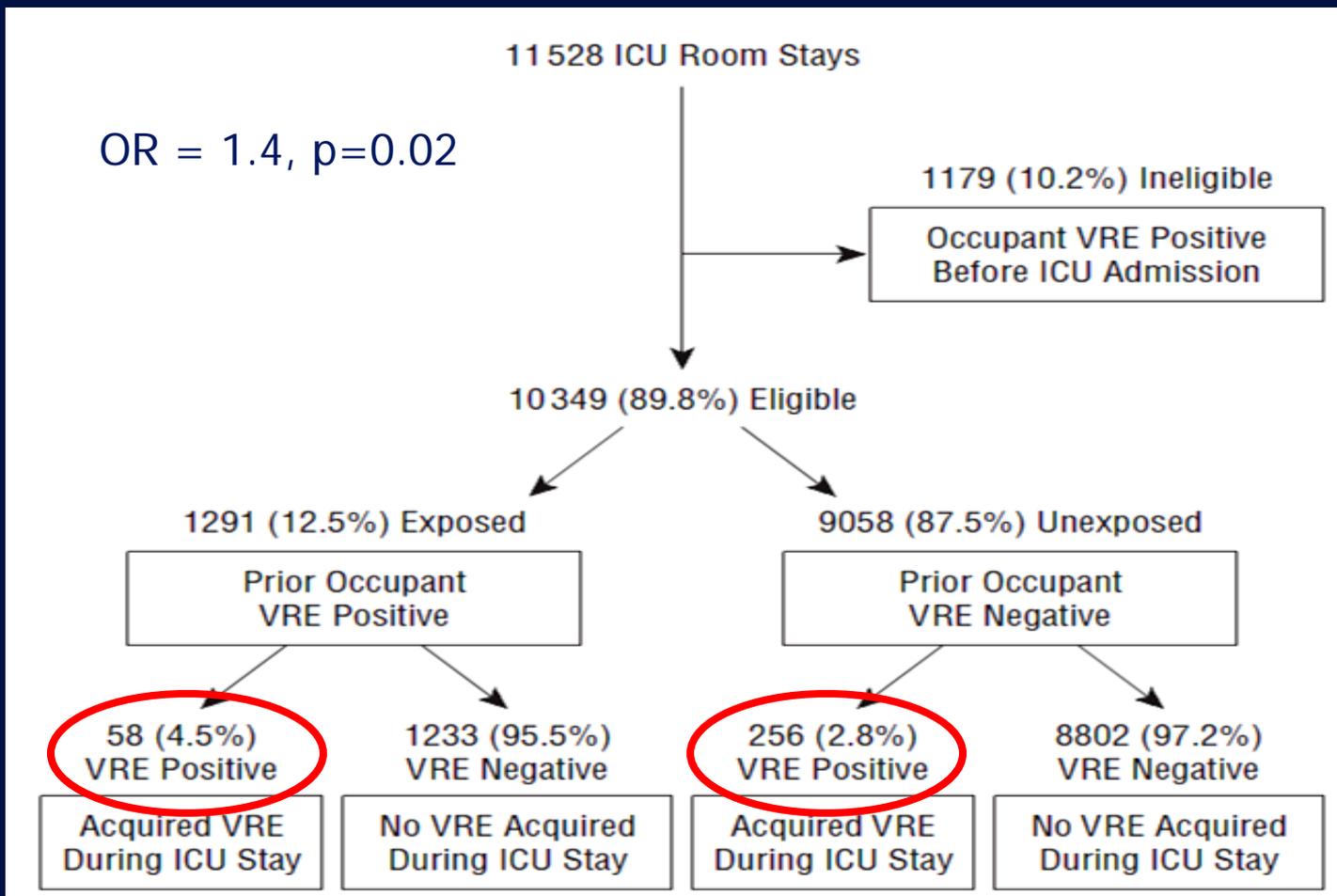
⁴ Rampling A et al. J Hosp Infection 2001;49:109-16

Risk of MRSA from Prior Room Occupant

20 month study, 10 ICUs



Risk of VRE from Prior Room Occupant 20 month study, 10 ICUs



NOROVIRUS: MICROBIOLOGY AND EPIDEMIOLOGY

- Classified as a calicivirus: RNA virus, non-enveloped
- Prevalence
 - Causes an estimated 23 million infections per year in the US
 - Results in 50,000 hospitalizations per year (310 fatalities)
 - Accounts for >90% of nonbacterial and ~50% of all-cause epidemic gastroenteritis
- Infectious dose: 10-100 viruses ($ID_{50} = 18$ viruses)
- Fecal-oral transmission (shedding for up to 2-3 weeks)
 - Direct contact and via fomites/surfaces; food and water
- Droplet transmission? (via ingestion of airborne droplets of virus-containing particles)
- May cause chronic infection in transplant recipients

FACTORS LEADING TO ENVIRONMENTAL TRANSMISSION OF NOROVIRUS

- Stable in the environment
- Low inoculating dose
- Common source of infectious gastroenteritis
- Frequent contamination of the environment
- Susceptible population (limited immunity)
- Relatively resistant to disinfectants

ROLE OF THE ENVIRONMENT

1. Prolonged outbreaks on ships suggest norovirus survives well
2. Outbreak of GE affected more than 300 people who attended a concert hall over a 5-day period. Norwalk-like virus (NLV) confirmed in fecal samples by RT-PCR. The index case was a concert attendee who vomited in the auditorium. GI illness occurred among members of 8/15 school parties who attended the following day. Disinfection procedure was poor. Evans et al. *Epid Infect* 2002;129:355
3. Extensive environmental contamination of hospital wards
Suggest transmission most likely occurred through direct contact with contaminated fomites.

GUIDELINE FOR THE PREVENTION OF NOROVIRUS OUTBREAKS IN HEALTHCARE, HICPAC, 2011

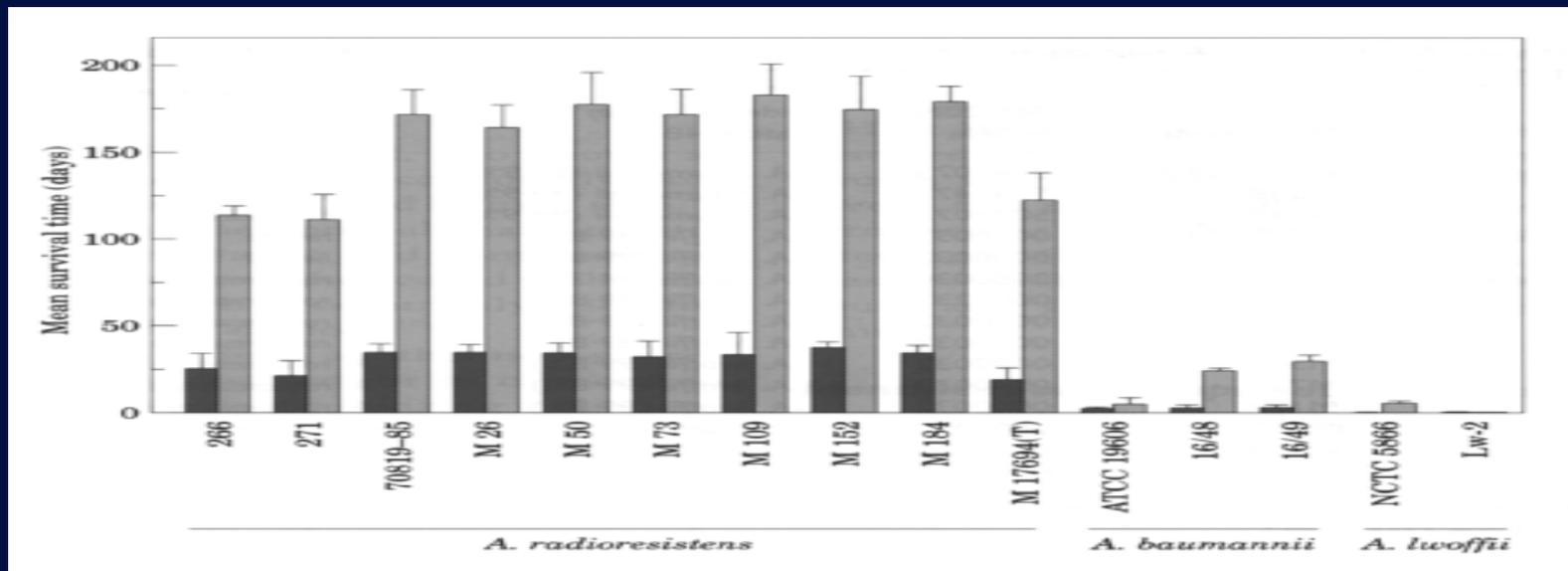
- Avoid exposure to vomitus or diarrhea. Place patients with suspected norovirus on Contact Precautions in a single room (IB)
 - Continue Precautions for at least 48 hours after symptom resolution (IB)
 - Use longer isolation times for patients with comorbidities (II) or <2 yrs (II)
- Consider minimizing patient movements within a ward (II)
 - Consider restricting movement outside the involved ward unless essential (II)
 - Consider closure of wards to new admissions (II)
- Exclude ill personnel (IB)
- During outbreaks, use soap and water for hand hygiene (IB)
- Clean and disinfect patient care areas and frequently touched surfaces during outbreaks 3x daily using EPA approved healthcare product (IB)
- Clean surfaces and patient equipment prior to disinfection. Use product with an EPA approved claim against norovirus (IC)

ACINETOBACTER AS A HOSPITAL PATHOGEN

- Gram negative aerobic bacillus
- Common nosocomial pathogen
- Pathogenic: High attributable mortality (Falagas M, et al. Crit Care 2007;11:134)
 - Hospitalized patients: 8-23%
 - ICU patients: 10-43%
- Ubiquitous in nature and hospital environment
 - Found on healthy human skin
 - Found in the environment
- Survives in the environment for a prolonged period of time
- Often multidrug resistant

A. baumannii SURVIVAL ON DRY SURFACES

- Environmental survival (Sheifert et al. J Clin Microbiol 1998;36:1938)
 - 27.29 days, sporadic strains
 - 26.55 days, outbreak strains



ACINETOBACTER CONTAMINATION OF THE ENVIRONMENT

- *Acinetobacter* isolated from curtains, slings, patient-lift equipment, door handles, and computer keyboards (Wilks et al. ICHE 2006;27:654)
- *A. baumannii* isolated from 3% of 252 environmental samples: 2/6 stethoscopes, 1/12 patient records, 4/23 curtains, 1/23 OR lights (Young et al. ICHE 2007;28:1247)
- *A. baumannii* isolated from 41.4% of 70 environmental cultures: 9 headboards, 2 foot of bed, 6 resident desks, 8 external surface ET tube (Markogiannakis et al. ICHE 2008;29:410)
- *Acinetobacter* isolated from environmental surfaces on 2 occasions (Shelburne et al. J Clin Microbiol 2008;46:198)
- *A. baumannii* isolated from 21 environmental samples: 4 ventilator surfaces, 4 bedside curtains, 1 bed rail (Chang et al. ICHE 2009;30:34)

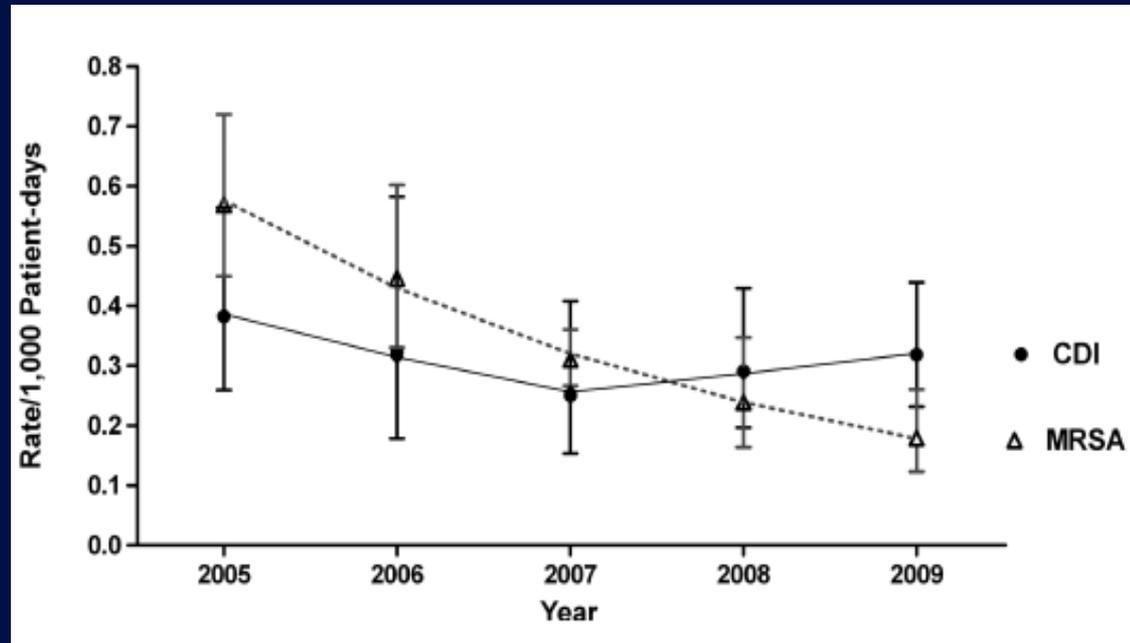
C. difficile:

MICROBIOLOGY AND EPIDEMIOLOGY

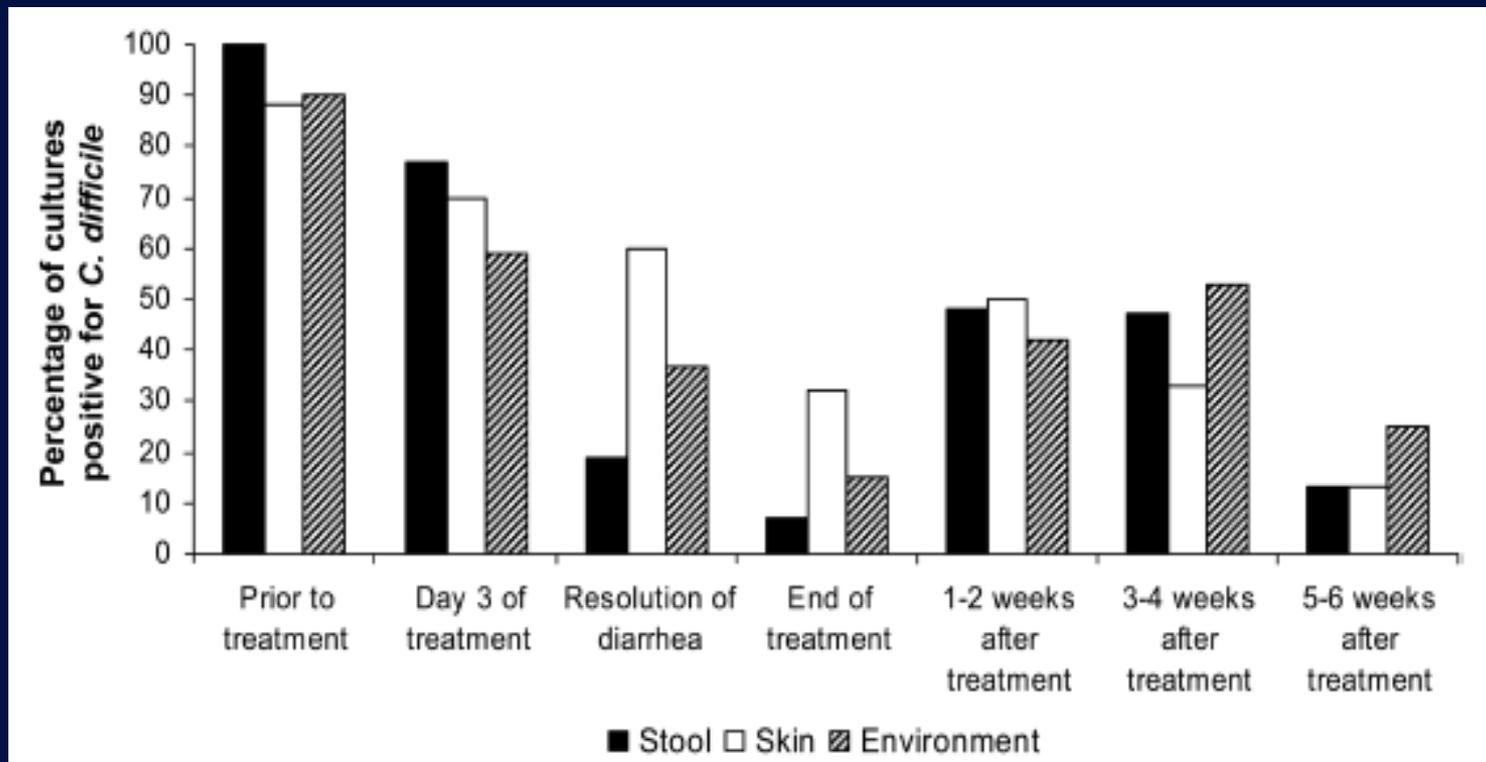
- Gram-positive bacillus: Strict anaerobe, spore-former
- Colonizes human GI tract
- Increasing prevalence and incidence
- New epidemic strain that hyperproduces toxins A and B
- Introduction of CDAD from the community into hospitals
- High morbidity and mortality in elderly
- Inability to effectively treat fulminant CDI
- Absence of a treatment that will prevent recurrence of CDAD
- Inability to prevent CDAD

CDI NOW THE MOST COMMON HEALTHCARE-ASSOCIATED PATHOGEN

- Analysis of 10 community hospitals, 2005-2009, in the Duke DICON system



PERCENT OF STOOL, SKIN, AND ENVIRONMENT CULTURES POSITIVE FOR *C. difficile*



Skin (chest and abdomen) and environment (bed rail, bedside table, call button, toilet seat)

Sethi AK, et al. ICHE 2010;31:21-27

FREQUENCY OF ENVIRONMENTAL CONTAMINATION AND RELATION TO HAND CONTAMINATION

- Study design: Prospective study, 1992
- Setting: Tertiary care hospital
- Methods: All patients with CDI assessed with environmental cultures
- Results
 - Environmental contamination frequently found (25% of sites) but higher if patients incontinent (>90%)
 - Level of contamination low (<10 colonies per plate)
 - Also contaminated: BP cuff, electronic thermometer, IV accurate control device and oximeter

Frequency of Cultures Positive for *Clostridium difficile* From Different Environmental Sites Within the Hospital Room

Site	All Rooms	Double Rooms	
	No. Positive/ No. Tested (%)	Index Side (%)	Roommate Side (%)
Floor	15/31 (48)	NA	NA
Commode	7/17 (41)	NA	NA
Windowsill	6/16 (38)	NA	NA
Toilet	15/45 (33)	NA	NA
Buzzer	11/57 (19)	6/19 (32)	1/17 (6)
Bedsheets	12/56 (21)	4/20 (20)	2/14 (14)
Bedrails	15/81 (18)	7/26 (27)	2/25 (8)
Totals	81/303 (27)	17/65 (26)*	5/56 (9)

*P = 0.02 by Fisher's exact test, index side versus roommate side.
NA = not applicable.

Correlation Between Proportion of Positive Environmental Sites and Isolation of *Clostridium difficile* From Hands of Hospital Personnel

Environmental Sites Positive (%)	No. of Index Cases With Environmental Sites and Personnel Cultured	No. of Positive Personnel/ No. of Personnel Cultured (%)
0	12	0/25
1-25	5	0/11
26-50	5	1/12 (8)
>50	6	9/25 (36)*

*Chi-square test for linear trend in proportions: P <0.01.

EVALUATION OF HOSPITAL ROOM ASSIGNMENT AND ACQUISITION OF CDI

- Study design: Retrospective cohort analysis, 2005-2006
- Setting: Medical ICU at a tertiary care hospital
- Methods: All patients evaluated for diagnosis of CDI 48 hours after ICU admission and within 30 days after ICU discharge
- Results (acquisition of CDI)
 - Admission to room previously occupied by CDI = 11.0%
 - Admission to room not previously occupied by CDI = 4.6% (p=0.002)

TABLE 3. Multivariate Analysis of Risk Factors for Acquisition of *Clostridium difficile* Infection (CDI)

Risk factor	HR (95% CI)	P
Prior room occupant with CDI	2.35 (1.21–4.54)	.01
Greater age	1.00 (0.99–1.01)	.71
Higher APACHE III score	1.00 (1.00–1.01)	.06
Proton pump inhibitor use	1.11 (0.44–2.78)	.83
Antibiotic exposure		
Norfloxacin	0.38 (0.05–2.72)	.33
Levofloxacin	1.08 (0.67–1.73)	.75
Ciprofloxacin	0.49 (0.15–1.67)	.23
Fluoroquinolones	1.17 (0.72–1.91)	.53
Clindamycin	0.45 (0.14–1.42)	.17
Third- or fourth-generation cephalosporins	1.17 (0.76–1.79)	.48
Carbapenems	1.05 (0.63–1.75)	.84
Piperacillin-tazobactam	1.31 (0.82–2.10)	.27
Other penicillin	0.47 (0.23–0.98)	.04
Metronidazole	1.31 (0.83–2.07)	.24
Vancomycin		
Oral	1.38 (0.32–5.89)	.67
Intravenous	1.55 (0.88–2.73)	.13
Aminoglycosides	1.27 (0.78–2.06)	.35
Multiple (≥3 antibiotic classes)	1.28 (0.75–2.21)	.37

NOTE. APACHE, Acute Physiology and Chronic Health Evaluation; CI, confidence interval; HR, hazard ratio.

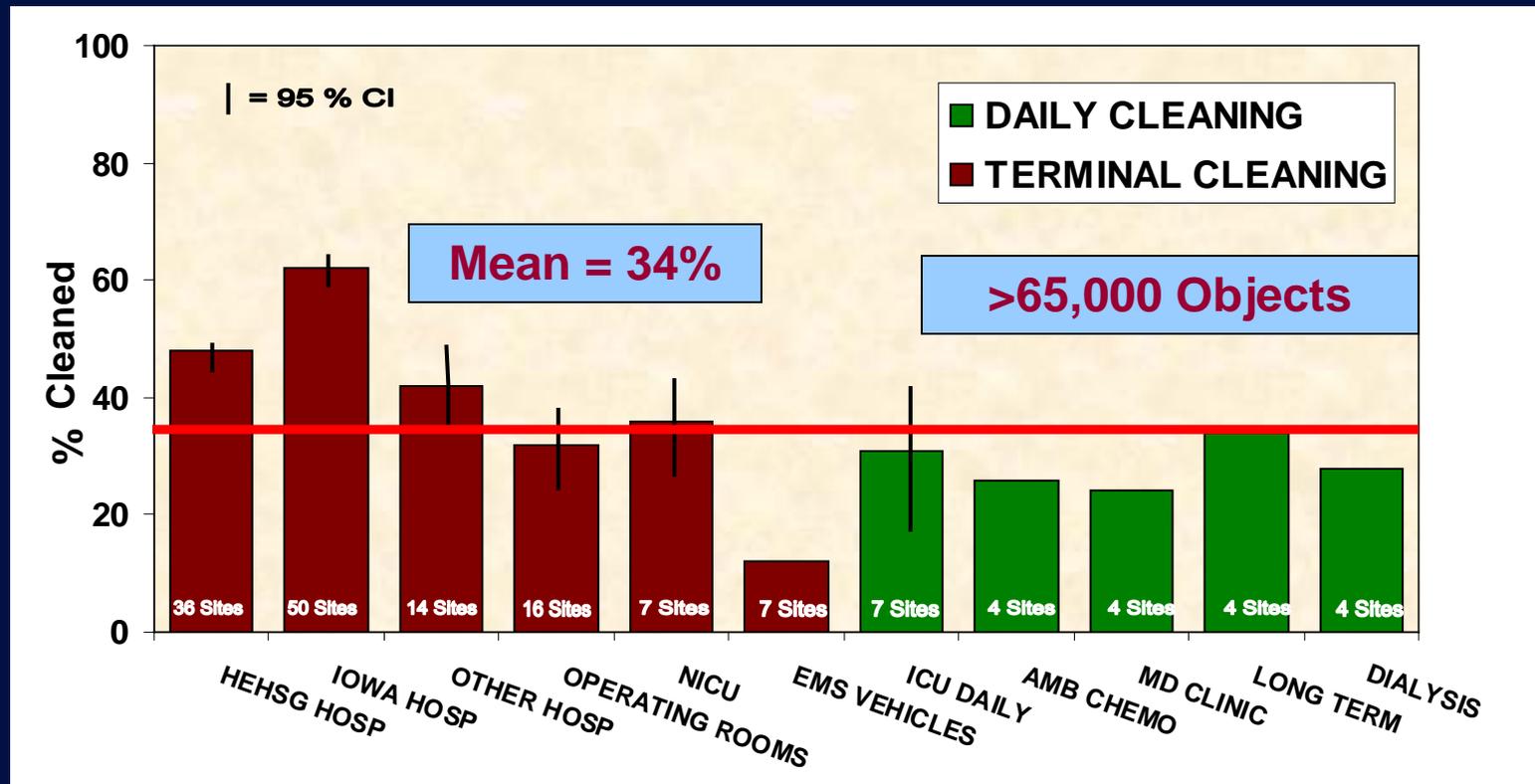
PROVING THAT ENVIRONMENTAL CONTAMINATION IMPORTANT IN *C. difficile* TRANSMISSION

- Environmental persistence (Kim et al. JID 1981;14342)
- Frequent environmental contamination (McFarland et al. NEJM 1989;320:204)
- Demonstration of HCP hand contamination (Samore et al. AJM 1996;100:32)
- Environmental \Rightarrow hand contamination (Samore et al. AJM 1996;100:32)
- Person-to-person transmission (Raxach et al. ICHE 2005;26:691)
- Transmission associated with environmental contamination (Samore et al. AJM 1996;100:32)
- CDI room a risk factor (Shaughnessy et al. ICHE)
- Improved disinfection \Rightarrow \Downarrow epidemic CDI (Kaatz et al. AJE 1988;127:1289)
- Improved disinfection \Rightarrow \Downarrow hyperendemic CDI (Boyce et al. ICHE 2008;29:723)

BEST PRACTICES FOR ROOM DISINFECTION USING STANDARD GERMICIDES

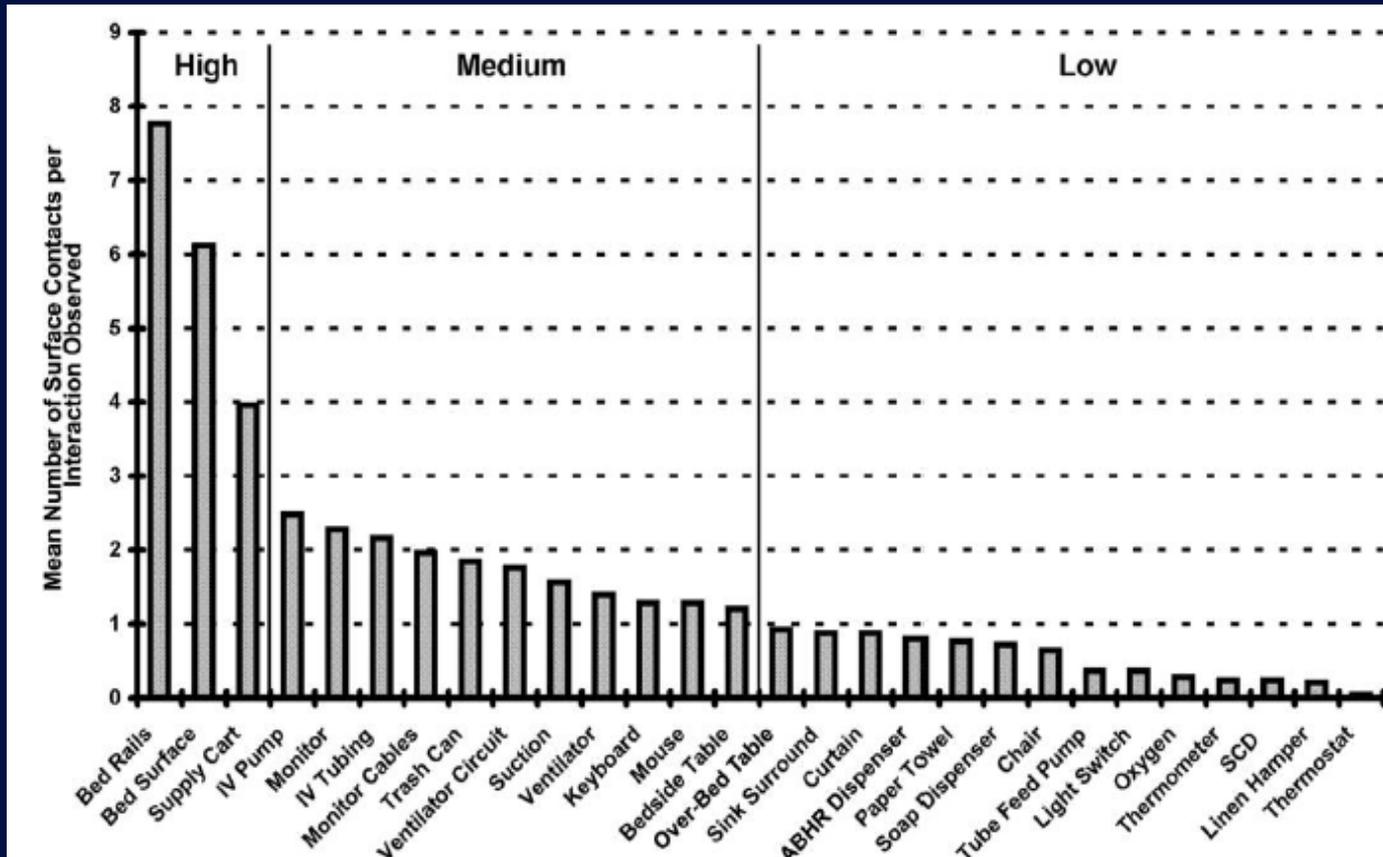
- Follow the CDC Guideline for Disinfection and Sterilization with regard to choosing an appropriate germicide and best practices for environmental disinfection
- Appropriately train environmental service workers on proper use of PPE and clean/disinfection of the environment
- Have environmental service workers use checklists to ensure all room surfaces are cleaned/disinfected
- Assure that nursing and environmental service have agreed what items (e.g., sensitive equipment) is to be clean/disinfected by nursing and what items (e.g., environmental surfaces) are to be cleaned/disinfected by environmental service workers
- Use a method (e.g., fluorescent dye) to ensure proper cleaning

Thoroughness of Environmental Cleaning



DEFINING HIGH TOUCH SURFACES

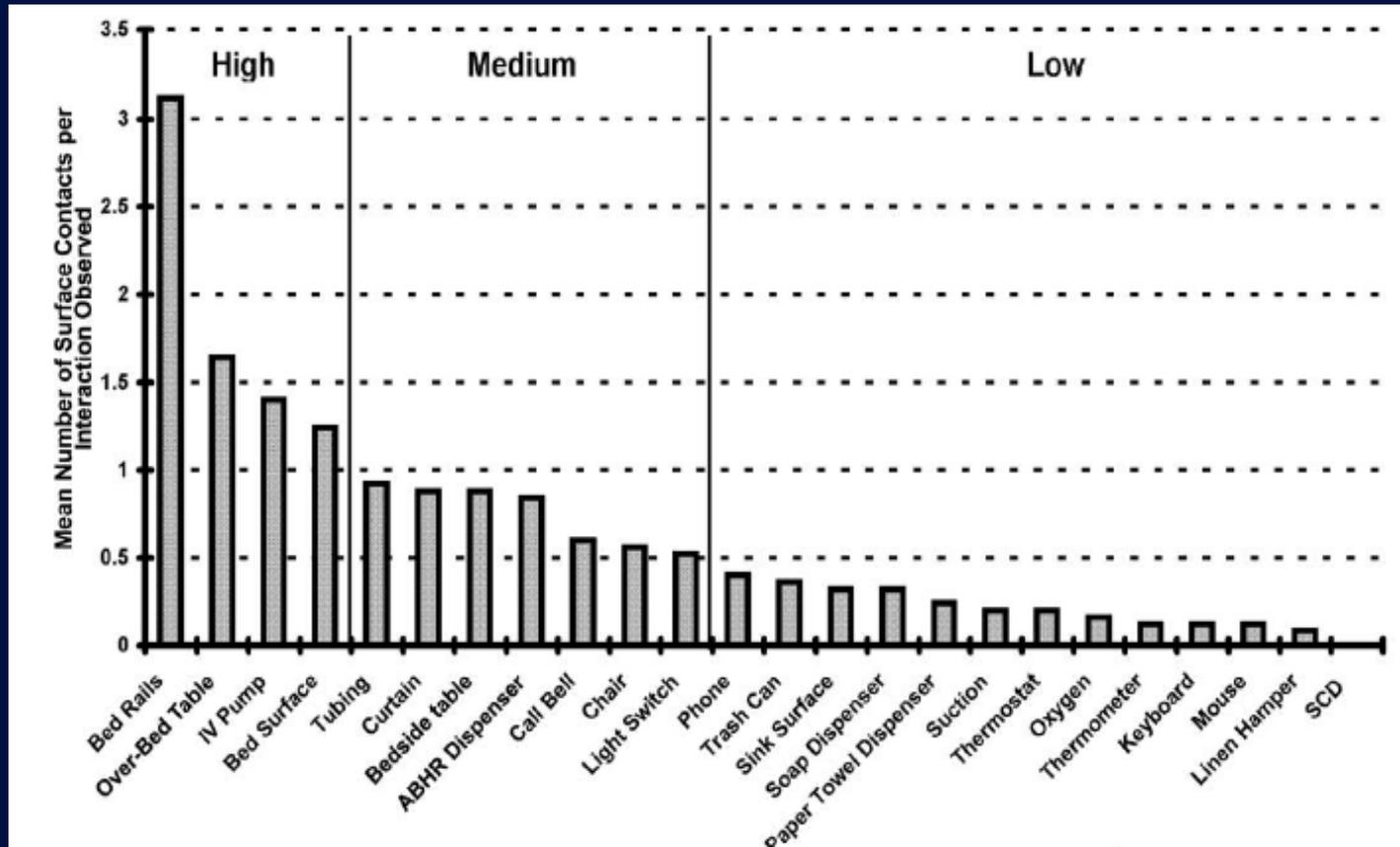
ICU



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

DEFINING HIGH TOUCH SURFACES

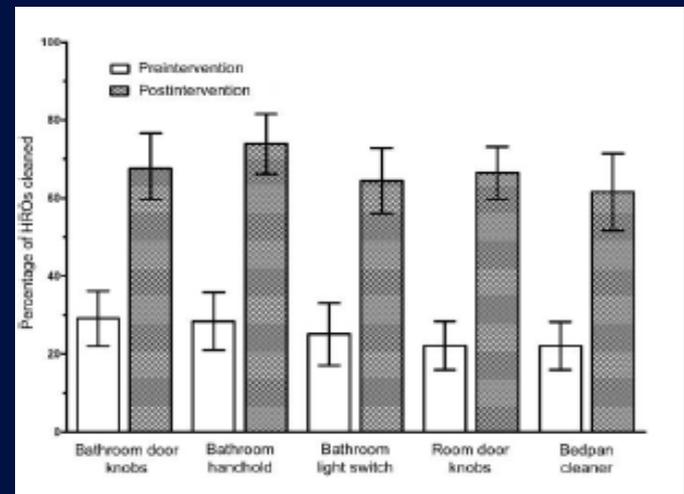
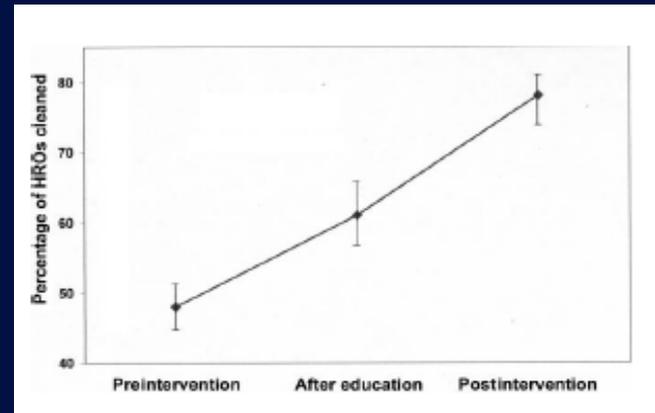
Non-
ICU



TERMINAL ROOM CLEANING: DEMONSTRATION OF IMPROVED CLEANING

- Evaluated cleaning before and after an intervention to improve cleaning
- 36 US acute care hospitals
- Assessed cleaning using a fluorescent dye
- Interventions
 - Increased education of environmental service workers
 - Feedback to environmental service workers

Carling PC, et al. ICHE 2008;29:1035-41



Surface Disinfection

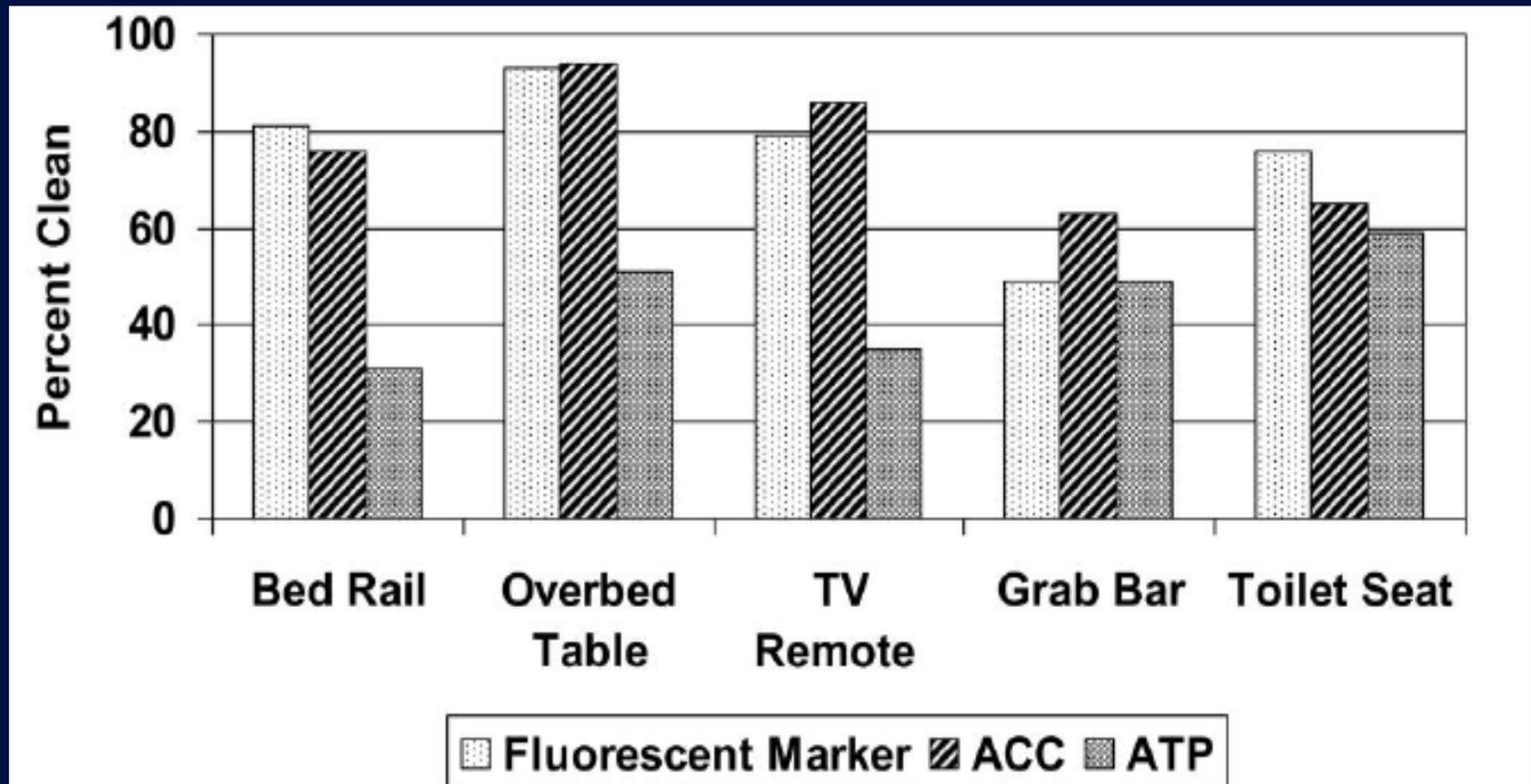
Effectiveness of Different Methods

Technique (with cotton)	MRSA Log ₁₀ Reduction (QUAT)
Saturated cloth	4.41
Spray (10s) and wipe	4.41
Spray, wipe, spray (1m), wipe	4.41
Spray	4.41
Spray, wipe, spray (until dry)	4.41
Disposable wipe with QUAT	4.55
Control: detergent	2.88

Target Enhanced



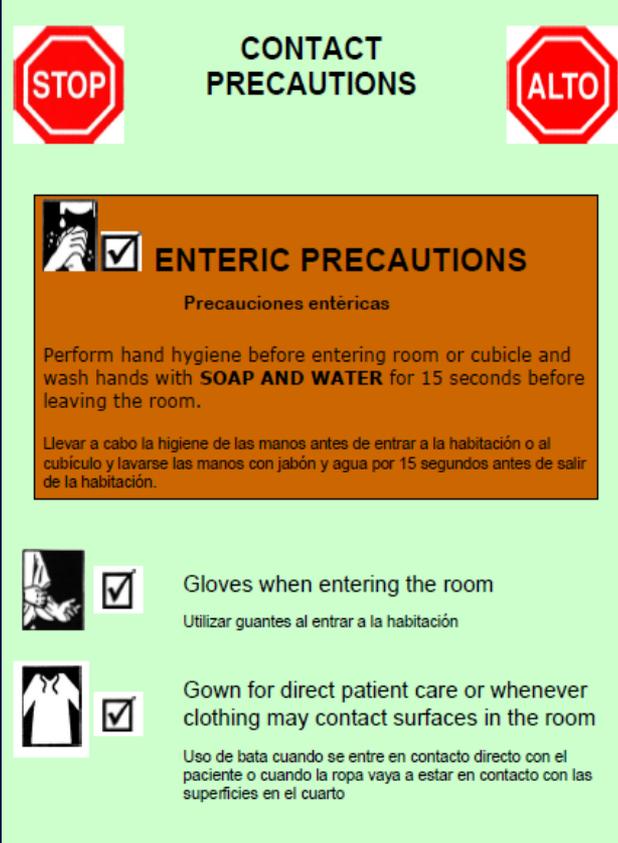
COMPARISON OF DIFFERENT METHODS OF ASSESSING TERMINAL ROOM CLEANING PRACTICES



ACC, aerobic colony count; ATP, adenosine triphosphate Boyce JM, et al. ICHE 2011;32:1187

UNC ISOLATION SIGN FOR PATIENTS WITH ROTAVIRUS, NOROVIRUS OR *C. difficile*

- Use term contact-enteric precautions
- Requires gloves and gown when entering room
- Recommends hand hygiene with soap and water (instead of alcohol based antiseptic)
- Information in English and Spanish



The sign is rectangular with a light green background. At the top, it features two red octagonal stop signs: one with the word "STOP" in white and one with the word "ALTO" in white. Between these signs, the text "CONTACT PRECAUTIONS" is written in bold black capital letters. Below this, there is a large orange rectangular box containing the following text: "ENTERIC PRECAUTIONS" in bold black capital letters, followed by "Precauciones entéricas" in a smaller font. Below this, there are two paragraphs of text in English and Spanish, each preceded by a small icon of hands being washed and a checkmark in a square box. Below the orange box, there are two more rows of text, each preceded by a small icon of a person wearing a gown and a checkmark in a square box. The first row is in English and Spanish, and the second row is in Spanish.

STOP **CONTACT PRECAUTIONS** **ALTO**

 **ENTERIC PRECAUTIONS**
Precauciones entéricas

Perform hand hygiene before entering room or cubicle and wash hands with **SOAP AND WATER** for 15 seconds before leaving the room.

Llevar a cabo la higiene de las manos antes de entrar a la habitación o al cubículo y lavarse las manos con jabón y agua por 15 segundos antes de salir de la habitación.

 Gloves when entering the room
Utilizar guantes al entrar a la habitación

 Gown for direct patient care or whenever clothing may contact surfaces in the room

Uso de bata cuando se entre en contacto directo con el paciente o cuando la ropa vaya a estar en contacto con las superficies en el cuarto

CONCLUSIONS

- Determining the role of environmental contamination in the transmission of healthcare-associated pathogens is very difficult (difficult to separate roles played by direct person-to-person transmission versus person-to-environment-to-person transmission)
- Contaminated environment likely important for MRSA, VRE, norovirus, *Acinetobacter*, and *C. difficile*
- Eliminating the environment as a source for transmission of HIA pathogens: contact precautions, adherence to proper room cleaning and disinfection protocols (or use of UV or VHP), compliance with proper hand hygiene (soap & water for norovirus and *C. difficile*)
- Additional research required before widespread adoption of “no touch” disinfections methods and/or use of self disinfecting surfaces (key outcome should be reduction of HAIs)

THANK YOU!!

