New Technologies and Challenges in Environmental Decontamination

Martin Kiernan
Visiting Clinical Fellow
University of West London

Clinical Director, GAMA Healthcare

Cleaning

- So, what's scientific and technical about environment cleaning?
  - All of it!
- The evidence base for the environment being a source of transmission of pathogens between patients has steadily grown over the past 10 years
  - Even though actually some others were interested in this years ago

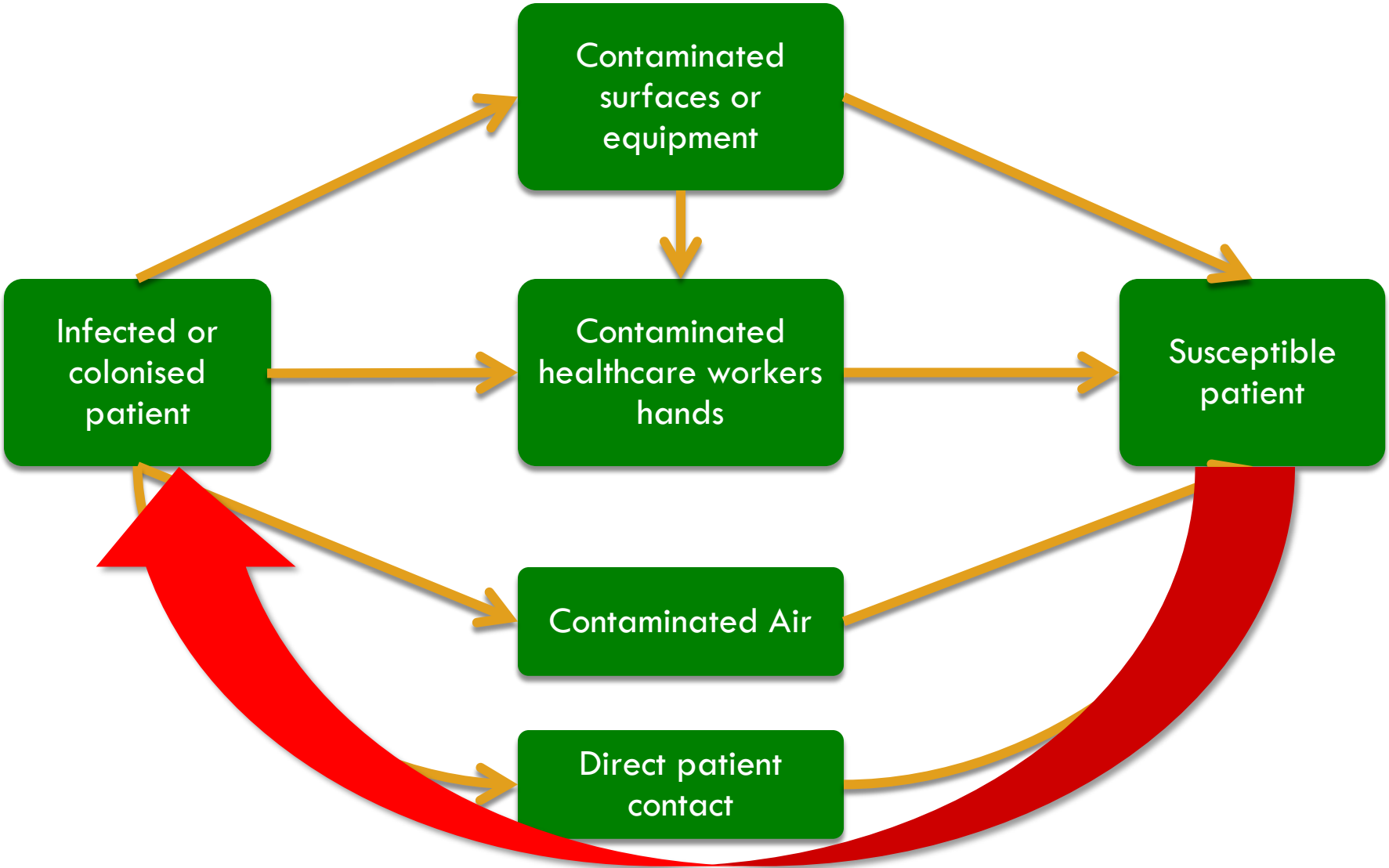
When the evidence is lacking

NW England Communicable Disease Task Force (1995)

- We were concerned about cleaning reductions
- No solid evidence base, but we theorised:
  - Contamination of the environment by human pathogens can be shown
  - These microbes can persist in the environment
  - A significant route to patients can be shown
  - A useful level of decontamination of the environment can be achieved

Contamination of the Environment and Transmission in Healthcare Settings

Otter JA et al. ICHE 2011; 32:687-699



Linking the Environment and Infection

- We have moved forward (eventually)
  - Dettenkofer (2004) AJIC
    - quality of evidence poor; no convincing evidence that disinfection of surfaces reduces infection
  - Donskey (2013) AJIC
    - High quality studies support environmental decontamination as a control strategy
- Debate continues, but not as much as it used to..
  - Cleaning has never been considered to be an evidence-based profession

Environmental Survival of Key Pathogens on Hospital Surfaces

Pathogen	Survival Time
S. aureus (including MRSA)	7 days to >12 months
Enterococcus spp. (inclding VRE)	5 days to >48 months
Acinetobacter spp	3 days to 11 months
Clostridium difficile (spore form)	>5 months
Norovirus	8 hours to 28 days (Temp dependent)
Pseudomonas aeruginosa	6 hours to 16 months
Klebsiella spp.	2 hours to >30 months

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

Is there a “safe” level of surface contamination?

Pathogen	Amount shed	Minimum infectious dose
Norovirus	Up to 10^{12} per g faeces	1-100
C. difficile	Up to 10^{9} per g faeces	1 cfu / cm^2
S. aureus	Up to 10^{7} per g faeces	<15 cfu

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

Virus links with the environment

Boone and Gerba (2007) Applied and Environmental Microbiology 73(6)

Virus	Optimal Environmental Conditions	Mode of Acquisition	Evidence of Transmission
RSV	Composition of surface more important than humidity and temp	Intranasal inoculation	Proven
Rhinovirus	Survives well in high humidity	Intranasal inoculation	Proven
Influenza	Survival for 48 h on dry surface; 72 h for avian influenza virus on dry surface	Intranasal inoculation	Proven
Norovirus	Survived at 4°C when dried for 56 days; survival decrease with Temp increase	Ingestion, very low dose (10-100 particles)	Not proven, indirect evidence supports

Transmission in Outpatients

Lu et al, Clin Infect Diseases, Dec 2015

- Coxsackie and Enterovirus A - Hand, Foot and Mouth
  - Non-enveloped virus, survives well in the environment (2 weeks plus)

Table 1. Environment Surveillance of Enterovirus in 2 Pediatric Hospitals in Guangzhou City, Guangdong China

	Enterovirus Positive, No./Total Sample, No. (%)			
	Children's Hospital 1		Children's Hospital 2	
Sample Site	HFMD Clinics	Other Clinics	HFMD Clinics	Other Clinics
Waiting room chair	15/16 (94)	18/50 (48)	3/7 (43)	7/25 (28)
Lift button and escalator rail	Null	4/9 (44.4)	Null	1/9 (11)
Door handle in toilet	2/4 (50)	3/7 (43)	2/4 (50)	3/7 (43)
Chair, door handle, and desk in clinic and nurse station	4/7 (57)	13/40 (33)	6/15 (40)	14/42 (33)
Total	21/27 (78)	38/106 (36)	11/26 (42)	25/83 (30)

Control: fomite transmission?

- MERS-CoV has been shown to survive on dry surfaces for hours; studies evaluating extended survival times / conditions currently lacking [1]

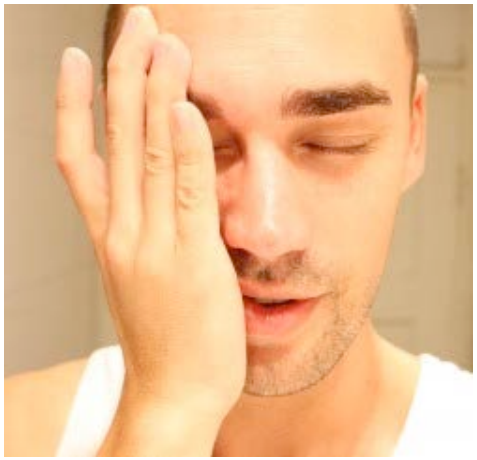
- In addition to survival on dry hospital surfaces, aerosols of human coronaviruses and influenza viruses can survive in the air for long periods of time. For example, a human coronavirus aerosol was able to survive for 6 days in one study [2]

1. van Doremalen *et al. Eurosurveillance* 2013;18
2. Ijaz *et al. J Gen Virol* 1985;66:2743-2748

Face Touching

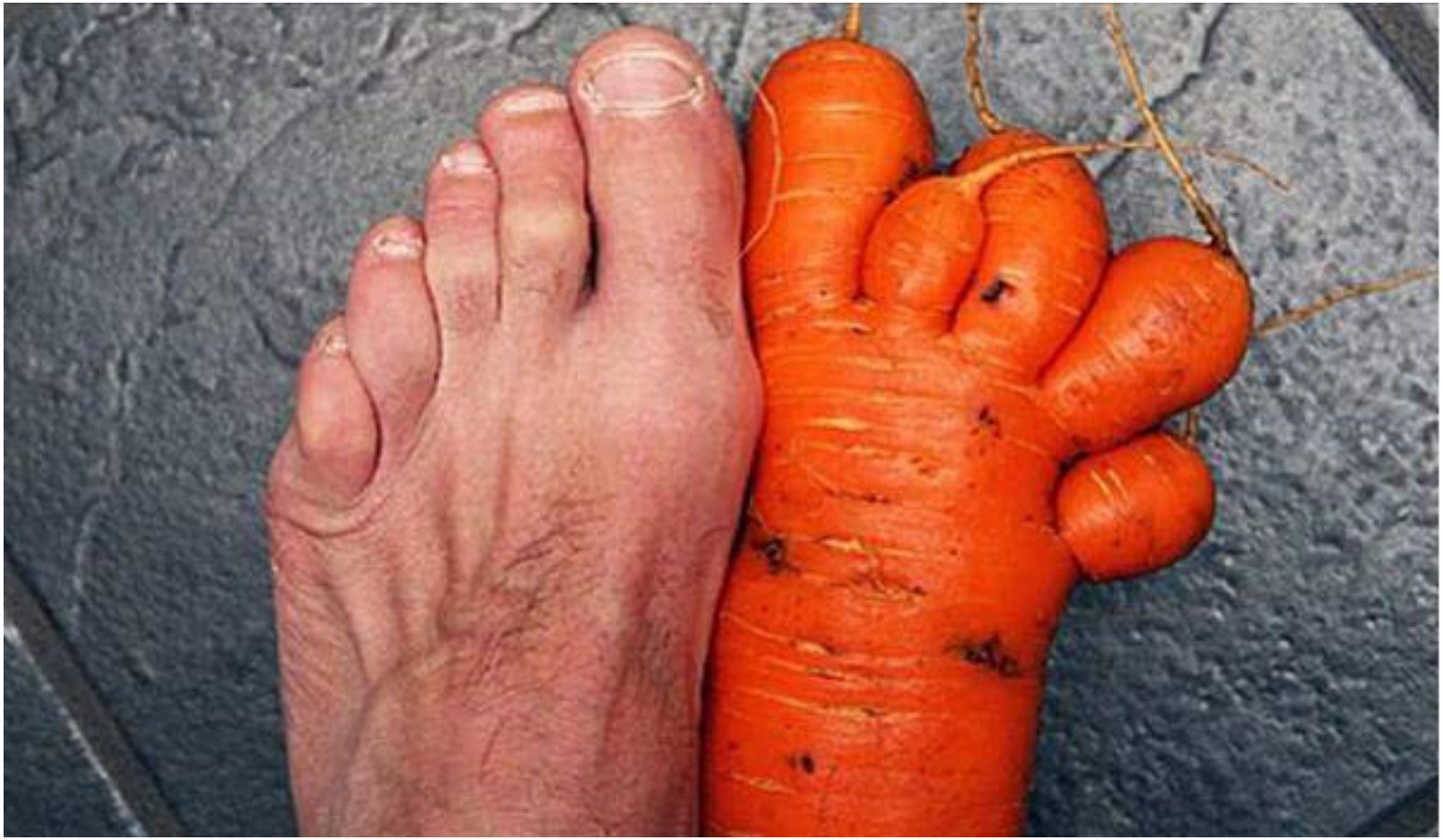
Kwok et al (2015) AJIC 43

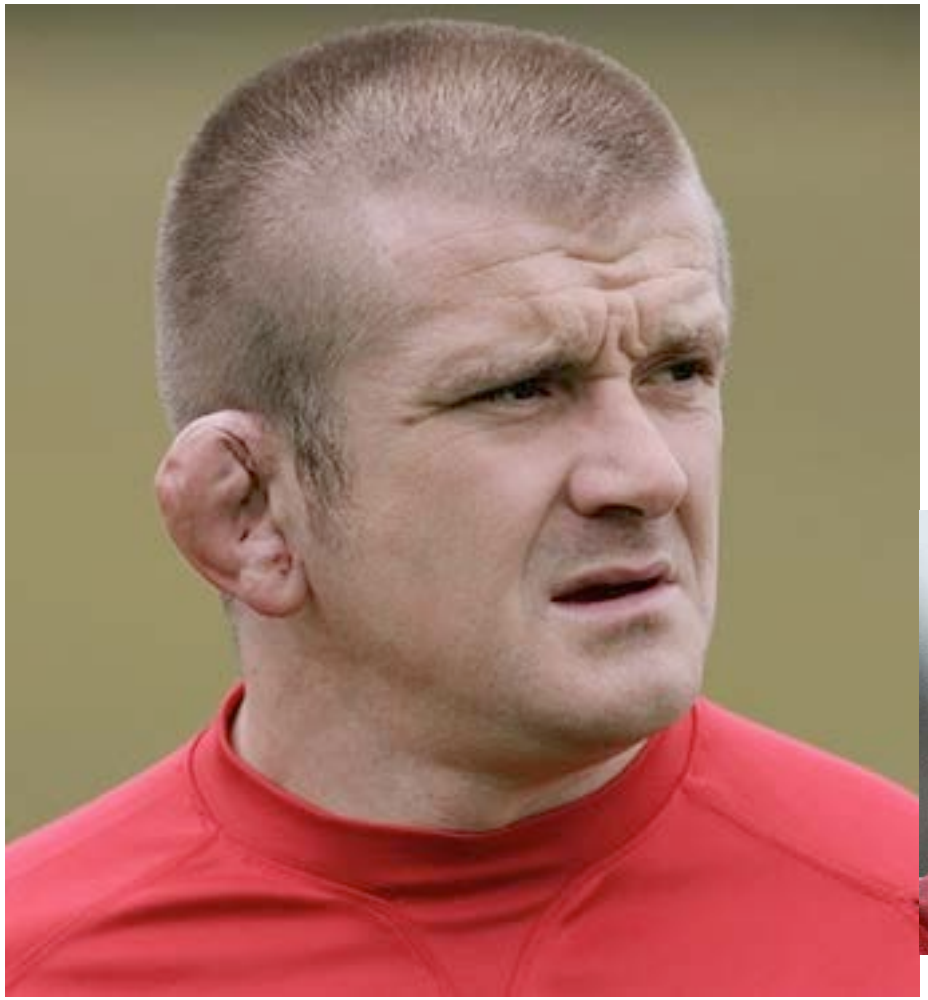
- Adults touch their face 23 times per hour
  - 44% mucous membrane
    - 36% mouth
    - 31% nose
    - 27% eyes
    - 6% all three
  - Mouth 4x
  - Nose 3x
  - Eye 3x



Evidence for Organism Transfer in Clinical Environments

- Inoculation of cauliflower mosaic virus DNA onto phone in an neonatal ICU cubicle
  - Virus spread to 58% of ward sampling sites within 7 days of inoculation
  - Spread to all five other cubicles
  - Door handles in other cubicles became positive first
    - Oelberg DG, et al. Detection of Pathogen Transmission in Neonatal Nurseries Using DNA Markers as Surrogate Indicators Pediatrics (2000) 105(2):311-5.





Demonstrating transmission from floors

- Study mimicking Oelberg's study
  - Koganti S et al. Infect Control Hosp Epidemiol. 2016:1-4
  - used bacteriophage MS2, a nonpathogenic, nonenveloped RNA virus, to examine the potential for dissemination of microorganisms from floors of isolation rooms to the hands of patients and to high-touch surfaces inside and outside of rooms
    - Patients isolated for MRSA, C. difficile and other MDROs

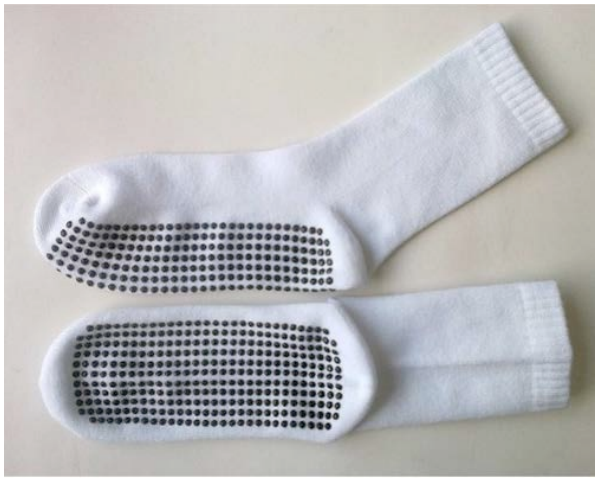
Results

- MS2 detected on multiple surfaces of **all** patient rooms the day after inoculation
  - concentration was higher for surfaces less than or equal to 3 feet vs more than 3 feet from the bed ($P < 0.02$)
  - more sites were contaminated at less than or equal to 3 feet (day 1, $P < 0.06$; day 3, $P < 0.0001$)
- Contamination was common on high-touch surfaces
  - in adjacent rooms (11%)
  - on portable equipment (100%)
    - wheelchairs, medication carts, vital signs equipment, and pulse oximeters
  - at the nursing station (67%), especially keyboards

Socks?

Mahida N. et al, J Hosp Inf (2016) 94(3) 273-5

- Non-slip socks as a ‘solution’ to patient falls issues
  - Socks meant to be worn continuously
  - Patient gets onto and into the bed wearing them
- Sampling revealed
  - 85% contaminated with VRE (no known cases)
  - 7% with MRSA (no known cases)
- Would nurses removing them consider them to be contaminated?

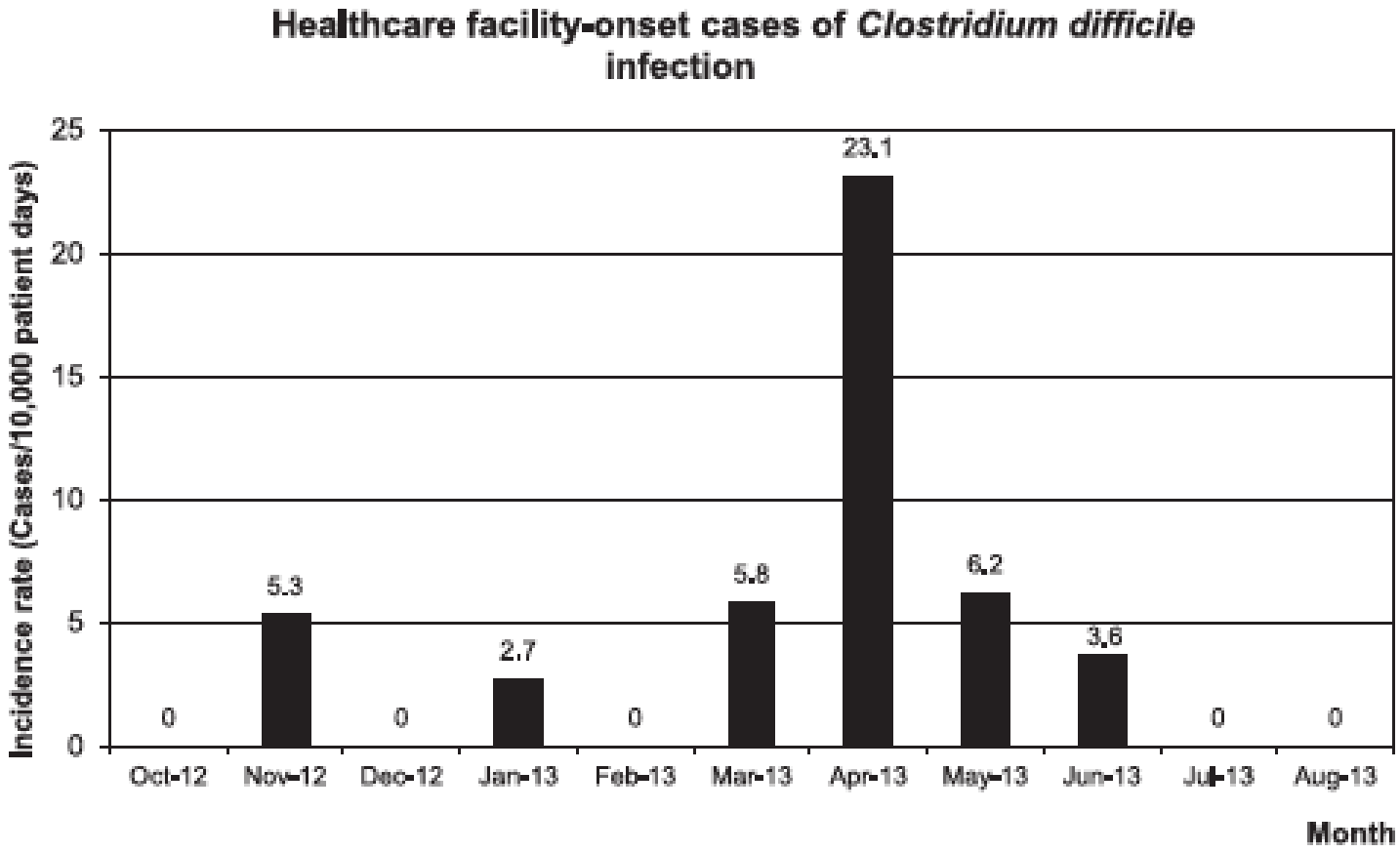


Study Conclusions

- A non-pathogenic virus inoculated onto floors in hospital rooms disseminated rapidly to the footwear and hands of patients and to high-touch surfaces in the room
  - The virus was also frequently found on high-touch surfaces in adjacent rooms and at nursing stations
  - Floors in hospital rooms could be an underappreciated source for dissemination of pathogens
- Because nonsporicidal disinfectants are often used on floors in rooms of patients with C. difficile infection, there is a particular need for data on how effectively the burden of spores is reduced on floors

Clostridium difficile

Sooklal, S., et al. Am J Infect Control, 2014. **42**(6): p. 674-5



Clostridium difficile

Sooklal, S., et al. Am J Infect Control, 2014. **42**(6): p. 674-5

- No differences in patient groups, community CDI rate, staffing, testing methods, other factors
- Then they examined the laundry records
  - Laundry Bleach use did not match expected use
    - Machine accidentally switched to microfibre setting
    - Estimated that 100 loads of floor mop pads used for C. difficile washed without bleach
    - Return to zero cases when microfibre setting was made obsolete
- But floors are rarely considered to be a risk?

A series of unfortunate events

- Colonised person
  - Shedding of pathogens
    - Environmental contamination
      - Contamination persists
        - Failure to clean or disinfect
          - Staff acquire
            - Staff fail to remove
              - Transfer to new patient
                - Patient becomes colonised, risk of infection

Tranmission from previous room occupant

Mitchell et al, J Hosp Inf (2015) 91(3) 211-7

- Pooled acquisition odds for the study pathogens (MRSA, VRE, CD, AB, ESBL-GNs) was 2.14
  - 1.89 for gram-positives (95% CI: 1.62-2.21)
  - 2.65 for gram-negatives (95% CI: 2.02-3.47)
    - Acinetobacter had the biggest effect; 4.53 (95% CI: 2.32-8.86)

Other points

- 5/6 studies were undertaken on single rooms
  - In which the status of previous patient was known and a higher level of decontamination was carried out
  - Or certainly should have been
- We only know what we know
  - “There is a need for renewed interest and emphasis on cleaning and particularly discharge or terminal cleaning”

Patient Environment

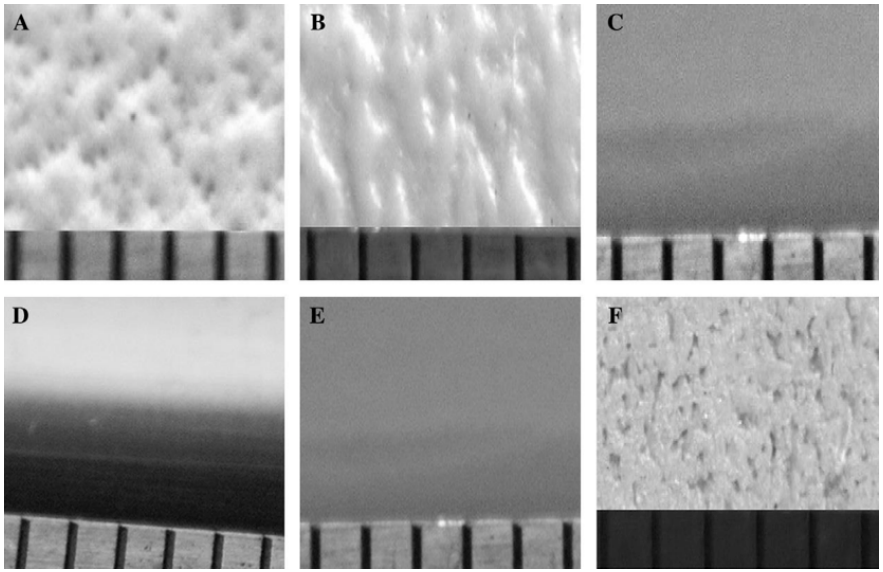
- Doorknobs, bed rails, curtains, touchscreens, keyboards contaminated by hands which onward transmit
  - MRSA on door handles of 19% of rooms housing MRSA & 7% of door handles of non-MRSA rooms
    - Oie S. et al. J Hosp Infect. 2002;51(2):140-3
  - ‘But I did not touch the patient’
    - 42% of nurses contaminated gloves with MRSA with no direct patient contact but by touching objects in rooms of MRSA patients
      - Boyce JM. et al ICHE 1997;18(9):622-7.

Clostridium difficile contamination

- Contamination of the environment spores more common in symptomatic cases than asymptomatic carriers: 49% v 29%
  - Kim et al *J. Infect Dis* 1981
  - Range from 10%-50%; correlates with frequency of C. difficile acquisition
    - Weber DJ et al, AJIC 2013; S105-S110
  - Blood Pressure cuffs 10% contamination rate (vs. 11.5% for bedside commodes (toilets)
    - Manian FA, et al. ICHE 1996;17:180-182

Think before you buy

Ali et al. J Hosp Infect 2012;80:192-198.



- 6 hospital bedrails - very different surfaces
  - ease of cleaning as inversely proportional to the transfer of S. aureus from the surfaces
  - If you cannot clean it, do not buy it

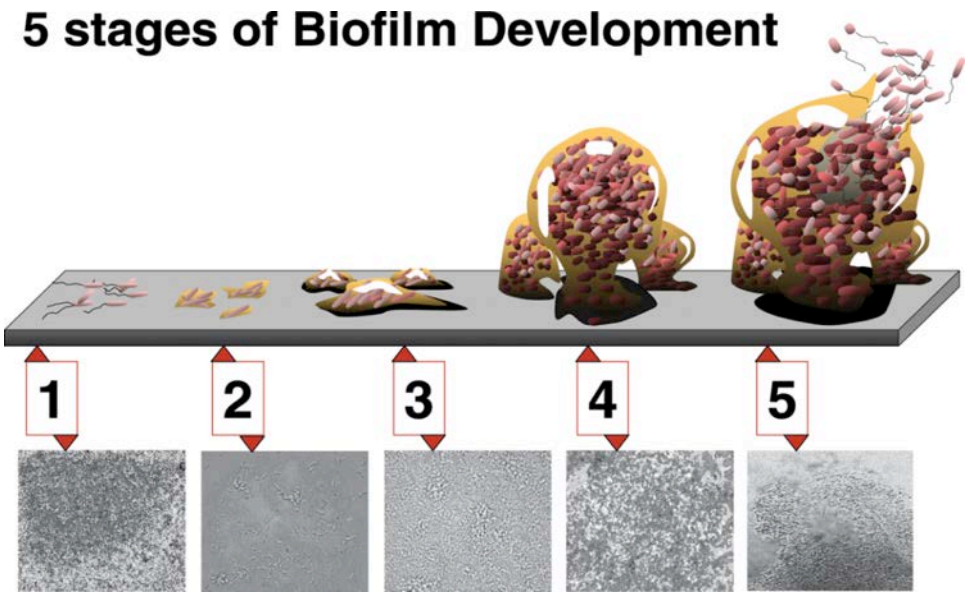
Background

Contaminated environment leads to risk

Interventions decrease environmental contamination

Decreased environmental contamination decreases risk

Issues With Routine Cleaning



- Biofilms form at interfaces
  - Solid/liquid
  - Solid/air
  - Liquid/air
- Biofilms are nearly always mixed species
  - They protect organisms within them
  - Sessile (dormant) state makes organisms intrinsically less sensitive

Biofilms in the environment

- Viable MRSA grown from biofilm clinical surfaces from an ICU despite terminal cleaning
  - Current cleaning practices may not be adequate to control biofilm development
  - Organisms protected within biofilms may be the mechanism by which they persist within hospital environments
    - Vickery K, Deva A et al J Hosp Infect. 2012;80(1):52-5

Biofilm survival

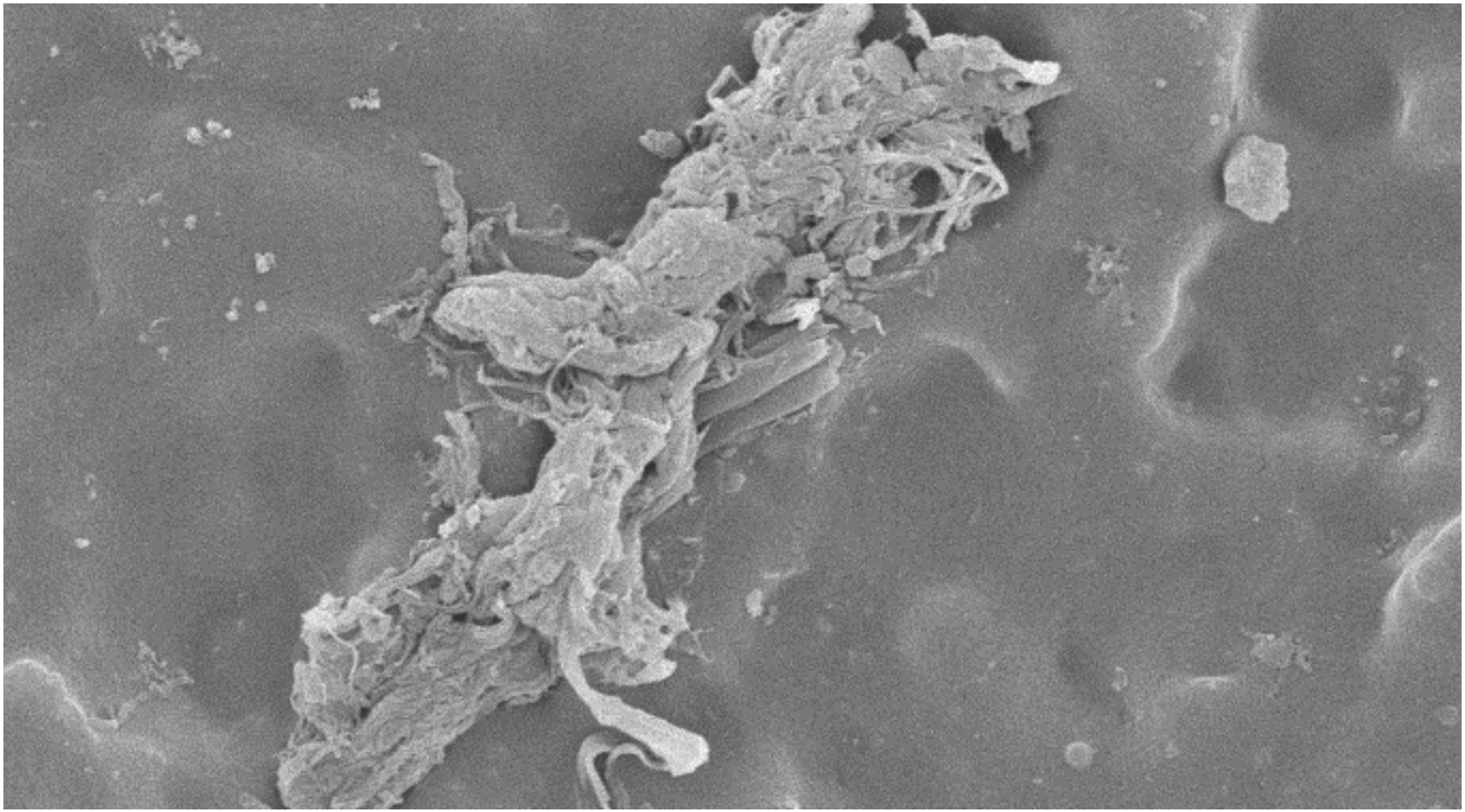
Hu et al, JHI (2015)

- ITU decommissioned, two terminal cleans with hypochlorite
  - At least one MDRO grew from 52% of cultures
  - Electron microscopy of surfaces

Item	N	Biofilm	Live at 12 months
Mattress	6	6	5
Pillow	5	5	3
Curtain	9	8	4

Mattress

Hu et al, JHI (2015)



Tracing the source of an outbreak

Halachev et al (2014) Genome Medicine 6:70

- Epidemiology of a protracted Acinetobacter baumanii outbreak
  - Patients did not overlap
  - Used Whole Genome Sequencing and epi data
- Long-term contamination of ward environment thought to account for transmission
  - confirmed by environmental swabbing of side rooms after patients had been discharged and room cleaned
  - Identified contaminated bed and burns theatre as sources of transmission

Acinetobacter spp - True survivors

- 10 strains of A. radioresistens extremely resistant to desiccation and survived for an average of 157 days at 31% relative humidity
  - Two strains of A. iwoffi and three strains of A. baumannii survived for an average of three and 20 days respectively, at 31% RH (normally found in UK & I hospitals)
  - Cases of A. radioresistens infection may be under-reported due to misidentification as A. iwoffii
    - Jawad et al, (1998) JHI 39 235-40

Acinetobacter resistance transfer

Poirel, L. et al (2008) Antimicrob Agents Chemother **52**(4): 1252-1256

- Hypothesized that bla$_{OXA-23}$ gene donor may share reservoirs with the recipient A. baumannii isolate, i.e., human skin
  - *A. radioresistens* frequently found on skin of patients
    - Seifert H. et al J. Clin. Microbiol. 35:2819–2825
  - Rarely a clinical pathogen but identified as a silent source of the *bla*$_{OXA-23}$ gene
- Studies have shown this to be the most common environmental isolate
  - Webster, C. A. et al (1998) Eur J Clin Microbiol Infect Dis **17**(3): 171-176.

Biofilms and Gram-negatives

- Biofilm-producing strains of A. baumanii survive more than twice as long in the environment
  - Electron microscopy shows a polysaccharide layer and appendages in biofilm-forming strains, not non-biofilm forming ones
    - Espinal et al, JHI (2012) 80; 56-60
  - Conjugative plasmid, encoding type 3 fimbriae, resulting in enhanced biofilm formation of the plasmid-harbouring strain
    - Klebsiella, Enterobacter, other Enterobacteriaceae
      - Burmolle, M., et al (2008) Microbiology 154 (Pt 1): 187-195.

Cleaning is variable

Hong Xu, Hui Jin et al (2015) AJIC 43(292-4)

High-touch surfaces in Intensive care unit

- Significant variability in cleaning efficacy
- Evidence of ESWs re-contaminating the environment

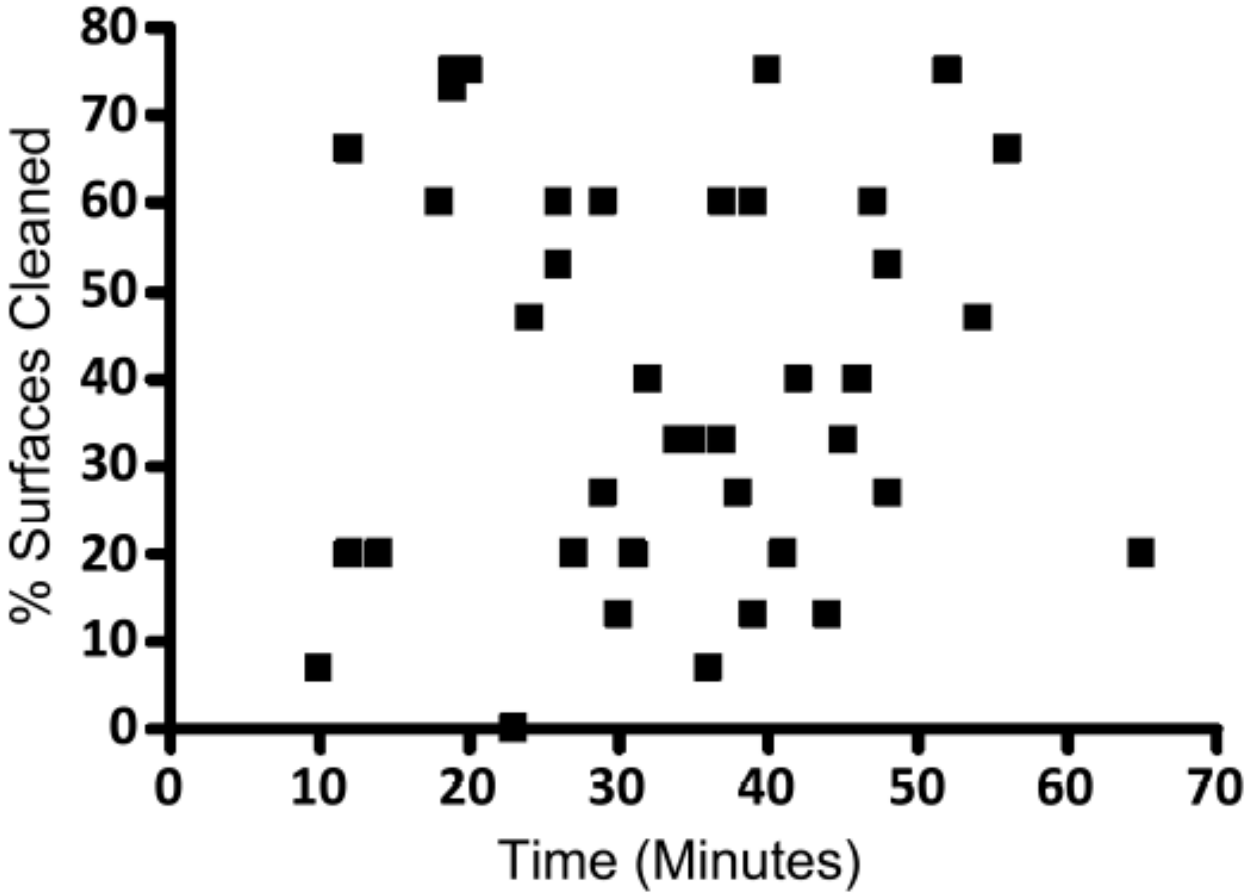
MRSA isolated from the same surface before and after cleaning

MRSA isolation (before cleaning → after cleaning)	Surfaces no. in ICPs group (%)	Surfaces no. in ESWs group (%)
Positive → positive	0 (0)	9 (22.5)
Positive → negative	22 (55)	11 (27.5)
Negative → positive	0 (0)	3 (7.5)
Negative → negative	18 (45)	17 (42.5)

ESW, environmental service worker; *ICP*, infection control professional; *MRSA*, methicillin-resistant *Staphylococcus aureus*.

Time spent cleaning does not show that it was done well..

Rupp ME, Adler A et al, ICHE 34(1) 100-2 (2013)



Cleaning

- Removal of soil, not all contamination
- Heavily dependent on the person doing the cleaning
  - Skill
    - Training
  - Knowledge
    - Education
- Normally carried out by employees of low status who are poorly paid and valued in the organisation
- Can automated systems work?

Automated room decontamination (ARD)

Hydrogen peroxide vapour 30% H_2O_2 (HPV)

Aerosolised hydrogen peroxide 5-6% H_2O_2 (AHP)

Ultraviolet radiation (UVC)

Pulsed-xenon UV (PX-UV)

Otter *et al*. *J Hosp Infect* 2013;83:1-13.

Hydrogen peroxide

- Portable self-contained decontamination units
  - Emits dry mist of hydrogen peroxide (5%) and silver cations (<50 ppm) or Vapourised Hydrogen peroxide (30%)
  - 99.99% biodegradable, non-toxic and non-corrosive
- Not all systems are equal in terms of in-use practicality and efficacy

ARD systems – overview of HPV

	HPV **30-35% H_2O_2 vapour**	**AHP** **5-6% H_2O_2 + Ag aerosol**
Efficacy	1 >6-log reduction	2 ~4-log reduction
Distribution	1 Homogeneous	2 Non-homogenous
Ease of use	4 Multiple units; sealing / monitoring	3 Sealing & monitoring
Cycle time	3 ~1.5 hrs single room	4 >2 hrs single room
Purchase cost	2	1
Running cost	4	3

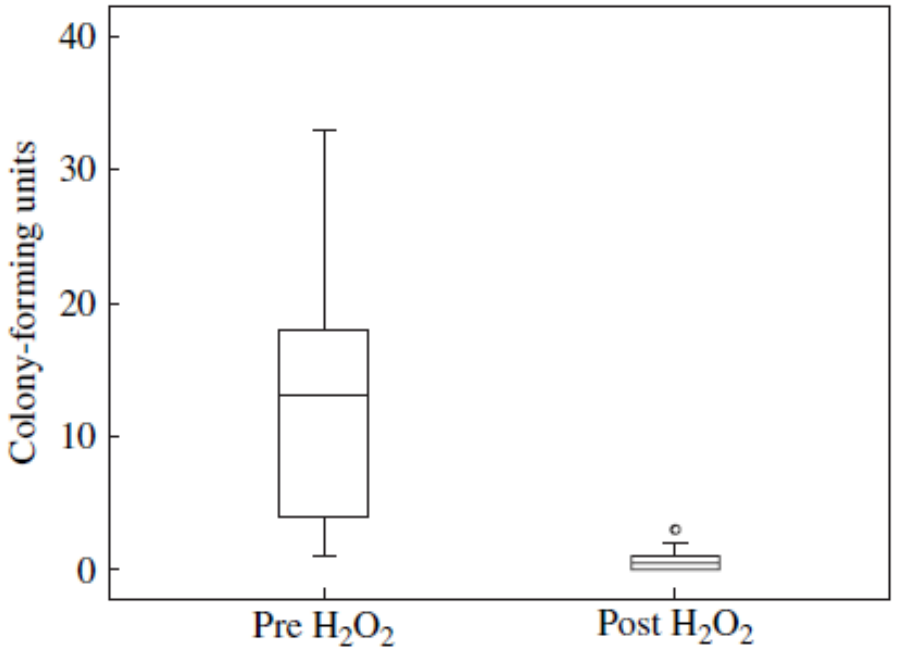
Otter *et al. J Hosp Infect* 2013;83:1-13.

Gaseous hydrogen peroxide v C.difficile in patient isolation rooms

Table I Overall recovery of environmental *C. difficile* from low, medium and high risk wards, and recovery of *C. difficile* before and after hydrogen peroxide decontamination

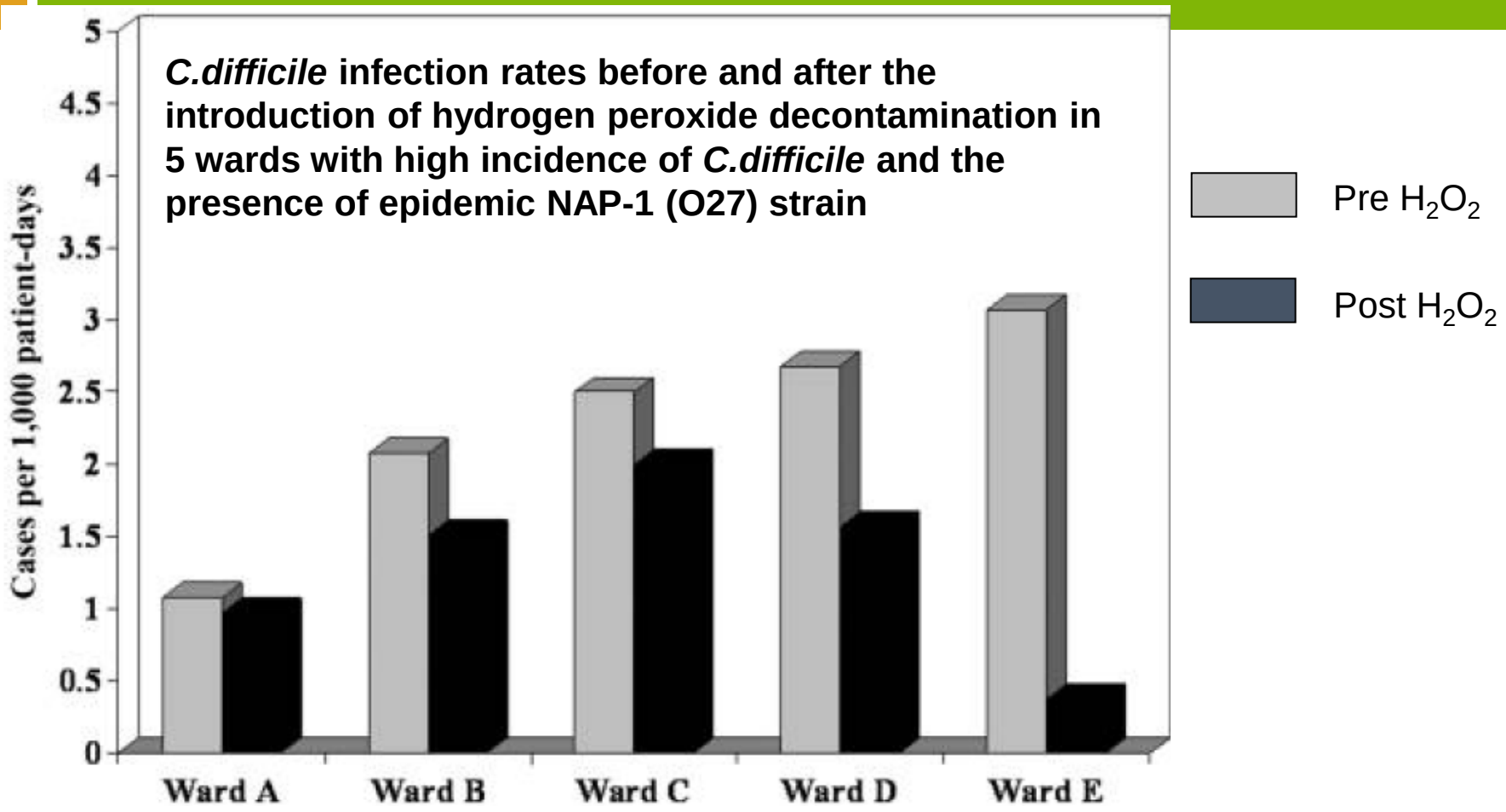
	% (no.) of rooms positive for *C. difficile*	% (no.) of samples positive for *C. difficile*	Mean *C. difficile* cfu per 10 samples
Low risk areas	67% (2/3)	3% (2/60)	0.3
Moderate risk areas	100% (2/2)	11% (5/44)	1.1
High risk areas	100% (11/11)	26% (58/223)	6.2
Before H_2O_2 decontamination	100% (10/10[a])	24% (48/203)	6.8
After H_2O_2 decontamination	50% (5/10[a])	3% (7/203)	0.4

[a] Due to a technical failure of the Sterinis® on one occasion only 10/11 rooms in the high risk areas had paired sampling results before and after hydrogen peroxide decontamination.



Shapey *et al*. Activity of a dry mist hydrogen peroxide system against environmental *Clostridium difficile* contamination in elderly care wards. J Hosp Infect (2008) 70:136-141

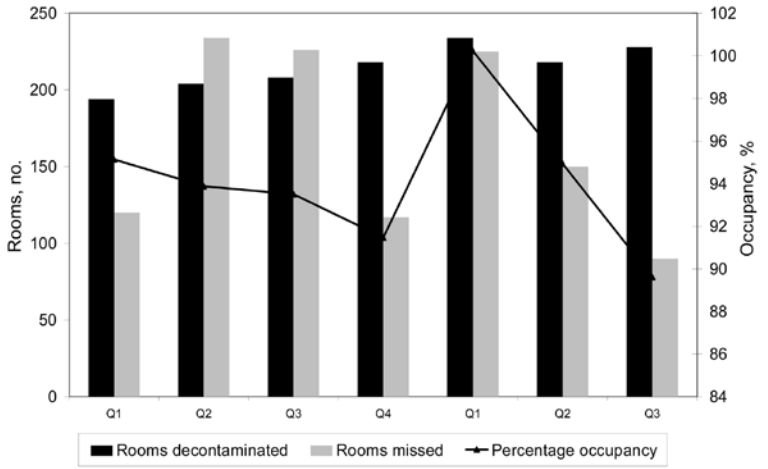
Reduction in CDI in 10 month period before and after introduction of gaseous H^2O^2



Boyce JM *et al*. Impact of hydrogen peroxide vapor room decontamination on *C.difficile* environmental contamination and transmission in a healthcare setting. Infect Cont Hosp Epidemiol (2008) 29: 723-729

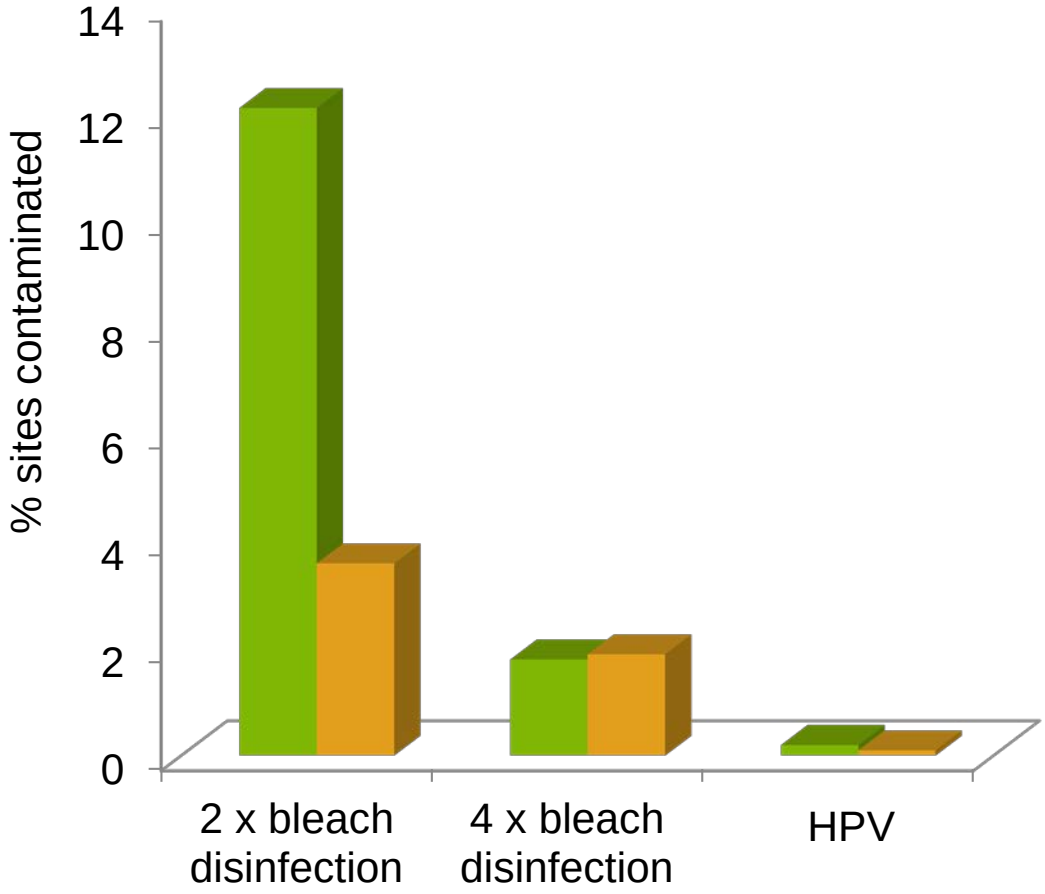
Feasibility

- Biggest issue is related to turn-around time
  - Originally quoted as up to 4-5 hours
  - Hopkins trial = 1.5 to 3 hours
- 1,565 rooms in 500-bed teaching hospital
  - Mean occupancy of hospital = 94%
  - HP system run by personnel from company
  - Total added time ~3.5 hours of additional turnover time
    - ~3 hours from machine



Otter et al. ICHE 2009 30:574-577

Persistent contamination – fixed!



- 140 samples from 9 rooms after 2xbleach
- 5705 samples from 312 rooms after 4xbleach
- 2680 sites from 134 rooms after HPV

Manian *et al. Infect Control Hosp Epidemiol* 2011;32:667-672.

UV Light - Overview

- UV light damages nucleic acid and destroys the ability of bacteria/viruses to replicate
- The UV light is highly and predictably germicidal
- UV light in this spectrum rapidly removes >99% of microbial contamination from the air and on surfaces
- Competition – multiple companies now make UV-emitting devices

How does UV-C Work?

- UV irradiation has been used for the control of pathogens in a variety of applications
  - legionella, air, surfaces and instruments
- Some wavelengths of UV break the molecular bonds in DNA, thereby destroying the organism
  - UV-C has a characteristic wavelength of 200 nm to 270 nm, which lies in the germicidally active portion of the electromagnetic spectrum of 200 nm to 320 nm
- Efficacy is a function of many different parameters, such as intensity, exposure time, lamp placement and air movement patterns

UV History – started with the air..

Year	Event
1877	Downes and Blunt discover the ability of sunlight to prevent microbial growth. Later shown that the ability of light to inactivate microorganisms is dependent on the dose (intensity x time) and wavelength of radiation and the sensitivity of the specific type of microorganism
1930	Gates publishes first bactericidal spectrum with peak effectiveness at 265 nm
1935	Wells and Fair demonstrate ability of UV to efficiently inactivate airborne microorganisms and prove the concept of infection via the airborne route, later looking at measles transmission
1956 –1962	Riley exposed guinea pigs to air from occupied TB ward and proved spread via the airborne route. Guinea pigs receiving infected air via a UV irradiated duct were not infected, while a group receiving air via a non-irradiated duct were infected

Then..

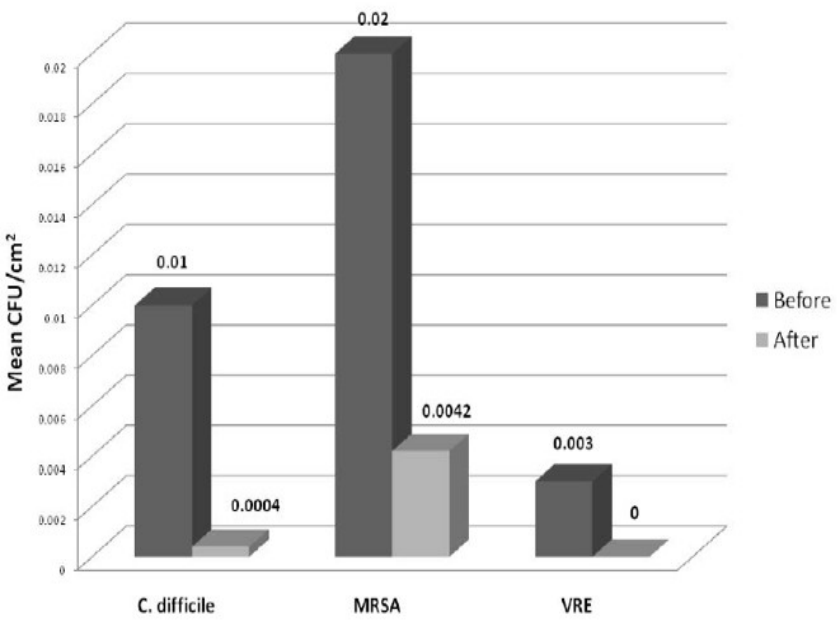
- The period of disillusionment
  - Felt to be maybe useful for air disinfection but people had moved on – antibiotics were the answer!
- The water industry did however think this was a good idea and use has been widespread
  - You can’t treat water with antibiotics (ish..)
- All was well until antibiotics began to run out
  - Back to the future then

Mobile Ultraviolet Light Systems

- UV units can be programmed
  - short cycle times to kill vegetative bacteria
  - longer cycle times to kill spores
  - Room size and layout also needs to be taken into account
    - Ensuite rooms may need 3 placements
- Several systems have been shown by independent investigators to significantly reduce bacterial counts in patient rooms
  - Easy to use, minimal training needed

Nerandzic MM et al. BMC Infect Dis 2010;10:197
Rutala WA et al. Infect Control Hosp Epidemiol 2010;31:1025

UV-C Surface Swabs



- High touch surfaces of a bathroom
  - 60,000 cm^2
  - *C. difficile* spores
    - Before: 600 spores
    - After: 24 spores
  - MRSA
    - Before: 1,200
    - After: 240
  - VRE
    - Before: 180
    - After: 0

From Nerandzic MM et al. *BMC Infect Dis* 2010;10:197

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

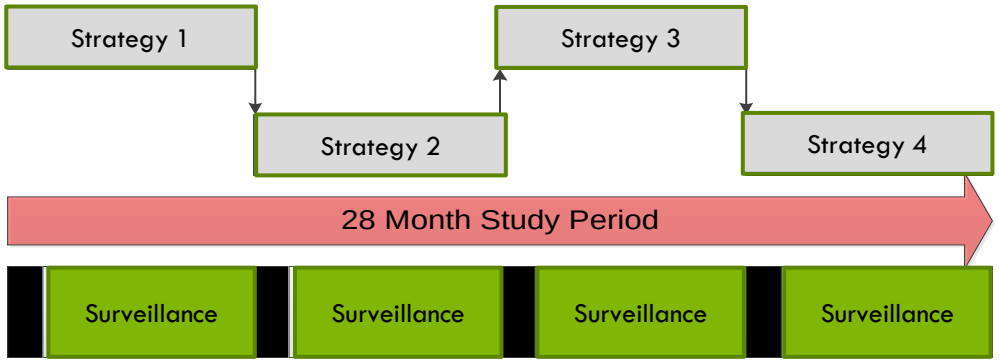
Deverick J Anderson, Luke F Chen, David J Weber, Rebekah W Moehring, Sarah S Lewis, Patricia F Triplett, Michael Blocker, Paul Becherer, J Conrad Schwab, Lauren P Knelson, Yuliya Lokhnygina, William A Rutala, Hajime Kanamori, Maria F Gergen, Daniel J Sexton; for the CDC Prevention Epicenters Program

- Objective - to determine if enhanced methods for terminal room disinfection decrease acquisition and infection due to multidrug-resistant organisms (MDROs)

- Design - prospective, multicenter, cluster-randomized, crossover trial to evaluate three strategies for enhanced terminal room disinfection

Methods

- 28 months – all 4 cleaning strategies
  - Each strategy for 7 months
    - Sequence randomized
  - First month: “wash in” between phases



	No UV-C	UV-C
Quat*	A	B
Bleach	C	D

BETR Results

- Enhanced terminal room disinfection strategies decreased the clinical incidence of target MDROs by 10-30% among exposed patients
  - Biggest decrease – adding UV to “standard” cleaning with QUATs
  - Biggest impact on vegetative bacteria
  - Impact on *C. difficile*?
    - Indirect benefit
    - For logistical ease, easiest to target contact precautions
- Many lessons learned
  - Need specific strategies to improve compliance if using enhanced strategies

The problem of absorbtion

- Light is either absorbed, reflected or transmitted when it hits a surface
  - White plastic will absorb approx 95% of UV light
  - Light only travels in straight lines, so only a small amount is reflected
  - Shadows are the worst enemy
  - Effectiveness data may be derived from direct line of sight tests
    - Shadowed surfaces may receive a factor 1000 less

Reflective paints can help

Rutala et al, ICHE (2014)

- Study demonstrating effectiveness of coating walls with UV-reflective paint
  - Cost $300
  - Line of sight still most effective, but
    - C. difficile reduction to achieve same effect from 43 to 8 min.
    - Reduced downtime by approx 80% to 5-10 min. per room

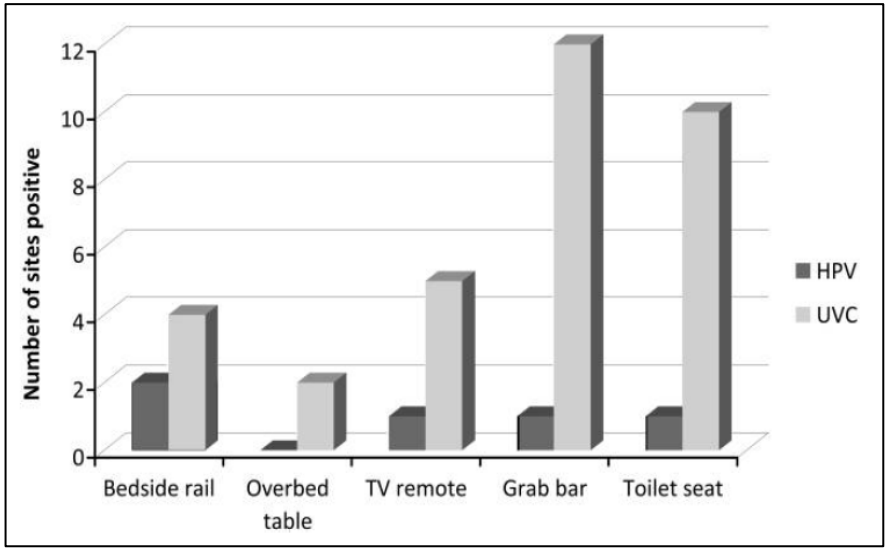
ARD systems – overview of UV-C

	UVC **UVC (280 nm)**	**PX-UV** **Pulsed-xenon UV**
Efficacy	3 ~2-4 log reduction	4 ~1-3 log reduction
Distribution	3 Line of sight issues	3 Line of sight issues
Ease of use	2 Multiple positions; no sealing / monitoring	2 Multiple positions; no sealing / monitoring
Cycle time	1 ~10-30 mins	1 ~10-30 mins
Purchase cost	3	3
Running cost	1	1

Otter *et al. J Hosp Infect* 2013;83:1-13.

UV v. HP

- Experimental conditions in 15 rooms
  - *C. difficile* spores
  - Biologic indicators (*G. stearothermophilus*)
- Log reduction greater for HP than UV
  - >6 v ~2 ($p<0.0001$)
  - More growth if "shadow"
- HP twice as much additional time



Havill et al. ICHE 2012;33:507

No-Touch Methods for Disinfection

Advantages

UV	Hydrogen peroxyde
Eliminates 2-4 log_{10} spores seeded on formica surfaces[1]	Achieves high-level disinfection (>6-log_{10} reduction for HPV, 4 log_{10} for aHP) [2,3]
HVAC (heating, ventilation, air conditioning) does not need to be disabled and the room does not need to be sealed	Compatible with hospital materials including electronics
No safety and health concerns	Environmentally friendly – degrades to O_2 and water vapour
3 clinical studies, including a large multi-centre RCT	3 clinical studies (reduce CDI incidence)
Good distribution of UV energy via an automated monitoring system	Does not rely on the operator for distribution, contact time and repeatability Real-time monitoring and feedback and can be validated using BIs* / cycle data

1-Rutala *et al.,* ICHE 2010, 31, 1025-1029
2- Fu TY *et al.,* JHI 2012, 80, 190-205
3- Barbut F, ICHE 2009;30(6):507-14

No Touch Methods for Disinfection

Disadvantages

UV	Hydrogen peroxide
Cleaning must precede disinfection	
Patients or staff should be removed prior to decontamination (cannot be used for daily disinfection)	
Capital equipment cost are substantial Staff time to transport the equipment to the room.	
Sensitive to use parameters (eg wavelength, UV dose delivered)	HPV is hazardous to humans so needs to be contained
Efficacy is significantly lower when the surface is out of direct line of sight of the device	Doors must be closed with gaps sealed by tapes
Full UV-C spore cycle requires **68 min. (34-100)**	Disinfection requires **2.5 - 5 hours**

HPV vs UV Systems

- Choice between HPV and UV systems will depend on a number of factors, including its intended use and practicalities

Variable	UV-C	Hydrogen Peroxide Vapor
Intended use	Decontaminate a relatively large proportion of rooms	Primarily decontaminate rooms with difficult-to-kill or highly virulent pathogens
Level of efficacy needed	Significant reduction of pathogens	Near-total or total eradication of pathogen
Cycle times	15 min – 45 min	2 – 2.3 hrs

Havill NL et al. Infect Control Hosp Epidemiol 2012;33:507
Otter JA et al. J Hosp Infect 2013;83:1

Or, to put it another way

- Hand hygiene with soap and water is the ‘gold standard’, at least in perception
  - But it is time consuming, costly (infrastructure, materials, waste disposal etc,) labour intensive and potentially damaging unless special measures are implemented (hand creams etc)
- Alcohol hand rub is promoted as an effective, pragmatic substitute
  - Effective ‘enough’, cheaper, faster, less labour intensive, less resource and infrastructure

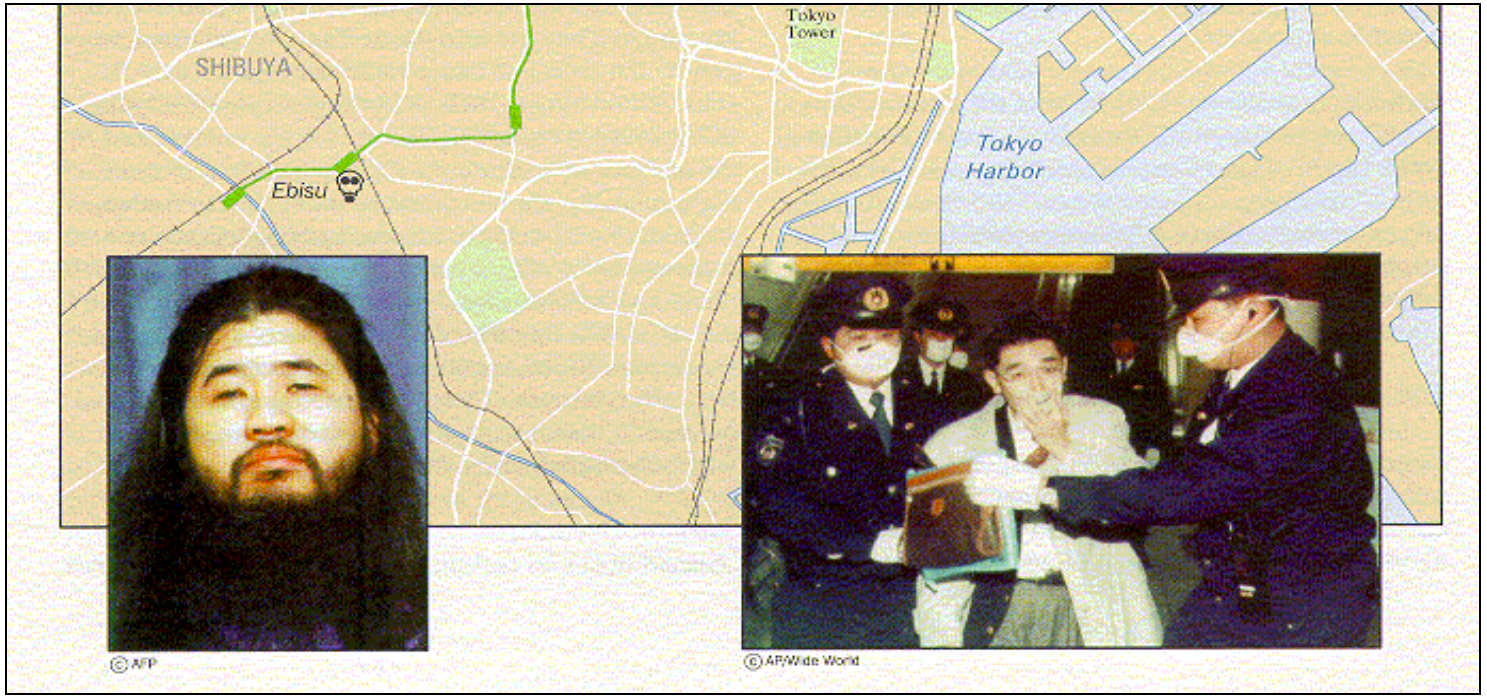
Summary

- Environmental disinfection is important
  - Enhanced disinfection is sometimes needed
- Novel strategies exist to improve environmental disinfection
- UV and HP have emerged as the leading, evidence-based strategies
  - But have significant logistical hurdles to overcome
  - Increasing use of UV light as fewer logistical hurdles
  - Increasing amount of data to support the use of enhanced strategies
- Cleaning is a science and we must recognize it as such and value those that do it

History of Biological Warfare

- Oldest of agents
- Used for > 2,000 years
  - Sieges of middle ages
  - Smallpox blankets given to Native Americans
  - Germany in World War I
  - Japan in World War II
  - Modern Bioterrorism

Aum Shinrikyo Cult



- Sarin Nerve Agent attacks 1994 and 1995
- Attempted Botulinum Toxin release multiple times
- Anthrax released multiple times
- Attempted to obtain Ebola virus in Zaire

Anthrax Letters
United States

Potential Bioterrorism Agents

- Bacterial Agents
  - Anthrax
  - Brucellosis
  - Cholera
  - Plague, Pneumonic
  - Tularemia
- Viruses
  - Smallpox
  - VEE
  - VHF
- Biological Toxins
  - Botulinum
  - Staph Entero-B
  - Ricin
  - T-2 Mycotoxins

Infective Aerosol Doses of Selected Biological Agents

Anthrax spores	8,000 (or fewer)
Plague	100-500 organisms
Q Fever	1-10 organisms
Tularemia	10-50 organisms
Smallpox	10-100 organisms
Viral encephalitides	10-100 organisms
VHFs	1-10 organisms
Botulinum toxin	0.001 ug/kg

Epidemiologic Clues

- Large epidemic with high illness and death rate
- Immunocompromised individuals may have first susceptibility
- Respiratory symptoms predominate
- Infection non-endemic for region
- Multiple, simultaneous outbreaks
- Multi-drug-resistant pathogens
- Sick or dead animals
- Delivery vehicle or intelligence informatio

Anthrax: Microbiology

- Environmental Survival
  - Spores are hardy
    - Resistant to drying, boiling <10 minutes
    - Survive for years in soil
    - Still viable for decades in perma-frost
  - Favorable soil factors for spore viability
    - High moisture
    - Organic content
    - Alkaline pH
    - High calcium concentration

Anthrax: Bioweapon Potential

- Estimated effects of inhalational anthrax
  - 100 kg spores released over city size of Washington DC
    - 130,000 – 3 million deaths depending on weather conditions
  - Economic impact
    - $26.2 billion/100,000 exposed people

Anthrax: Epidemiology

- Three forms of natural disease
  - Inhalational
    - Rare (<5%)
    - Most likely encountered in bioterrorism event
  - Cutaneous
    - Most common (95%)
    - Direct contact of spores on skin
  - Gastrointestinal
    - Rare (<5%), never reported in U.S.
    - Ingestion

Anthrax: Infection Control

- No person to person transmission
- Standard Precautions
- Laboratory safety
  - Biosafety Level (BSL) 2 Precautions

Anthrax: Decontamination

- Highest risk of infection at initial release
  - Duration of aerosol viability
    - Several hours to one day under optimal conditions
    - Covert aerosol long dispersed by recognition 1st case
  - Risk of secondary aerosolization is low
    - Heavily contaminated small areas
      - May benefit from decontamination
    - Decontamination may not be feasible for large areas
- Personal decontamination
  - If direct contact with substance alleged to be anthrax, wash exposed skin & clothing with soap & water

Anthrax: Decontamination

- Skin, clothing
  - Thorough washing with soap and water
  - Avoid bleach on skin
- Instruments for invasive procedures
  - Utilize sporicidal agent
- Sporicidal agents for surfaces
  - Chlorine, Hydrogen peroxide – concentration dependent and inactivated by organic matter
  - Peracetic Acid

Anthrax: Decontamination

- Suspicious letters/packages
  - Do not open or shake
  - Place in plastic bag or leak-proof container
  - If visibly contaminated or container unavailable
    - Gently cover – paper, clothing, box, trash can
  - Leave room/area, isolate room from others
  - Thoroughly wash hands with soap and water
  - Report to local security / law enforcement
  - List all persons in vicinity

Anthrax: Decontamination

- Opened envelope with suspicious substance
  - Gently cover, avoid all contact
  - Leave room and isolate from others
  - Thoroughly wash hands with soap and water
  - Notify local security / law enforcement
  - Carefully remove outer clothing, put in plastic
  - Shower with soap and water
  - List all persons in area

Pneumonic Plague

- Yersinia pestis
  - Gram-negative coccobacillus
- Flea bite in natural conditions
- Easily transmitted direct contact person-person
- High mortality
- Pneumonic form most deadly

Plague Infection Control

- Facemasks for close patient contact
- Avoid unnecessary close contact until on antibiotics 48 hours
- Biosafety level-2 labs for simple cultures
- No need for environmental decontamination of areas exposed to plague aerosol