
Environmental Control to Reduce Hospital GI Illness

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Disclosure: ASP and Clorox

Environmental Control to Reduce Hospital GI Illness

- Scientific rationale and application of environmental disinfection for control of
 - *C.difficile*
 - Norovirus
 - Rotavirus
- All three agents: contaminate and survive in the environment; are relatively resistant to chemical disinfection; and contaminated fomites in the environment have been suggested as a possible source of infection.

Decreasing Order of Resistance of Microorganisms to Disinfectants/Sterilants

Prions

Spores

Mycobacteria

Non-Enveloped Viruses

Fungi

Bacteria

Enveloped Viruses

Disinfection and Sterilization

EH Spaulding believed that how an object will be disinfected depended on the object's intended use.

CRITICAL - objects which enter normally sterile tissue or the vascular system or through which blood flows should be **sterile**.

SEMICRITICAL - objects that touch mucous membranes or skin that is not intact require a disinfection process (**high-level disinfection[HLD]**) that kills all microorganisms but high numbers of bacterial spores.

NONCRITICAL -objects that touch only intact skin require **low-level disinfection**.





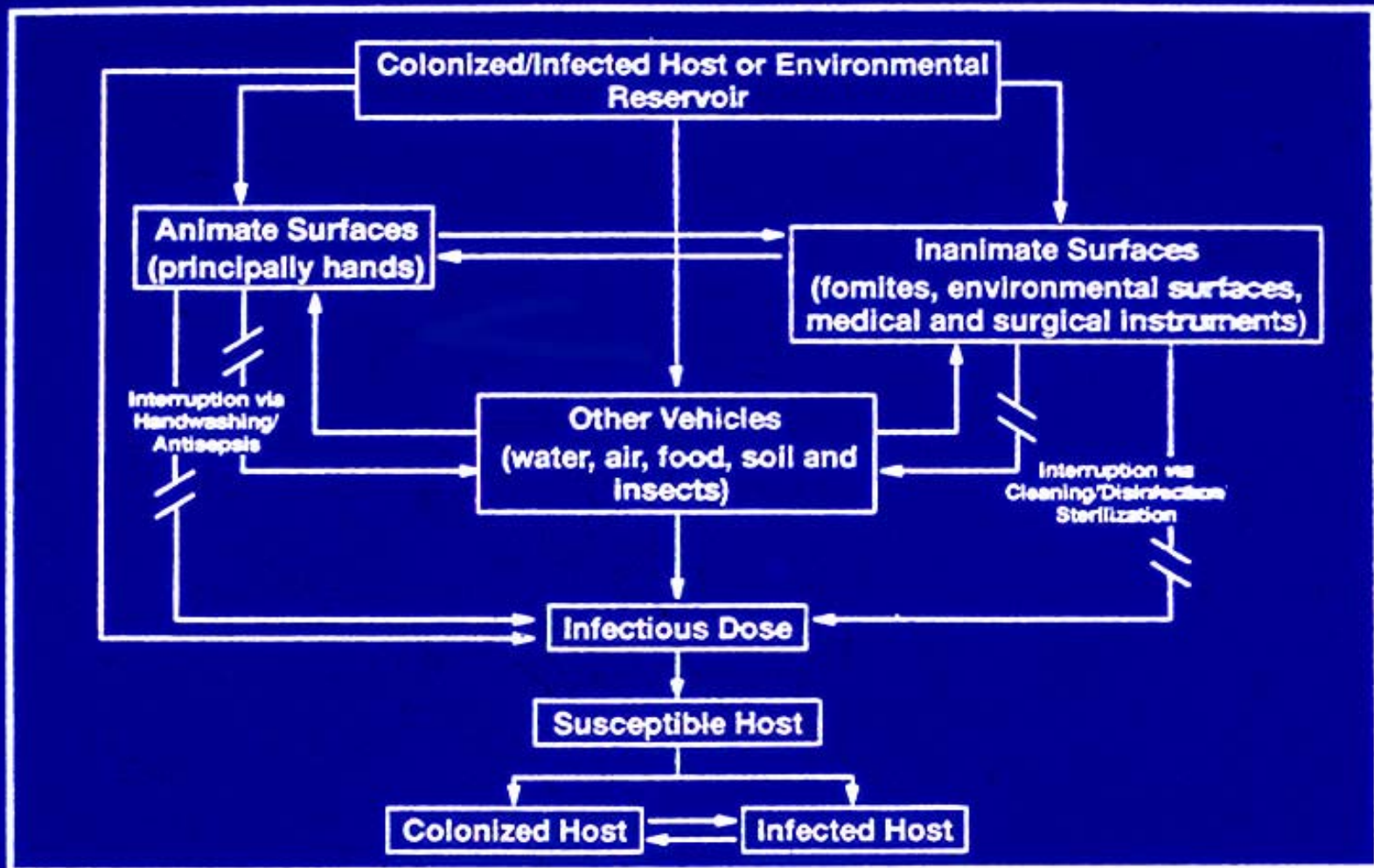


FIGURE. Transmission of infectious agents via animate and inanimate surfaces (modified from reference 25).

Clostridium difficile

C. difficile

- *C. difficile* is responsible for 15-25% of cases of antibiotic-associated diarrhea and for virtually all cases of antibiotic-associated pseudomembranous colitis.
- Costs approx \$3,669 per case or \$1.1 billion per year
- Overall mortality is 10-15%
- Over past 2 years, a new strain appears to be more virulent
- Patients can be contaminated from environmental surfaces, shared instrumentation, hospital personnel hands and infected roommates Clin Microbiol Infect 2001;7:405; Clin Micro Rev 2004;17:863



Comparison of Glutaraldehyde and OPA

>2.0% Glutaraldehyde

- HLD: 45 min at 25°C
- Needs activator
- 14 day use life
- 2 year shelf life
- ACGIH ceiling limit, 0.05ppm
- Strong odor
- MEC, 1.5%
- Cost - \$10/gallon

0.55% Ortho-phthalaldehyde

- HLD: 12 min at 20°C
- No activator needed
- 14 day use life
- 2 year shelf life
- No ACGIH or OSHA limit
- Weak odor
- MEC, 0.3%
- Cost - \$30/gallon

High-Level Disinfection

C. difficile spores

- 2% glutaraldehyde for 5 min resulted in 99% or more killing of *C. difficile* spores. Hughes et al. Gastro Endo 1986;32:7.
- 2% glutaraldehyde for 10 or 20 min inactivated *C. difficile* spores using the AOAC test. Rutala et al. ICHE 1993;14:36
- 2% glutaraldehyde and peracetyl ions inactivated *C. difficile* spores. Wullt et al. ICHE 2003;24:765.



Disinfectants and Antiseptics

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 Antiseptics

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

- ~4 log₁₀ reduction (3 *C. difficile* strains including BI-9)
 - Clorox, 1:10, ~6,000 ppm chlorine (but not 1:50)
 - Clorox Clean-up, ~1,910 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

High-Level Disinfection

C. difficile spores

- 2% glutaraldehyde is effective against *C. difficile* at 20 minutes
- 0.55% ortho-phthalaldehyde is effective against *C. difficile* at 12 minutes
- Steris 20 is effective against *C. difficile* at 10 and 20 minutes

Environmental Contamination

C. difficile

- 25% (117/466) of cultures positive (<10 CFU) for *C. difficile*. >90% of sites positive with incontinent patients. Samore et al. Am J Med 1996;100:32.
- 31.4% of environmental cultures positive for *C. difficile*. Kaatz et al. Am J Epid 1988;127:1289.
- 9.3% (85/910) of environmental cultures positive (floors, toilets, toilet seats) for *C. difficile*. Kim et al. J Inf Dis 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. Am J Med 1981;70:907.

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.

Role of the Environment

C. difficile

- The presence of *C. difficile* on the hands correlated with the density of environmental contamination. Samore et al. Am J Med 1996;100:32.
 - 0-25% environmental sites positive-0% hand cultures positive
 - 26-50% environmental sites positive-8% hand cultures positive
 - >50% environmental sites positive-36% hand cultures positive
- *C. difficile* incidence data correlated significantly with the prevalence of environmental *C. difficile*. Fawley et al. Epid Infect 2001;126:343.
- Environmental contamination does not play a major role in nosocomial CDAD in some endemic situations. Cohen et al. Clin Infect Dis 1997;24:889.
- 59% of 35 HCWs were *C. difficile* positive after direct contact with culture-positive patients.





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STERICARE®

**Antiseptic Alcohol
Personnel Handwash**

Dispense one full (7 grams) into one palm, rub hands and forearms, then rub between fingers 1 to 1-1/2 minutes.
Repeat to ensure.



Caution: Avoid getting in eyes. If contact occurs, flush thoroughly with water. For information on contents under pressure, see label. Do not store above 120°F (49°C).

Keep out of children's reach. In case of accidental ingestion or contact with eyes, flush with water. For best foam density, store in dispenser T325.

SDA-31-2278

Vestal

Hand Hygiene

CDC Guideline, October 2002

- Wash hands with non-antimicrobial soap and water or with antimicrobial soap and water if exposure to *Bacillus anthracis* is suspected or proven. The physical action of washing and rinsing hands under such circumstances is recommended because alcohols, chlorhexidine, iodophors, and other antiseptic agents have poor activity against spores. Category II.

What are the data for soap and water versus alcohol-based hand rubs for *C. difficile* spores?

Hand Hygiene with Alcohol

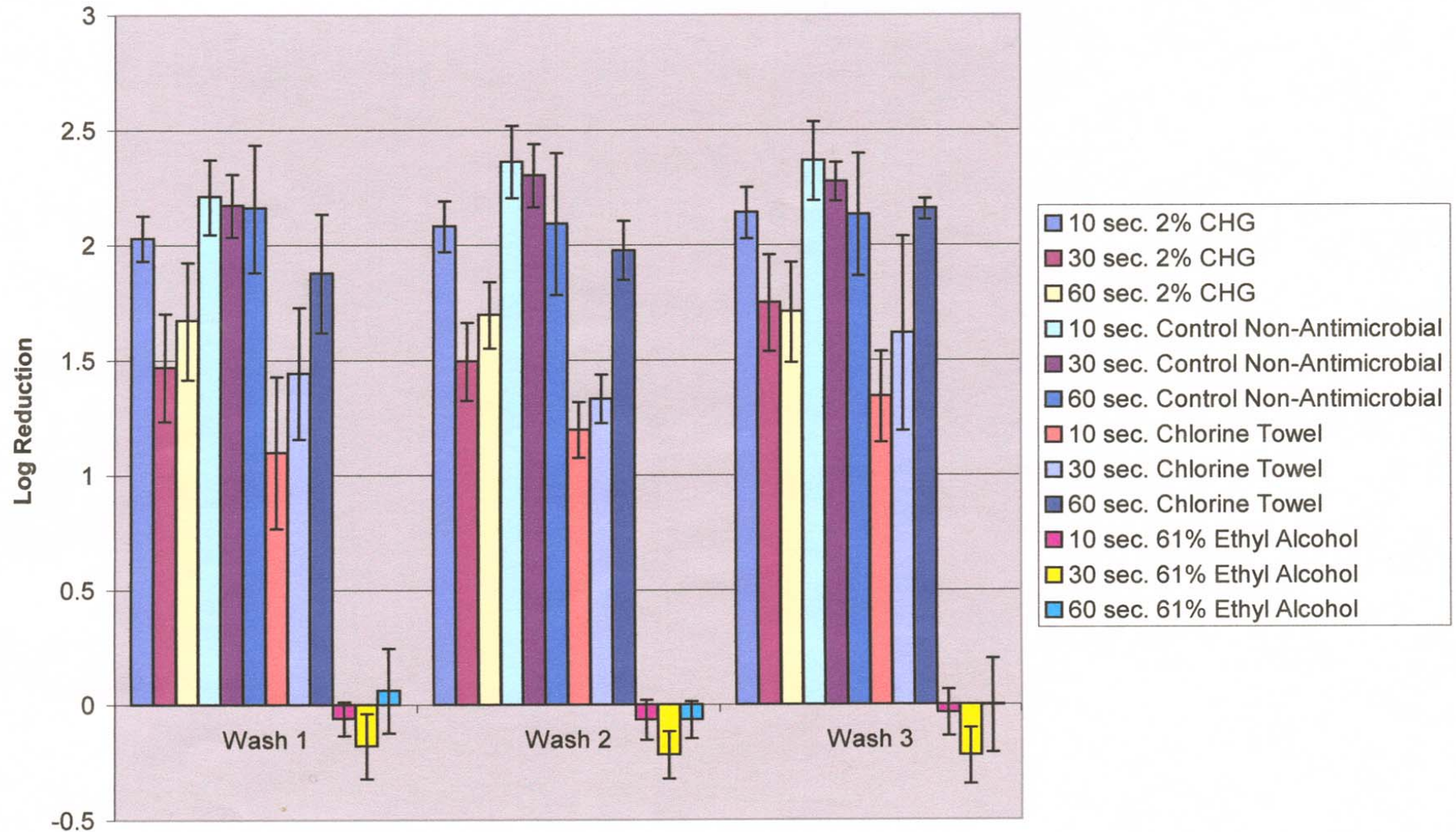
C. difficile

- Promoting the use of alcohol hand rub, **increased** incidence of *C. difficile*. Several factors may have influenced outcome (e.g., reduced HW, more specimens sent for toxin detection, etc). King et al. J Hosp Infect 2004;56:S10
- Introducing alcohol based gel, **decreased** incidence of *C. difficile* associated diarrhea (not statistically significant). Rao et al. J Hosp Infect 2002;50:42
- Introducing an alcohol-based handrub, the incidence of new isolates of *C. difficile* was **unchanged**. Gordin et al. ICHE 2005;26:650.

Hand Hygiene Agents Used to Remove Spores from Contaminated Hands

- Handwashing with soap and water, 2% chlorhexidine gluconate, or chlorine-containing towels reduced the amount of *B. atrophaeus* spore contamination, whereas use of a waterless rub containing ethyl alcohol was not effective in removing spores. Weber et al. JAMA 2003;289:2174.

Log Reduction of *Bacillus subtilis* spores



Hand Hygiene

- Either soap or CHG as a handwash for removal of *C. difficile*. Study did not evaluate alcohol-based hand rubs. ICHE 1994;15:697.
- 70% isopropyl showed no inactivation of *C. difficile* spores at exposure times of 5m, 15m, and 30m. Wullt et al. ICHE 2003;24:765.



CONTACT PRECAUTIONS



Visitors, including family, must comply with all precautions listed below. Please report to the Nursing Station before entering.



Perform hand hygiene



Gloves when entering room



Mask when patient coughing, for suctioning, and for wound irrigation



Gown if clothing will touch patient or patient items (for example, bed)

PRECAUCIONES DE CONTACTO

Los visitantes deben presentarse primero al puesto de enfermería antes de entrar. Lávese las manos. Póngase guantes al entrar al cuarto.



CONTACT PRECAUTIONS



Visitors, including family, must comply with all precautions listed below. Please report to the Nursing Station before entering.



Wash hands with soap and water

Lávese las manos con agua y jabón



Gloves when entering room



Mask when patient coughing, for suctioning, and for wound irrigation



Gown if clothing will touch patient or patient items (for example, bed)

PRECAUCIONES DE CONTACTO

Los visitantes deben presentarse primero al puesto de enfermería antes de entrar. Lávese las manos. Póngase guantes al entrar al cuarto.

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

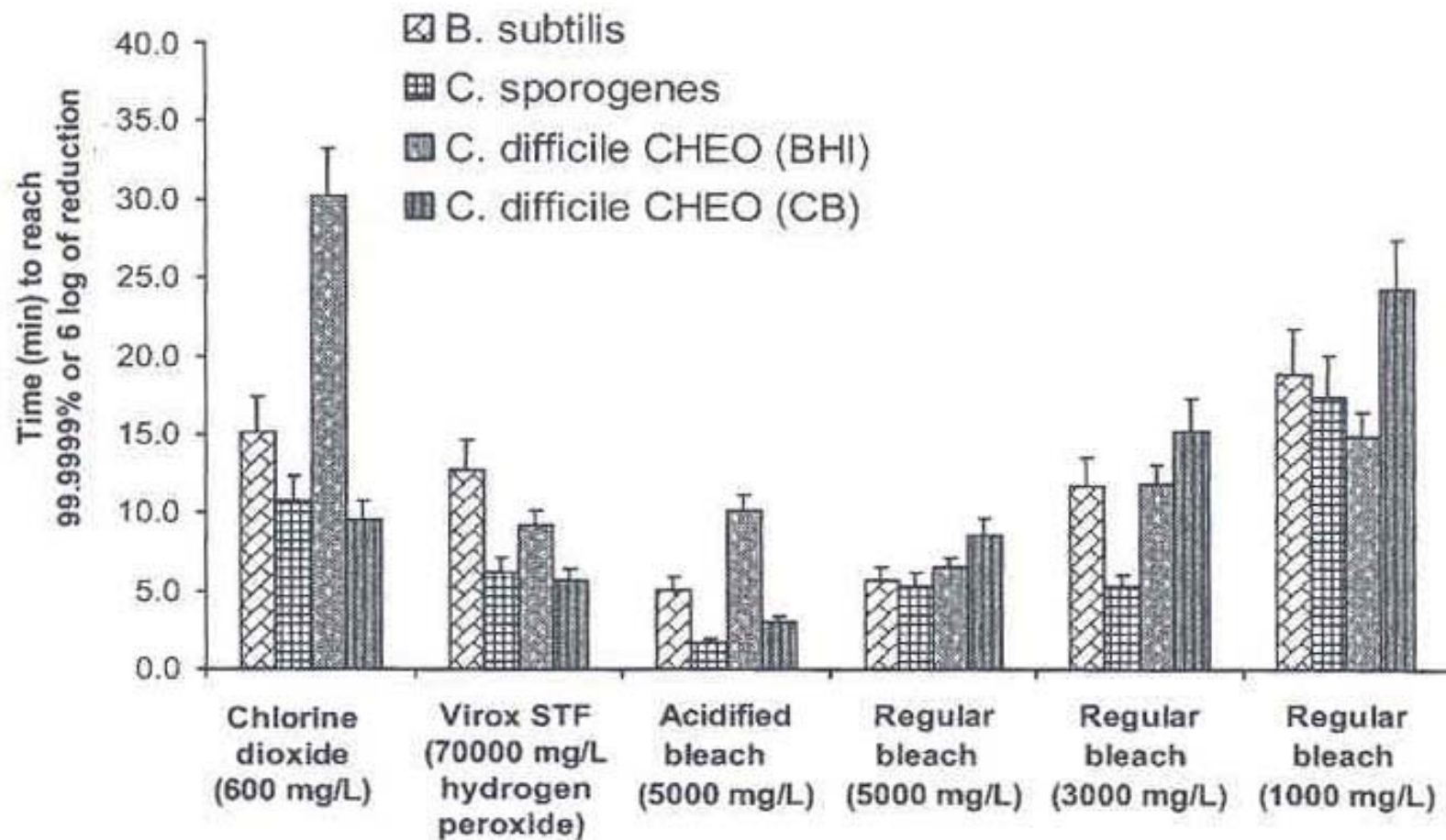


Fig 1. Times required for the microbicides to inactivate $\geq 6 \log_{10}$ (99.9999%) of the spores tested.

Control Measures

C. difficile

- Handwashing (soap and water) , contact precautions, and meticulous environmental cleaning with an EPA-registered disinfectant should be effective in preventing the spread of the organism. McFarland et al. NEJM 1989;320:204.
- 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)
- For semicritical equipment, glutaraldehyde (20m), OPA (12m) and peracetic acid (12m) reliably kills *C. difficile* spores using normal exposure times

Norovirus

Noroviruses

- Norovirus (formerly Norwalk-like viruses-NLV) is a genus within the family *Caliciviridae*. SS-RNA with a capsid structure provides increased resistance to chemical disinfection.
- Causes acute gastroenteritis in humans; fecal-oral transmission primarily, although droplet and fomite transmission may facilitate spread.
- Infective dose as low as 10-100 particles.
- Outbreaks have been reported in hospitals, homes, camps, schools, restaurants, hotels, rehabilitation centers and cruise ships
- Outbreaks in hospitals have increased in recent years and this may lead to the closure of wards
- This group of viruses cannot be grown in cell culture so feline calicivirus used as a surrogate

Norovirus

- Mainly transmitted from person-to-person through the fecal-oral route
- But also spread through
 - Ingestion of contaminated food or water
 - Droplets created by vomiting
 - Swimming in contaminated water

Environmental Contamination

Norovirus

- Hospital-11/36 (31%) environmental swabs were positive for RT-PCR. Positive swabs were from lockers, curtains and commodes and confined to the immediate environment of symptomatic patients. J Hosp Infect 1998;39:39.
- Hotel-61/144 (42%) were positive for NLV RNA. Cheesbrough et al. Epid. Infect 2000;125:93.
- Rehabilitation Center-Norovirus detected from patients and three environmental specimens (physiotherapy instrument handle, toilet seat (2-room of symptomatic guest, public toilet) RT-PCR. 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.

Some positive PCR results may represent non-infectious virus.

Environmental Survival

Norovirus

- Distilled water or saline: Survival 0-2 days West AP, et al. J Clin Path 1992;48:228
- Sterile river water: Survival 2 to 20-30 days Shahamat M, et al. Appl Environ Micro 1993;59:1231
- Tap water at 4°C: 4 days Fan EG, et al. J Gastroenterol Hepatol 1998;13:1096
- At 20°C a 9-log₁₀ reduction of FCV between 21-28 days in a dried state
Doultree et al. J Hosp Infect 1999;41:51
- At 20°C a 9-log₁₀ reduction of FCV between 14-21 days in suspension
Doultree et al. J Hosp Infect 1999;41:51
- At 20°C a 3-log₁₀ reduction in infectivity (two animal caliciviruses) occurred in 1 week. Duizer et al. Appl Env Micro 2004;70:4538.

Role of the Environment

Norovirus

1. Prolonged outbreaks on ships suggest NLV 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 a hospital ward.
Suggest transmission most likely occurred through direct contact with contaminated fomites.

Inactivation of Feline Caliciviruses

Sattar SA. J Hosp Infect 2004;56:S64

Disinfectant	Log Reduction	Contact Time (min)
Accel HP (5000 ppm)	>4.7	3
Chlorine dioxide (1000 ppm)	4.5	1
Chlorine (1000 ppm)	>4.5	1
QUAT	4.0	10
75% Ethanol	4.7	10

Inactivation of Feline Caliciviruses

Doultree et al. J Hosp Infect 1999;41:51

Disinfectant	Log Reduction	Contact Time
Glutaraldehyde, 0.5%	5	1
Hypochlorite, 1000 and 5000 ppm	5	1
QUAT	0	1
Iodine, 0.8%	5	1
Ethanol, 75%	1.25	1

Surface Disinfection

Norovirus

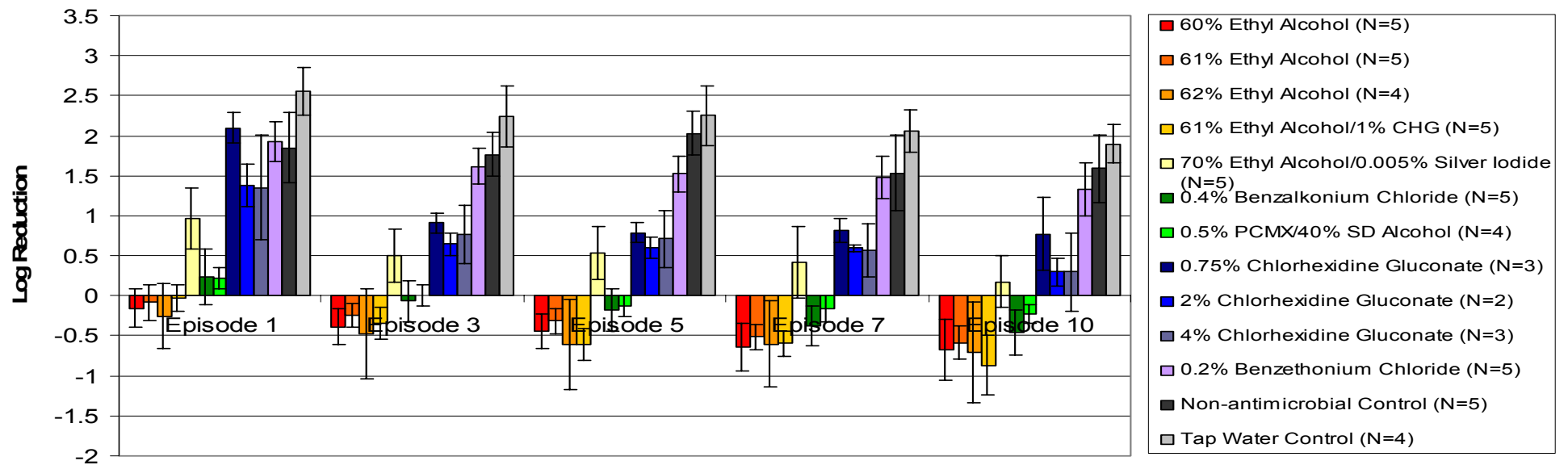
- School outbreak of NLV-cleaning with QUAT preparations made no impact on the course of the outbreak. **The outbreak stopped after the school closed for 4 days and was cleaned using chlorine-based agents.** Marks et al. Epid Inf 2003;131:727
- Detergent-based cleaning to produce a visibly clean surface consistently failed to eliminate norovirus contamination. **A hypochlorite/detergent formulation of 5000 ppm chlorine was sufficient to decontaminate surfaces.** Barker et al. J Hosp Infect 2004;58:42.

Alcohol-Based Hand Rubs

Norovirus

- Ethanol-based hand rub had superior efficacy against feline calicivirus than propanol. A higher ethanol concentration (2.17-95% ethanol, 1.25-80%, 1.07-75%, 30 sec) in hand rubs was associated with better efficacy against FCV using a fingerpad method. Kampf et al. J Hosp Infect 2005;60:144
- A new formula with reduced ethanol content (55%) in combination with other alcohols and 0.7% phosphoric acid exhibited activity ($>4 \log_{10}$) against four non-enveloped viruses (HAV, polio, rotavirus, FCV) in 30s using a suspension test. Kramer et al. J Hosp Infect 2006;62:98.

Efficacy of Hand Hygiene Agents in the Log Reductions of a Non-Enveloped Virus (MS2)



Control Measures

Norovirus

- Containment of infectious persons
- Symptomatic staff instructed to remain home for 48 hours after symptoms resolve
- Rigorous environmental cleaning procedures
- Implementation of strict contact precautions
- Soap and water for hand hygiene should be considered rather than alcohol-based hand rubs
- All surfaces disinfected with with an agent shown to have efficacy (e.g., hypochlorite, 1000 ppm)
- Ward closed to admissions (possibly)

Rotavirus

Rotavirus

- Rotovirus is a genus within the family *Reoviridae*
- Rotavirus particles are 65-75 nm in diameter, 11 strands of dsRNA
- Among the most important infectious causes of acute diarrhea in humans
- Every gram of feces may contain more than $>10^7$ viral particles
- Outbreaks of rotaviral infection are common in infants and young children in hospitals, daycare centers, and schools.

Environmental Contamination

Rotavirus

- Hospital-Rotavirus environmental contamination in a pediatric unit was investigated. Of 55 samples, 25 (46%) tested positive. Rotavirus RNA was more prevalent on surfaces in direct contact with children (play mats, thermometers) than on other environmental surfaces. ICHE 1999;20:432
- Day Care-Rotaviruses are highly prevalent on environmental surfaces in day care centers during outbreaks of diarrhea (e.g., 8/39, 21% by PCR). Wilde et al. J Infect Dis 1992;166:507.

Survival

Rotavirus

- Environmental Surfaces
 - Can remain viable on inanimate surfaces for several days (2->10 days)
 - The survival of rotaviruses on inanimate surfaces is also influenced by relative humidity and air temperature (low RH and low temperature, improves survival). Sattar et al. J Hyg. 1986;96:277.
- Hands
 - Rate of loss of viral infectivity on the hands of volunteers (7% recovered after 4 hours) was higher than inanimate surfaces. Ansari et al. Rev Infect Dis 1991;13:448 and Ansari et al. J Clin Micro 1988;26:1513.

Role of the Environment

Rotavirus

- Infectious rotavirus particles have been recovered from a variety of surfaces and objects
- Touching or handling of rotavirus-contaminated objects can transfer infectious virus to hands. Ansari et al. J Clin Micro 1988;26:1513.
- Volunteers who touched a rotavirus-contaminated surface with a finger and then put the finger in the mouth, 63% became infected.
- Disinfectants can interrupt the transfer of human rotavirus from SS disks to fingerpads of volunteers-phenolic, 500-800 ppm chlorine, phenolic/alcohol spray. Sattar et al. ICHE 1994;15:751.

Role of the Environment

Rotavirus

- Disinfectants have been shown to inactivate infectious human rotavirus dried on a surface in a stabilizing medium and prevent infection in human volunteers. Ward et al. J Clin Micro 1991;29:1991.
 - 10^3 rotavirus dried on surface and licked by volunteers, 93% (13/14) became infected
 - Spraying the surface with Lysol disinfecting spray (79% ethanol/0.1% phenolic) resulted in rotavirus titer $>5 \log_{10}$
 - None of the subjects who consumed rotavirus after Lysol treatment showed evidence of infection (0/14)

Disinfection

Rotavirus

- 2,000 ppm of chlorine to show a 3 log₁₀ reduction, 6,000 ppm of chlorine for a 6 log₁₀ reduction (10m). Sattar et al. J Virol Methods 2003;112:3
- OPA, 6 log₁₀ at 1,000 ppm (5m) Sattar et al. J Virol Methods 2003;112:3
- Glutaraldehyde, 2% showed a 3 log₁₀ reduction J Hyg 1986;97:163
- Peracetic acid, 0.35%, and PI showed a 3 log₁₀ reduction
- Phenolics, QUATS, and alcohol (70 and 95% ethyl, 70% isopropyl) ineffective (1m) Lloyd-Evans et al. J Hyg 1986;97:163
- A new alcohol formulation reduced infectivity titer of four non-enveloped viruses >10³ (including rotavirus, HAV, FCV) within 30 sec using a suspension test. Kramer et al. J Hosp Infect 2006;26:98.

Control Measures

Rotavirus

- Effective decontamination of inanimate surfaces and objects, particularly in institutional settings
- Implementation of contact precautions
- Soap and water for hand hygiene should be considered rather than alcohol-based hand rubs
- All surfaces disinfected with with an agent shown to have efficacy (e.g., hypochlorite, 1000 ppm)

Conclusions

C. difficile, Rotavirus, Norovirus

- All three agents
 - have been found in abundance in the environment of individuals with disease
 - have been found on the hands of healthcare workers providing care to affected patients or touching the contaminated environment
 - survive in the environment (days to months [spores])
 - are relatively resistant to chemical disinfection (including alcohol)
 - have caused outbreaks in hospitals
 - are transmitted by either ingestion or direct inoculation of the GI tract
 - have epidemiological evidence that environmental surface contamination may be a source for infections

Conclusions

C. difficile, Rotavirus, Norovirus

- Environmental control
 - In general, changes in disinfectants to eliminate specific pathogens not required.
 - Current high-level disinfection recommendations are adequate to prevent healthcare-associated infections via semicritical items such as endoscopes
 - Because these three agents are resistant to many surface disinfectants, care must be taken to use agents with evidence of efficacy (e.g., hypochlorite-based products). Ensure all surfaces are disinfected and all equipment is assigned.
 - Areas with high rates of *C. difficile* (e.g., 3 cases/1000 patient days), rotavirus and norovirus may warrant hypochlorite-based products
 - Soap and water should be used preferentially to alcohol-based hands rubs for *C. difficile* and possibly for norovirus and rotavirus.

disinfectionandsterilization.org

Thank you