Role of Hospital Surfaces in the Spread of HA Pathogens: *Acinetobacter*, Norovirus, *C. difficile*

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DISCLOSURES

- Financial disclosures (consultation in past 3 years)
  - Clorox
  - Advanced Sterilization Products (a J&J Company)
- Thank you to David J. Weber, MD for use of some slides

LECTURE OBJECTIVES

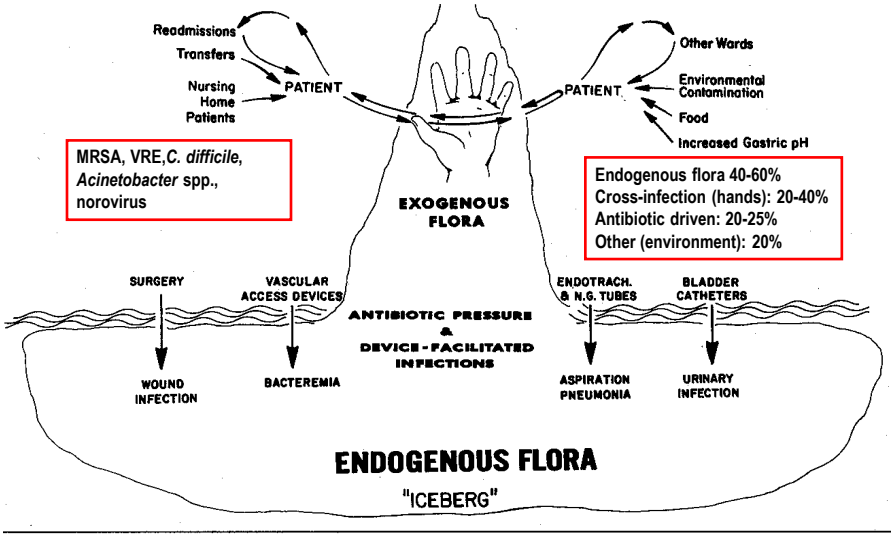
- Understand the pathogens for which contaminated hospital surfaces play a role in transmission
- Understand the characteristics of healthcare-associated pathogens associated with contaminated surfaces
- Understand how to prevent transmission of pathogens associated with contaminated surfaces
- Identify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

HEALTHCARE-ASSOCIATED INFECTIONS IN THE US: IMPACT

- 1.7 million infections per year
- 98,987 deaths due to HAI
  - Pneumonia 35,967
  - Bloodstream 30,665
  - Urinary tract 13,088
  - Surgical site infection 8,205
  - Other 11,062
- 6th leading cause of death (after heart disease, cancer, stroke, chronic lower respiratory diseases, and accidents)[1]

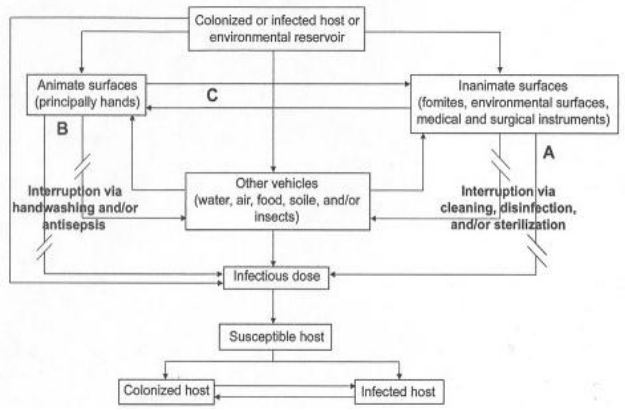
[1] National Center for Health Statistics, 2004

HAZARDS IN THE HOSPITAL



Weinstein RA. Am J Med 1991;91(suppl 3B):179S

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.

THE ROLE OF THE ENVIRONMENT IN DISEASE TRANSMISSION

- Over the past decade there has been a growing appreciation that environmental contamination makes a contribution to HAI with MRSA, VRE, *Acinetobacter*, norovirus and *C. difficile*
- Surface disinfection practices are currently not effective in eliminating environmental contamination
- Inadequate terminal cleaning of rooms occupied by patients with MDR pathogens places the next patients in these rooms at increased risk of acquiring these organisms

MICROBIAL FACTORS THAT FACILITATE ENVIRONMENTAL TRANSMISSION

- Colonized/infected patient contaminates the environment
- Ability to survive in the environment for hours to days (all)
- Ability to remain virulent after environmental exposure
- Deposition on surfaces frequently touched by HCWs must occur (all)
- Transmission directly or via the contaminated hands of HCWs (all)
- Low inoculating dose (norovirus, *C. difficile*)
- Ability to colonize patients (*C. difficile*, MRSA, VRE, *Acinetobacter*)
- Relative resistance to disinfectants (norovirus, *C. difficile*)

KEY PATHOGENS WHERE ENVIRONMENTAL SURFACES PLAY A ROLE IN TRANSMISSION

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

KEY PATHOGENS WHERE ENVIRONMENTAL SURFACES PLAY A ROLE IN TRANSMISSION

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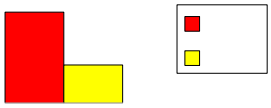
- Norovirus
- Rotavirus
- SARS

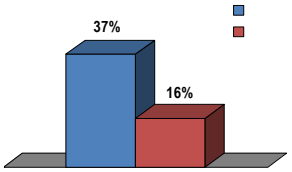
RISK OF ACQUIRING MRSA, VRE, and *C. difficile* FROM PRIOR ROOM OCCUPANTS

- Admission to a room previously occupied by an MRSA-positive patient or VRE-positive patient significantly increased the odds of acquisition for MRSA and VRE (although this route is a minor contributor to overall transmission). Huang et al. Arch Intern Med 2006;166:1945.
- Prior environmental contamination, whether measured via environmental cultures or prior room occupancy by VRE-colonized patients, increases the risk of acquisition of VRE. Drees et al. Clin Infect Dis 2008;46:678.
- Prior room occupant with CDAD is a significant risk for CDAD acquisition. ICACC (K-4194) 2008. Shaughnessy et al.

MRSA AND VRE

- Prevalence (CLA-BSI, CA-UTI, VAP)
  - ***S. aureus*, 14.5% (rank = #2): 56.2% were MRSA**
  - ***Enterococcus* spp, 12.1% (rank = #3): 33.3% were VRE**
- MRSA and VRE associated with increased mortality (see figures)





Hidron AI, et al. ICHE 2008;29:996-1011 - Cosgrove SE et al. *CID*. 2003;36:53-59.
Whitby M et al. *MJA*. 2001;175:264-267 - CDC. MMWR 1993;42:597-599

MRSA

- Frequency of environmental contamination in areas housing MRSA patients has ranged from 1 to 74% (23.1%, 53.6% from isolation rooms) of surfaces cultured.
- MRSA viable in the environment for days to weeks
- HCP can contaminate their hands or gloves by touching contaminated surfaces
- Cleaning or disinfecting the environment can reduce transmission but cleaning regimens, as currently practiced, may not eliminate MRSA from surfaces
- Since MRSA sensitive to all germicides, likely due to surfaces not cleaned/disinfected
- Need targeted methods to evaluate the thoroughness of room cleaning

MRSA: FREQUENCY OF SURFACE CONTAMINATION

Boyce et al. ICHE 1997;18:622

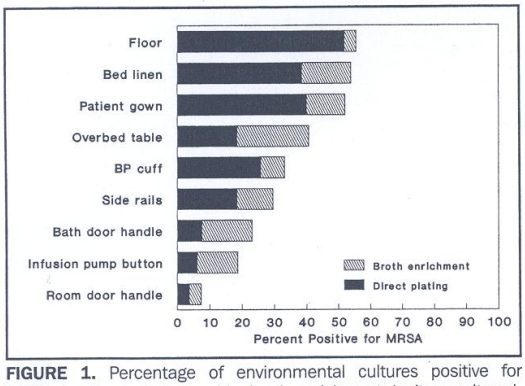


FIGURE 1. Percentage of environmental cultures positive for MRSA, by direct plating and by broth enrichment, by item cultured.

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%

Dancer SJ et al. Lancet ID 2008;8(2):101-13

ENVIRONMENTAL SURVIVAL OF KEY PATHOGENS

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

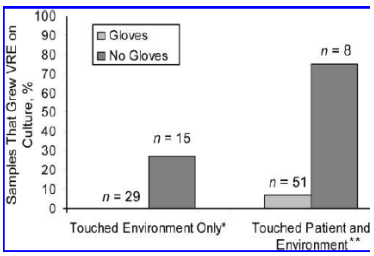
Adapted from Hota B, et al. Clin Infect Dis 2004;39:1182-9 and Kramer A, et al. BMC Infectious Diseases 2006;6:130

FREQUENCY OF HAND/GLOVE CONTAMIANTION AFTER CONTACT WITH VRE POSITIVE PATIENT OR ENVIRONMENTAL SITES

- **Goal: To estimate frequency of hand or glove contamination with VRE among HCP who touch a colonized patient of the patient's environment**
- **Conclusion: HCP almost as likely to have contaminated their hands or gloves after touching the environment as after touching a colonized patient**

TABLE 2. Rates of Contamination with Vancomycin-Resistant *Enterococcus* (VRE) for the Hands and/or Gloves of 103 Healthcare Workers (HCWs), by Type of Contact

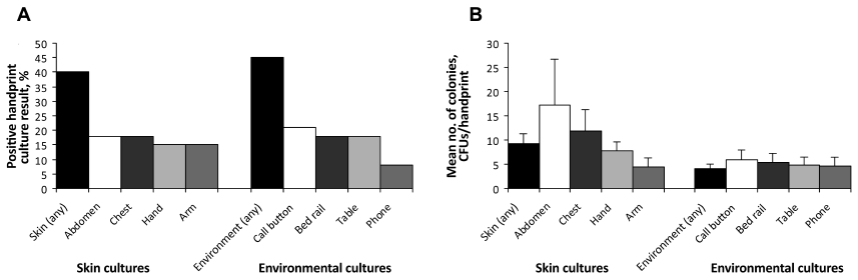
	Rate of contamination, proportion (%)[a]			
HCW group, culture type	Total (N = 103)	Touched environment only (n = 44)	Touched environment and patient (n = 59)	P
Wore gloves (n = 84)				
A. Glove samples	57/84 (68)	19/29 (66)	38/55 (69)	.808
B. Hand samples after gloves removed	4/84 (5)	0/29 (0)	4/55 (7)	.293
Did not wear gloves				
C. Hand samples	7/19 (37)	4/15 (27)	3/4 (75)	.117
Total of rows A and C	64/103 (62)	23/44 (52)	41/59 (70)	.101



Hayden MK, et al. Infect Control Hosp Epidemiol 2008;29:149-154

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)



Stiefel U, et al. ICHE 2011;32:185-187

DECREASING ORDER OF RESISTANCE OF MICROORGANISMS TO DISINFECTANTS/STERILANTS

Most Resistant

Prions

Spores (*C. difficile*)

Mycobacteria

Non-Enveloped Viruses (norovirus)

Fungi

Bacteria (MRSA, VRE, *Acinetobacter*)

Enveloped Viruses

Most Susceptible

EFFECTIVENESS OF DISINFECTANTS AGAINST MRSA AND VRE

TABLE 2
DISINFECTANT ACTIVITY AGAINST ANTIBIOTIC-SUSCEPTIBLE AND ANTIBIOTIC-RESISTANT BACTERIA

	Log_{10} Reductions							
	VSE		VRE		MSSA		MRSA	
Product	0.5 min	5 min	0.5 min	5 min	0.5 min	5 min	0.5 min	5 min
Vesphene IIse	>4.3	>4.3	>4.8	>4.8	>5.1	>5.1	>4.6	>4.6
Clorox	>5.4	>5.4	>4.9	>4.9	>5.0	>5.0	>4.6	>4.6
Lysol Disinfectant	>4.3	>4.3	>4.8	>4.8	>5.1	>5.1	>4.6	>4.6
Lysol Antibacterial	>5.5	>5.5	>5.5	>5.5	>5.1	>5.1	>4.6	>4.6
Vinegar	0.1	5.3	1.0	3.7	+1.1	+0.9	+0.6	2.3

Abbreviations: MRSA, methicillin-resistant *Staphylococcus aureus;* MSSA, methicillin-susceptible *S aureus;* VRE, vancomycin-resistant *Enterococcus;* VSE, vancomycin-susceptible *Enterococcus.* Data represent mean of two trials (n=2). Values preceded by ">" represent the limit of detection of the assay. Assays were conducted at a temperature of 20°C and a relative humidity of 45%. Results were calculated as the log of Nd/No, where Nd is the titer of bacteria surviving after exposure and No is the titer of the control.

Rutala WA, et al. *Infect Control Hosp Epidemiol* 2000;21:33-38.

SURFACE DISINFECTION

Effectiveness of Different Methods
Rutala, Weber, Gergen, Unpublished Results

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

KEY PATHOGENS WHERE ENVIRONMENTAL SURFACES PLAY A ROLE IN TRANSMISSION

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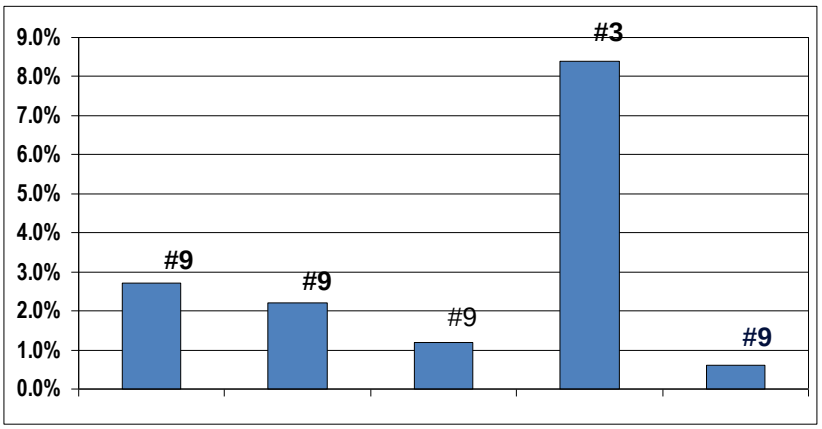
- *Acinetobacter* spp.
- *Clostridium difficile*
- Norovirus
- Rotavirus
- SARS

Acinetobacter

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

PREVALENCE OF *ACINETOBACTER* IN DEVICE RELATED HAIs, NHSN, 2006-2007



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)
- CRAB-isolated from 24/135 (17.9%) environmental samples and 7/65 (10.9%) of HCWs; genetically related (Choi et al. JKMS

A. baumannii SURVIVAL ON DRY SURFACES

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

TABLE 2. Survival times of outbreak strains of *A. baumannii* suspended in distilled water and kept at 31% RH and at a room temperature of 22 ± 3°C

Strain no.	Site of isolation	Outbreak[a]	Mean survival time (days) ± SD[b]
St-284	Blood	G-III	22 ± 4.42
St-14733	Blood	G-III	31 ± 0.71
St-1650	Blood	G-X	25 ± 1.14
St-1954	Blood	G-X	27 ± 0.71
St-2312	Blood	G-VIII	27 ± 1.14
St-8195	Catheter	G-VIII	21 ± 3.53
St-11681	Blood	G-VIII	21 ± 1.14
St-7961	Blood	G-VIII	23 ± 4.42
St-14970	Catheter	G-V	28 ± 4.42
St-15598	Catheter	G-V	26 ± 2.12
St-16706	Blood	G-IV	26 ± 1.14
St-20820	Blood	G-IV	30 ± 2.82
St-21359	Catheter	G-IV	32 ± 1.14
St-17093	Blood	G-VI	27 ± 2.12
V-7459	Tracheal aspirate	G-VI	26 ± 0.71
St-17108 I	Blood	G-VI	26 ± 1.14
St-17108 II	Blood	G-VI	25 ± 2.12
U-1901	Urine	G-I	24 ± 0.71
W-5420	Tracheal aspirate	G-I	30 ± 5.56
U-10247	Urine	G-II	24 ± 4.42
U-11177	Urine	G-II	33 ± 1.41
U-11432	Urine	G-II	30 ± 0.71

[a] Outbreak designations are as shown in reference 26.
[b] Overall mean, 26.54 days; range, 21 to 33 days.

Frequency of Contamination of Gowns, Gloves and Hands of HCPs after Caring for Patients

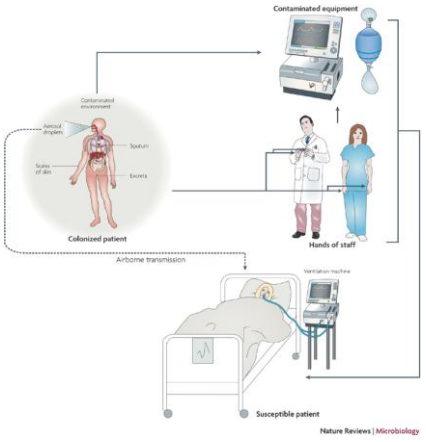
72 (36.2%) resulted in HCW contamination of gloves and 9 (4.5%) resulted in hand contamination after glove removal and before HH. Morgan et al. ICHE 2010;31:716

TABLE 1. Frequency of Contamination of Gowns, Gloves, and Hands of Healthcare Workers (HCWs) after Caring for Patients Colonized or Infected with Specified Bacteria

	No. (% [95% CI]) of observations	
Source of culture-positive sample	Patients with MDR *Acinetobacter baumannii* carriage (n = 199)	Patients with MDR *Pseudomonas aeruginosa* carriage (n = 134)
Gloves	72 (36.2 [29.5–42.9])	9 (6.7 [2.5–11.0])
Gown	22 (11.1 [6.7–15.4])	6 (4.5 [1.0–8.0])
Gloves and/or gown	77 (38.7 [31.9–45.5])	11 (8.2 [3.6–12.9])
Hands[a]	9 (4.5 [1.6–7.4])	1 (0.7 [0–2.2])

NOTE. CI, confidence interval; MDR, multidrug-resistant.
[a] After removal of gloves and gown and before hand hygiene.

TRANSMISSION OF *ACINETOBACTER*



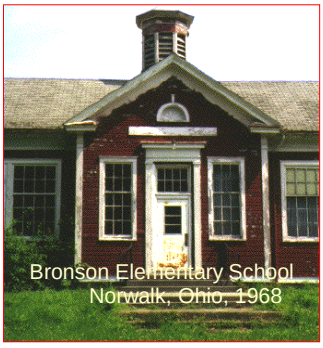
Dijkshoorn L, et al. Nature Rev Microbiol 2007;5:939-951

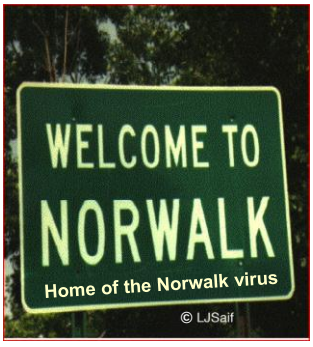
CONTROL MEASURES

- Reemphasis of hand hygiene
- Practice of sterile technique for all invasive procedures
- Cleaning the environment of care
- Contact Isolation (donning gowns and gloves)
- Enhanced infection control measures: cohorting of patients with cohorting of staff; use of dedicated patient equipment; surveillance cultures; enhanced environmental cleaning; covert observations of practice; educational modules; disinfection of shared patient equipment

The Discovery of Norwalk Virus

Dr. Al Kapikian, NIH





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)
- HA outbreaks involve patients and staff with high attack rates

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

HOSPITAL OUTBREAKS

- Attack rate: 62% (13/21) for patients and 46% (16/35) for staff (Green et al. J Hosp Infect 1998;39:39)
- Number ill: 77 persons (28 patients and 49 staff) (Leuenberger et al. Swiss Med Weekly 2007;137:57)
- Attack rate: 21% (20 of 92) of all patients admitted to the pediatric oncology unit (Simon et al. Scand J Gastro 2006;41:693)
- Attack rate: 75% (3 of 4) of patients and 26% (10 of 38) staff (Weber et al. ICHE 2005;26:841)

ENVIRONMENTAL CONTAMINATION

- Hospital-11/36 (31%) environmental swabs were positive by RT-PCR. Positive swabs were from lockers, curtains and commodes and confined to the immediate environment of symptomatic patients (Green et al. J Hosp Infect 1998;39:39)
- Rehabilitation Center-Norovirus detected from patients and three environmental specimens (physiotherapy instrument handle, toilet seat [2-room of symptomatic guest, public toilet]) RT-PCR (Kuusi et al. Epid Infect 2002;129:133-138)
- LTCF-5/10 (50%) of the environmental samples were positive for norovirus by RT-PCR (Wu et al. ICHE 2005;26:802)

ENVIRONMENTAL SURVIVAL

- At 20°C a 9-$\log_{10}$ reduction of FCV between 21-28 days in a dried state (Doultree et al. J Hosp Infect 1999;41:51)
- HuNV was detected by RT-PCR on stainless steel, ceramic, and formica surfaces for 7 days (D'Souza D et al. Int J Food Microbiol 2006;108:84-91)
- MNV survived more than 40 days on diaper material, on gauze, and in a stool suspension (JungEun L et al. Appl Environ Microbiol 2008;74:2111-17)
- FCV can survive up to 3 days on telephone buttons and receivers, 1-2 days on a computer mouse, and 8-12 hours on a keyboard (Clay S et al. AJIC 2006;34:41-3)

FCV, feline calicivirus; HuNV, human norovirus; MNV, mouse norovirus

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.

SURFACE DISINFECTION

- School outbreak of NLV-cleaning with QUAT preparations made no impact on the course of the outbreak. The outbreak stopped after the school closed for 4 days and was cleaned using chlorine-based agents (Marks et al. Epid Inf 2003;131:727)
- Detergent-based cleaning to produce a visibly clean surface consistently failed to eliminate norovirus contamination. A hypochlorite/detergent formulation of 5,000 ppm chlorine was sufficient to decontaminate surfaces. (Barker et al. J Hosp Infect 2004;58:42)

INACTIVATION OF MURINE AND HUMAN NOROVIRUES

Disinfectant, 1 min	MNV Log_{10} Reduction	HNV Log_{10} Reduction
70% Ethanol	>4 (3.3 at 15sec)	2
70% Isopropyl alcohol	4.2	2.2
65% Ethanol + QUAT	>2	3.6
79% Ethanol + QUAT	3.4	3.6
Chlorine (5,000ppm)	4	3
Chlorine (24,000ppm)	2.4	4.3
Phenolic, QUAT, Ag, 3% H_20_2	≤1	≤1 (2.1 QUAT)
0.5% Accel H_20_2	3.9	2.8

Rutala WA, Folan MP, Tallon LA, Lyman WH, Park GW, Sobsey MD, Weber DJ. 2007

INACTIVATION OF MURINE AND HUMAN NOROVIRUES

Antiseptic, 1 min	MNV Log_{10} Reduction	HNV Log_{10} Reduction
Ethanol Hand Spray	3.2	0.4
Ethanol Based Rub	1.9	2.1
Iodophor (10%)	0.8	0.5
4% CHG	0.1	0.3
0.5% Triclosan	1.3	0.2
1% PCMX	0	2.4

Rutala WA, Folan MP, Tallon LA, Lyman WH, Park GW, Sobsey MD, Weber DJ. 2007

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 (IB)**

MacCannell T, et al. http://www.cdc.gov/hicpac/pdf/norovirus/Norovirus-Guideline-2011.pdf

ANTISEPSIS TO PREVENT NOROVIRUS INFECTIONS

YES!!

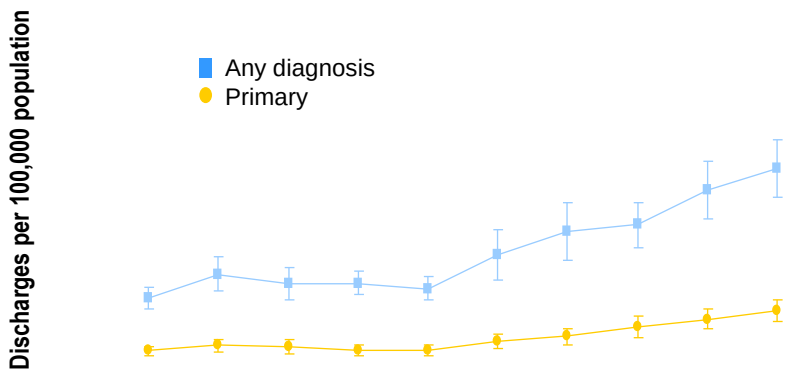
NO!!

C. difficile: A GROWING THREAT

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 CDI 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 CDI
- Inability to prevent CDI

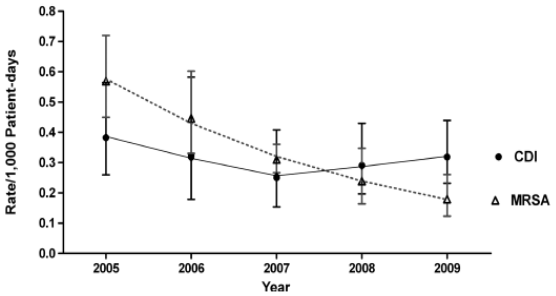
Rates of *C. difficile* Disease in U.S. Hospitals, 2000 - 2005



From McDonald LC, et al. *Emerg Infect Dis*. 2006;12(3):409-15 and unpublished CDC data

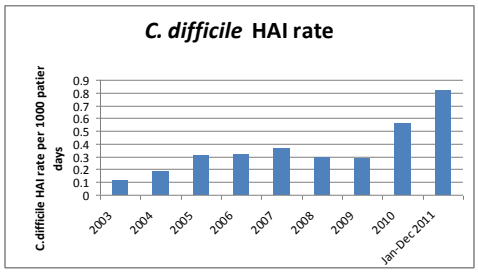
CDI NOW THE MOST COMMON HEALTHCARE-ASSOCIATED PATHOGEN

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

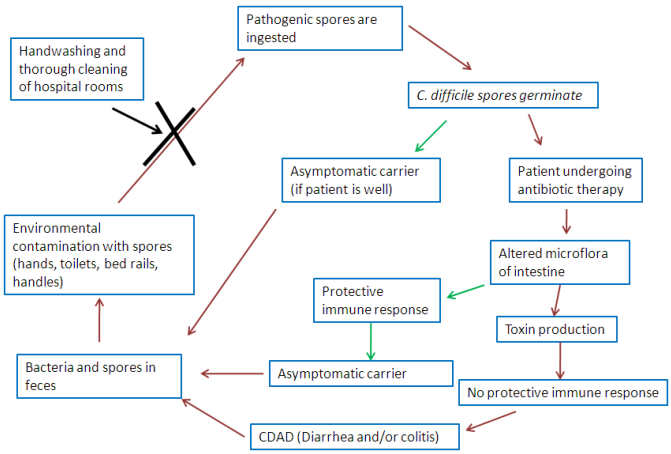


Miller BA, et al. ICHE 2011;32:387-390

UNC HEALTH CARE *C. difficile* HAI RATES, 2003-2011



C. difficile PATHOGENESIS

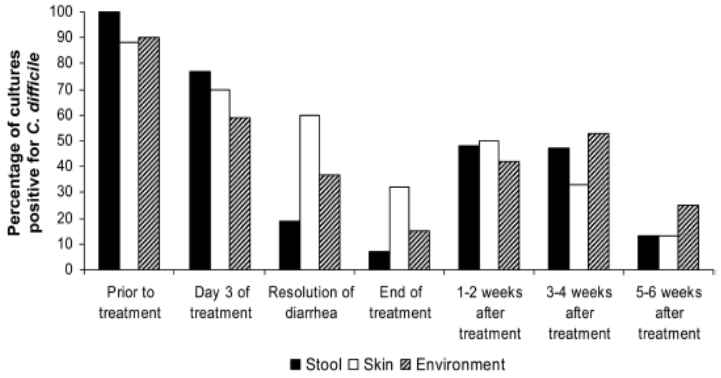


CDC

ENVIRONMENTAL CONTAMINATON

- **25% (117/466) of cultures positive (<10 CFU) for *C. difficile*. >90% of sites positive with incontinent patients. (Samore et al. AJM 1996;100:32)**
- **31.4% of environmental cultures positive for *C. difficile*. (Kaatz et al. AJE 1988;127:1289)**
- **9.3% (85/910) of environmental cultures positive (floors, toilets, toilet seats) for *C. difficile*. (Kim et al. JID 1981;143:42)**
- **29% (62/216) environmental samples were positive for *C. difficile*. 29% (11/38) positive cultures in rooms occupied by asymptomatic patients and 49% (44/90) in rooms with patients who had CDAD. (NEJM 1989;320:204)**
- **10% (110/1086) environmental samples were positive for *C. difficile* in case-associated areas and 2.5% (14/489) in areas with no known cases. (Fekety et al. AJM 1981;70:907)**

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)**
  - **Presence on hands correlated with prevalence of environmental sites**

Samore MH, et al. Am J Med 1996;100:32-40

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

Site	All Rooms: No. Positive/ No. Tested (%)	Double Rooms: Index Side (%)	Double Rooms: 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)

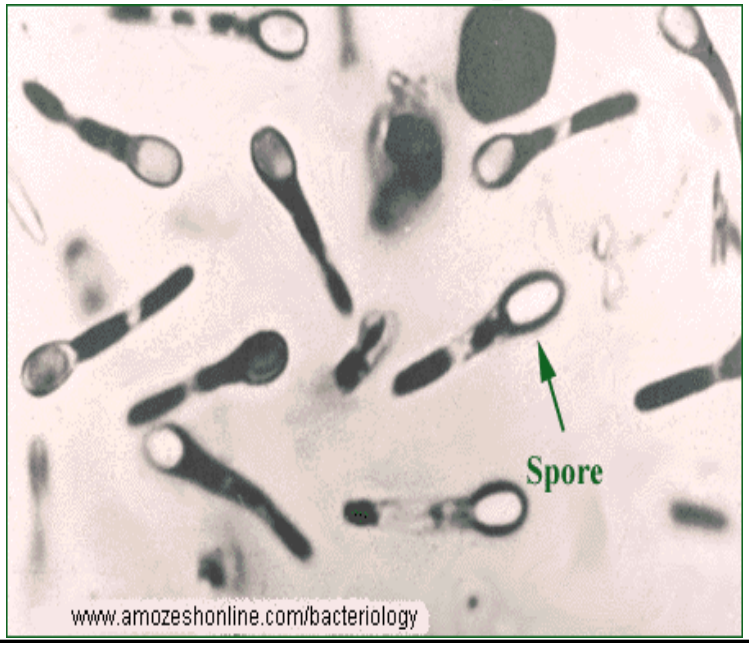
*$P = 0.02$ by Fisher's exact test, index side versus roommate side.
NA = not applicable.

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: $P < 0.01$.

C. difficile spores



SURVIVAL

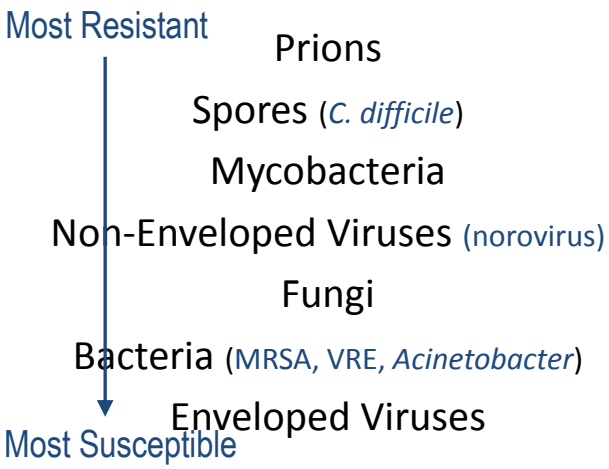
C. difficile

- Vegetative cells
  - Can survive for at least 24 h on inanimate surfaces
- Spores
  - Spores survive for up to 5 months. 10^6 CFU of *C. difficile* inoculated onto a floor; marked decline within 2 days. Kim et al. J Inf Dis 1981;143:42.

FACTORS LEADING TO ENVIRONMENTAL TRANSMISSION OF *CLOSTRIDIUM DIFFICILE*

- 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

DECREASING ORDER OF RESISTANCE OF MICROORGANISMS TO DISINFECTANTS/STERILANTS



DISINFECTANTS AND ANTISEPSIS

C. difficile spores at 20 min, Rutala et al, 2006

- No measurable activity (1 *C. difficile* strain, J9)
  - CHG
  - Vesphene (phenolic)
  - 70% isopropyl alcohol
  - 95% ethanol
  - 3% hydrogen peroxide
  - Clorox disinfecting spray (65% ethanol, 0.6% QUAT)
  - Lysol II disinfecting spray (79% ethanol, 0.1% QUAT)
  - TBQ (0.06% QUAT); QUAT may increase sporulation capacity-Lancet 2000;356:1324
  - Novaplus (10% povidone iodine)
  - Accel (0.5% hydrogen peroxide)

DISINFECTANTS AND ANTISEPSIS

C. difficile spores at 10 and 20 min, Rutala et al, 2006

- ~4 $\log_{10}$ reduction (3 *C. difficile* strains including BI-9)
  - Clorox, 1:10, ~6,000 ppm chlorine (but not 1:50)
  - Clorox Clean-up, ~19,100 ppm chlorine
  - Tilex, ~25,000 ppm chlorine
  - Steris 20 sterilant, 0.35% peracetic acid
  - Cidex, 2.4% glutaraldehyde
  - Cidex-OPA, 0.55% OPA
  - Wavicide, 2.65% glutaraldehyde
  - Aldahol, 3.4% glutaraldehyde and 26% alcohol

CLINICAL PRACTICE GUIDELINES FOR *C. difficile*, SHEA & IDSA, 2010

- **HCWs and visitors must use gloves (AI) and gowns (BIII) on entry to room**
- **Emphasize compliance with the practice of hand hygiene (AII)**
- **In a setting in which there is an outbreak or an increased CDI rate, instruct visitors and HCP to wash hands with soap (or antimicrobial soap) and water after caring for or contacting patients with CDI (BIII)**
- **Accommodate patients with CDI in a private room with contact precautions (BIII)**
- **Maintain contact precautions for the duration of diarrhea (CIII)**
- **Identification and removal of environmental sources of *C. difficile*, including replacement of electronic rectal thermometers with disposables, can reduce the incidence of CDI (BII)**
- **Use chlorine containing cleaning agents or other sporicidal agents in areas with increased rates of CDI (BII)**
- **Routine environmental screening for *C. difficile* is NOT recommended (CIII)**

Cohen SH, et al. ICHE 2010;31:431-435

CONTROL MEASURES

C. difficile Disinfection

- In units with high endemic *C. difficile* infection rates or in an outbreak setting, use dilute solutions of 5.25-6.15% sodium hypochlorite (e.g., 1:10 dilution of bleach) for routine disinfection. (Category II).
- We now use chlorine solution in all CDI rooms for routine daily and terminal cleaning (use to use QUAT in patient rooms with sporadic CDI). One application of an effective product covering all surfaces to allow a sufficient wetness for > 1 minute contact time. Chlorine solution normally takes 1-3 minutes to dry.
- For semicritical equipment, glutaraldehyde (20m), OPA (12m) and peracetic acid (12m) reliably kills *C. difficile* spores using normal exposure times

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 HCW hand contamination (Samore et al. AJM 1996;100:32)
- Environmental ⇒ 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)
- CDAD room a risk factor (Shaughnessy et al. IDSA/ICAAC. Abstract K-4194)
- Improved disinfection ⇒ ⇓ epidemic CDAD (Kaatz et al. AJE 1988;127:1289)

Effect of Hypochlorite on Environmental Contamination and Incidence of *C. difficile*

- Use of chlorine (500-1600 ppm) decreased surface contamination and the outbreak ended. Mean CFU/positive culture in outbreak 5.1, reduced to 2.0 with chlorine. (Kaatz et al. Am J Epid 1988;127:1289)
- In an intervention study, the incidence of CDAD for bone marrow transplant patients decreased significantly, from 8.6 to 3.3 cases per 1000 patient days after the environmental disinfection was switched from QUAT to 1:10 hypochlorite solution in the rooms of patients with CDAD. No reduction in CDAD rates was seen among NS-ICU and medicine patients for whom baseline rates were 3.0 and 1.3 cases per 1000-patient days. (Mayfield et al. Clin Inf Dis 2000;31:995)

Effect of Hypochlorite on Environmental Contamination and Incidence of *C. difficile*

- 35% of 1128 environmental cultures were positive for *C. difficile.* To determine how best to decontaminate, a cross-over study conducted. There was a significant decrease of *C. difficile* on one of two medicine wards (8.9 to 5.3 per 100 admissions) using hypochlorite (1,000 ppm) vs. detergent. (Wilcox et al. J Hosp Infect 2003;54:109)
- Acidified bleach (5,000 ppm) and the highest concentration of regular bleach tested (5,000 ppm) could inactivate all the spores in <10 minutes. (Perez et al. AJIC 2005;33:320)

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)**

Shaughnessy MK, et al. ICHE 2011;32:201-206

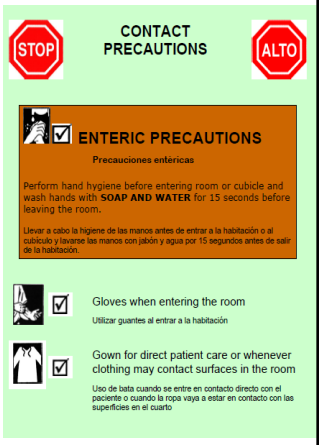
TABLE 3. Multivariate Analysis of Risk Factors for Acquisition of *Clostridium difficile* Infection (CDI)

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.

UNC ISOLATION SIGN FOR PATIENTS WITH 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



ANTISEPSIS TO PREVENT *C. difficile* INFECTIONS

YES!!

NO!!

The Role of the Environment in Disease Transmission

- Over the past decade there has been a growing appreciation that environmental contamination makes a contribution to HAI with MRSA, VRE, *Acinetobacter*, norovirus and *C. difficile*
- Surface disinfection practices are currently not effective in eliminating environmental contamination
- Inadequate terminal cleaning of rooms occupied by patients with MDR pathogens places the next patients in these rooms at increased risk of acquiring these organisms

Effective Surface Decontamination

Practice and Product

TABLE 2
DISINFECTANT ACTIVITY AGAINST ANTIBIOTIC-SUSCEPTIBLE AND ANTIBIOTIC-RESISTANT BACTERIA

	Log_{10} Reductions							
	VSE		VRE		MSSA		MRSA	
Product	0.5 min	5 min	0.5 min	5 min	0.5 min	5 min	0.5 min	5 min
Vesphene IIse	>4.3	>4.3	>4.8	>4.8	>5.1	>5.1	>4.6	>4.6
Clorox	>5.4	>5.4	>4.9	>4.9	>5.0	>5.0	>4.6	>4.6
Lysol Disinfectant	>4.3	>4.3	>4.8	>4.8	>5.1	>5.1	>4.6	>4.6
Lysol Antibacterial	>5.5	>5.5	>5.5	>5.5	>5.1	>5.1	>4.6	>4.6
Vinegar	0.1	5.3	1.0	3.7	+1.1	+0.9	+0.6	2.3

Abbreviations: MRSA, methicillin-resistant *Staphylococcus aureus;* MSSA, methicillin-susceptible *S aureus;* VRE, vancomycin-resistant *Enterococcus;* VSE, vancomycin-susceptible *Enterococcus.* Data represent mean of two trials (n=2). Values preceded by ">" represent the limit of detection of the assay. Assays were conducted at a temperature of 20°C and a relative humidity of 45%. Results were calculated as the log of Nd/No, where Nd is the titer of bacteria surviving after exposure and No is the titer of the control.

Rutala WA, Barbee SL, Aguiar NC, Sobsey MD, Weber DJ. Antimicrobial Activity of Home Disinfectants and Natural Products Against Potential Human Pathogens. *Infection Control and Hospital Epidemiology* 2000;21:33-38.

Surface Disinfection

Effectiveness of Different Methods

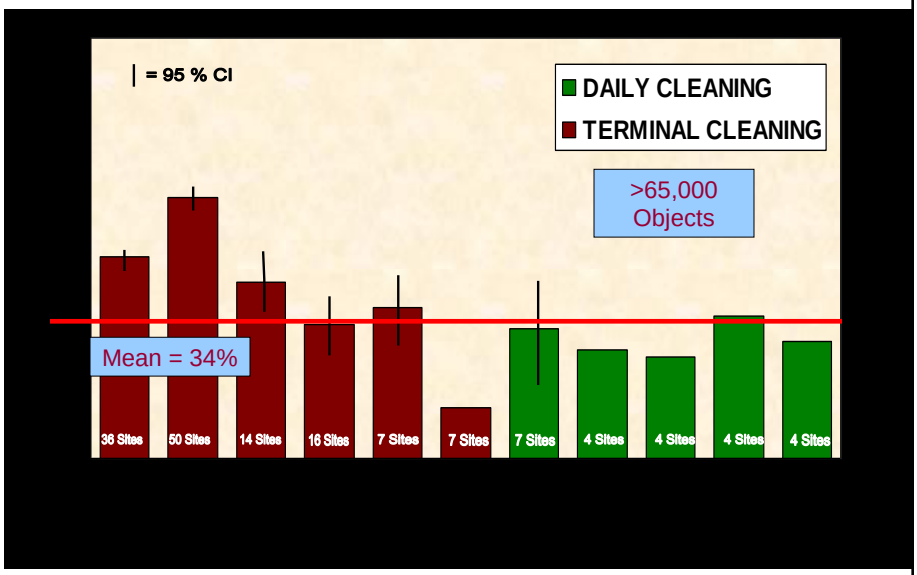
Technique (with cotton)	MRSA Log_{10} Reduction (QUAT)
Saturated cloth	4.41
Spray (10s) and wipe	4.41
Spray, wipe, spray (1m), wipe	4.41
Spray	4.41
Spray, wipe, spray (until dry)	4.41
Disposable wipe with QUAT	4.55
Control: detergent	2.88

Not Product: Is It Practice?

The Dazo Solution

Target Enhanced

Thoroughness of Environmental Cleaning
Carling and coworkers, SHEA 2010



Mean proportion of surfaces disinfected at terminal cleaning is <50%

Terminal cleaning methods ineffective (products effective practices deficient [surfaces not wiped]) in eliminating epidemiologically important pathogens

TABLE. Rates of Cleaning for 14 Types of High-Risk Objects

Object	Percentage cleaned		95% CI
	Mean ± SD	Range	
Sink	82 ± 12	57-97	77-88
Toilet seat	76 ± 18	40-98	68-84
Tray table	77 ± 15	53-100	71-84
Bedside table	64 ± 22	23-100	54-73
Toilet handle	60 ± 22	23-89	50-69
Side rail	60 ± 21	25-96	51-69
Call box	50 ± 19	9-90	42-58
Telephone	49 ± 16	18-86	42-56
Chair	48 ± 28	11-100	35-61
Toilet door knobs	28 ± 22	0-82	18-37
Toilet hand hold	28 ± 23	0-90	18-38
Bedpan cleaner	25 ± 18	0-79	17-33
Room door knobs	23 ± 19	2-73	15-31
Bathroom light switch	20 ± 21	0-81	11-30

NOTE. CI, confidence interval.

Practice* NOT Product

*surfaces not wiped

BEST PRACTICES FOR ROOM DISINFECTION USING STANDARD DISINFECTANTS

- **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**

NO TOUCH METHODS OF ROOM DISINFECTION

- Ultraviolet light
- Hydrogen peroxide (HP)
  - **Glosair/Sterinis: Fine mist by aerosolizing solution of 5% HP, <50 ppm silver**
  - **Steris: Vaporized HP from 35% HP**
  - **Bioquell: HP vapor from 35% HP**

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
- Identify effective environmental decontamination methods

CONCLUSIONS

- Contaminated environment likely important for MRSA, VRE, *Acinetobacter*, norovirus, and *C. difficile*
- Surface disinfectants are effective but surfaces must be thoroughly wiped to eliminate environmental contamination
- Inadequate terminal cleaning of rooms occupied by patients with MDR pathogens places the next patients in these rooms at increased risk of acquiring these organisms
- Eliminating the environment as a source for transmission of nosocomial pathogens requires: adherence to proper room cleaning and disinfection protocols (thoroughness), hand hygiene, and institution of Isolation Precautions

disinfectionandsterilization.org

THANK YOU!!