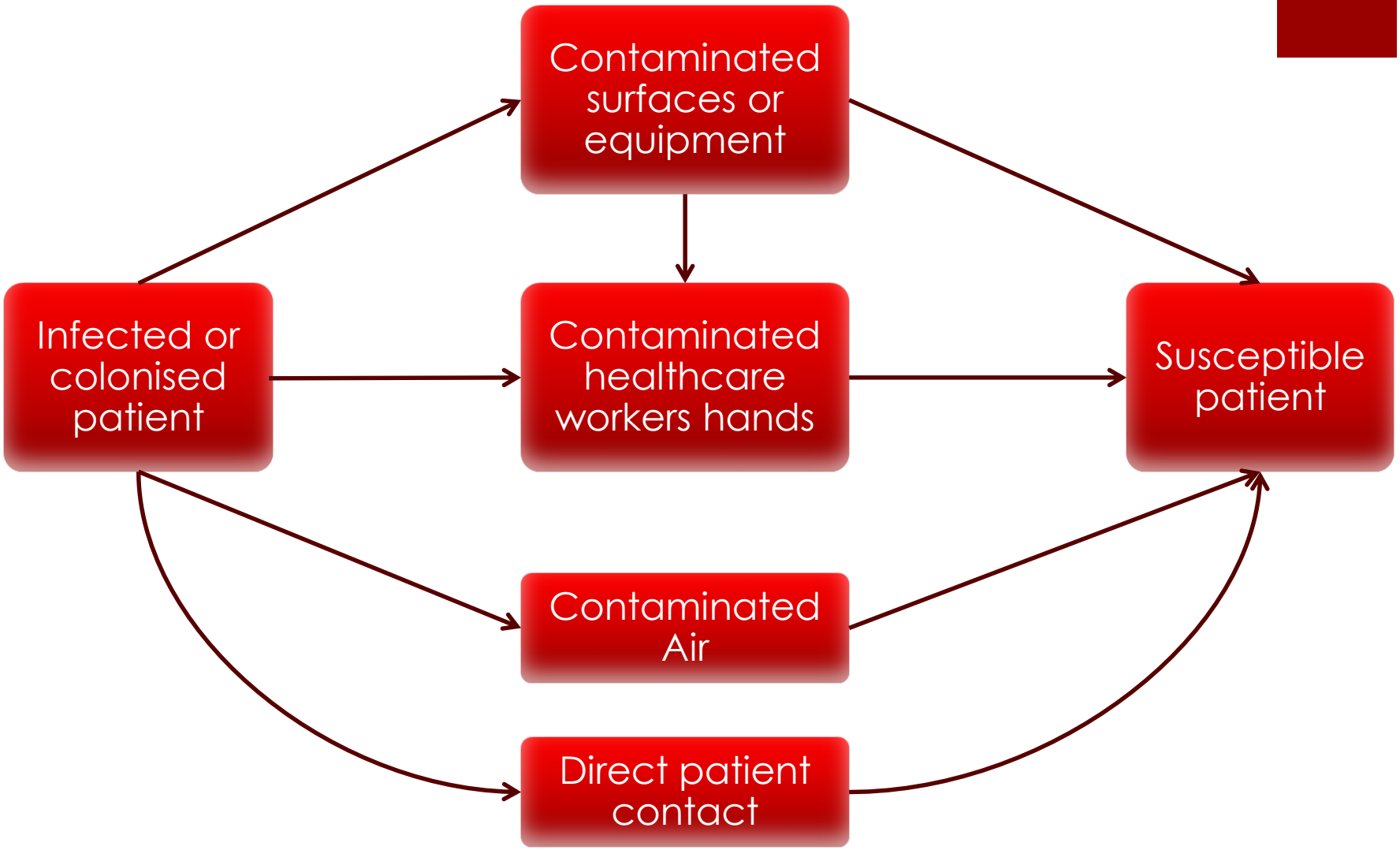
Transmission

Conflicts and controversies

Martin Kiernan - @emrsa15
Visiting Clinical Fellow, University of West London
Clinical Director, Gama Healthcare

Contamination of the Environment and Transmission of Pathogens in Healthcare Settings

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



Healthcare workers attire
Jury still out

- Systematic review - 72 individual studies
  - Haun, N., C. et al. ICHE 2016. **37**(11): p. 1367-1373.
  - Assessed contamination of white coats, neckties, stethoscopes, and mobile electronic devices
  - Contamination rates varied from 0 to 32% for MRSA and gram-negative rods, Enterococcus less common
  - Few explicitly evaluated for the presence of C. difficile
  - Sampling/micro techniques varied significantly
  - Four studies evaluated for possible connection between healthcare personnel contaminants and clinical isolates with no unequivocally direct link identified

Bare below the elbows

- Great idea – never official UK Policy but adopted by SHEA
  - Bearman G, et al. ICHE 2014;35:107–121
  - Sends a strong positive message about organisational culture and attitude towards IPC
- Terribly implemented in the UK - JDI
  - Stick not carrot
  - Problem: No evidence
- Some did not like being made ‘look stupid’

Standards differ..

Postulates

NW England Communicable Disease Task Force (1995)

- Cleaning budgets were being targeted to make savings and infection control teams were worried
- No solid evidence base, but we were able to show
  - Environmental contamination by human pathogens
  - They persist in the environment
  - A significant route to the patient can be demonstrated
  - A useful level of decontamination of the environment can be achieved

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
Neisseria gonorrhoae	20 seconds

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

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)

Transmission to staff
Hoyle et al (2016) AJIC

- Report of staff outbreak of adenovirus manifesting as conjunctivitis
  - 2 inpatients shedding virus
  - 4 nurses became ill with weeping red eyes
    - Same serotype as the patients
- Issues
  - Room ventilation was wall-mounted fan pointing at the door
  - Doors left open
  - Staff unaware that alcohol hand rub was not effective
- So, failure of contact precautions or aerosol settling on surfaces and self-inoculation?

Control: fomite transmission?

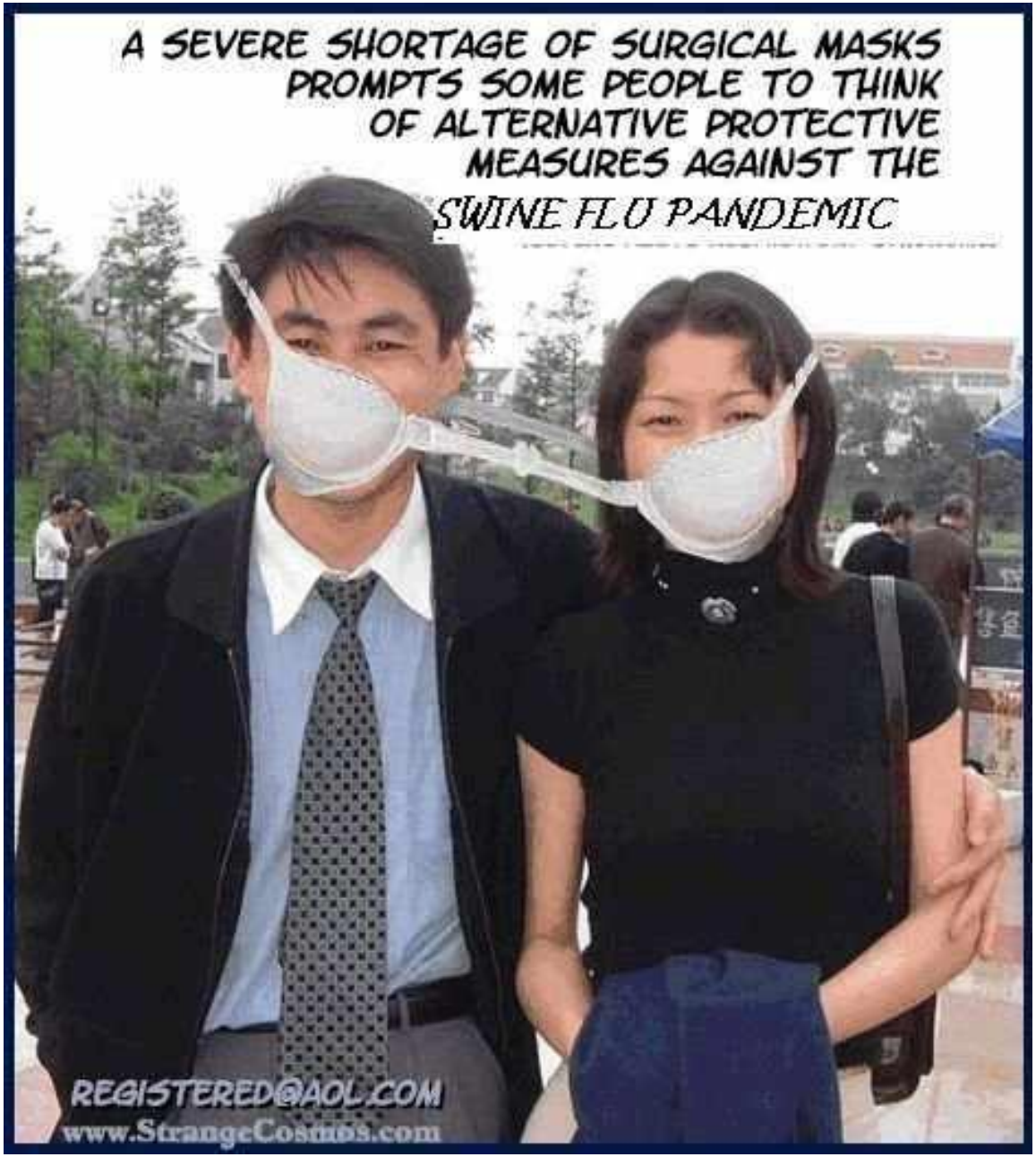
- MERS-CoV has been shown to survive on dry surfaces for hours; studies evaluating extended survival times / conditions currently lacking [1]

- 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

Bus Travel increases Risk of Respiratory Infections

- The more you ride a bus the more likely you will get a cold (6 times more likely)
  - Troko et al (2011) BMC Infectious Diseases


A SEVERE SHORTAGE OF SURGICAL MASKS PROMPTS SOME PEOPLE TO THINK OF ALTERNATIVE PROTECTIVE MEASURES AGAINST THE SWINE FLU PANDEMIC
REGISTERED@AOL.COM
www.StrangeCosmos.com

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 contact transmission of influenza

- Detectable on hands for up to 60 mins from inoculation
- Maintains infectivity
  - from several hours to a few days depending on how porous the surface is
  - for longer at low temperatures and low humidity
- Found on 50% of bank notes tested 24hrs after contamination with nasopharyngeal secretions from children
- If both surfaces and hands are contaminated heavily or repeatedly, the virus could survive long enough be propagated to hands, and ultimately mouth or nose mucosa

Universal Masking?
Iten et al, ICPIC Presentation 2015

- Masking all healthcare workers (HCW) and visitors was effective to reduce hospital-acquired influenza (I) during 2014/15 epidemic when there was reduced vaccine effectiveness

Something in the air?

- Norovirus genomes are frequently detected in the air of healthcare facilities during outbreaks, even outside patients' rooms
  - In vitro models suggest that this virus may withstand aerosolisation
    - Bonifait et al (2015). "Detection and Quantification of Airborne Norovirus During Outbreaks in Healthcare Facilities." Clin Infect Dis **61**(3): 299-304
  - So the discussion at ECCMID 2016 was what grade of mask…

Widespread contamination in a prolonged hotel outbreak

JS Cheesbrough; Epidemiol Infect 2000, 125: 93-98

Site	RT-PCR +
Carpets (known vomiting)	5/8 (62%)
Carpets (no vomiting)	9/12 (75%)
Toilet rims/seats	8/11 (73%)
Toilet handles, taps, basins	13/39 (39%)
Horizontal surfaces below 1.5 m	11/29 (37%)
Horizontal surfaces above 1.5 m	6/12 (50%)
Phones, door handles, etc.	7/29 (24%)
Soft furnishings	2/10 (20%)
Total	61/144 (42%)

Environmental contamination

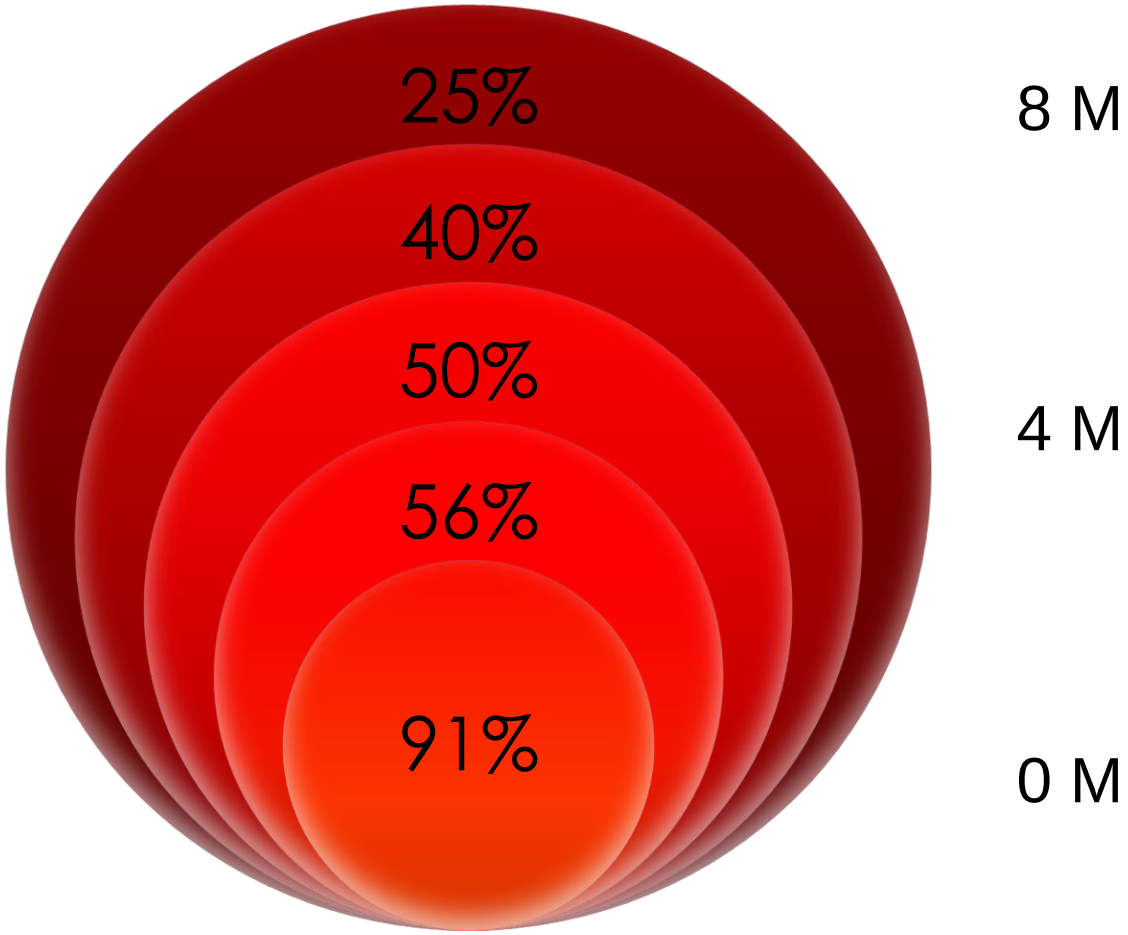
- Norovirus
  - Strong circumstantial evidence for the importance of the environment
  - Repeated outbreaks on Cruise ships
  - Concert Hall outbreak (Evans et al, 2002)

Evans MR *et al*. An outbreak of viral gastroenteritis following environmental contamination at a concert hall. Epidemiology and Infection (2002) 129: 355-60.

Evidence for airborne transmission of Norwalk-like virus in a hotel restaurant
PJ Marks; Epidemiol. Infect. 2000, 124: 481-487

- Hotel restaurant with 126 patrons
  - Patron vomited at table
  - 52 of 83 survey responders ill
  - 63% overall attack rate
- Attack rates higher at closer tables
  - Droplet or Air?

Effect by 2 metre segments



What do we know about outbreaks?

Curran et al, JIP (2015)

- Multi-centre study (75 organisations)
  - 550 outbreaks that identified index cases (IC)
  - In 50% of the outbreaks the IC had been an inpatient for longer than the incubation period
  - Only 25% of ICs admitted with symptoms were isolated on admission
  - 18% of 28 ill HCW ICs were symptomatic before coming on duty
  - 69% of 13 visitor ICs were ill before visiting

What do we know about outbreaks?
Curran et al, JIP (2015)

- Not much
  - True index case is commonly not identified, at least 50% of index cases being misclassified
  - Unrecognised norovirus cross-transmission occurs frequently suggesting that either Standard Precautions are being insufficiently well applied, and or are themselves insufficient to prevent outbreaks
  - Lots of reporting delays (often for days)

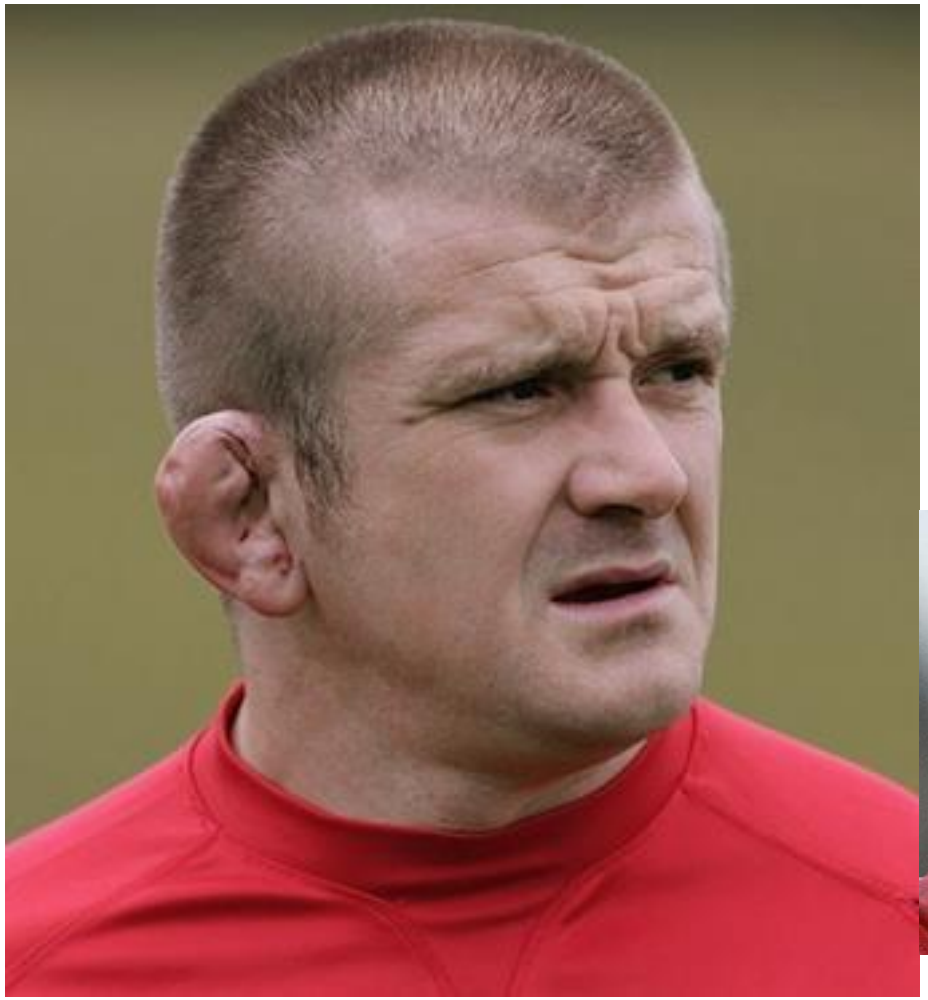
It's in your Genes

Currier et al, Clin Inf Dis (2015) 60(11)

- Noroviruses bind to gut histo-blood group antigens (HBGAs), but only 70%-80% of individuals have a functional copy of the FUT2 ("secretor") gene required for gut HBGA expression
  - GII.4 genotype is responsible for approximately 70% of all norovirus outbreaks in the United States
    - research to date has shown that this genotype almost exclusively infects secretor individuals

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.



Back to the floor

- “Patients do not lie on the floor”
  - So that’s alright then..
- Hospital floors are often heavily contaminated but are not considered an important source for pathogen dissemination because they are rarely touched
  - However, floors are frequently contacted by objects that are subsequently touched by hands (eg, shoes, socks, slippers). In addition, it is not uncommon for high-touch objects such as call buttons and blood pressure cuffs to be in contact with the floor
    - Koganti S, et al. Infect Control Hosp Epidemiol. 2016:1-4.

Socks?
Mahida, Boswell et al, J Hosp Inf (2016)

- Non-slip socks as a ‘solution’ to the patient falls issue
  - 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 a nurse removing them consider them to be contaminated?

Use of Shoe Covers

- Disposable medical shoe covers were briefly exposed (<5 minutes) to the surgical floor and were contaminated by a large number of bacteria
  - Galvin J, et al. Am J Infect Control. 2016
  - S aureus, Staphylococcus epidermidis, Escherichia coli, Pseudomonas aeruginosa, Enterococcus faecium, and Acinetobacter baumannii
- Pathogens attached to contaminated shoe covers can be transferred to surgical bedsheets

Demonstrating transmission from floors

- Study mimicking my favourite Oelberg study
  - Koganti S, Alhmidi H, Tomas ME, Cadnum JL, Jencson A, Donskey CJ. Evaluation of Hospital Floors as a Potential Source of Pathogen Dissemination Using a Nonpathogenic Virus as a Surrogate Marker. 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

Method

- Ten ambulatory patients in contact precautions (single rooms) for C. difficile infection or MRSA carriage enrolled
  - 30^2 cm area of floor by beds inoculated with 2mL of sterile water with 1×10^8 plaque-forming units of MS2/mL and allowed to dry
  - Patients were not aware of the precise area
  - Hospital personnel were not aware of the study
- Protocol for cleaning included daily disinfection of high-touch surfaces with bleach wipes each morning but floors were cleaned only if visibly soiled
  - Compliance monitored with fluorescent markers, with more than 85% of sites demonstrating marker removal during the study

Results

- DNA detected on multiple surfaces of all patient rooms the day after inoculation
  - concentration of MS2 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

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
  - These results suggest that floors in hospital rooms could be an underappreciated source for dissemination of pathogens
- Because non-sporicidal 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

Mechanisms for floor contamination to cause infection

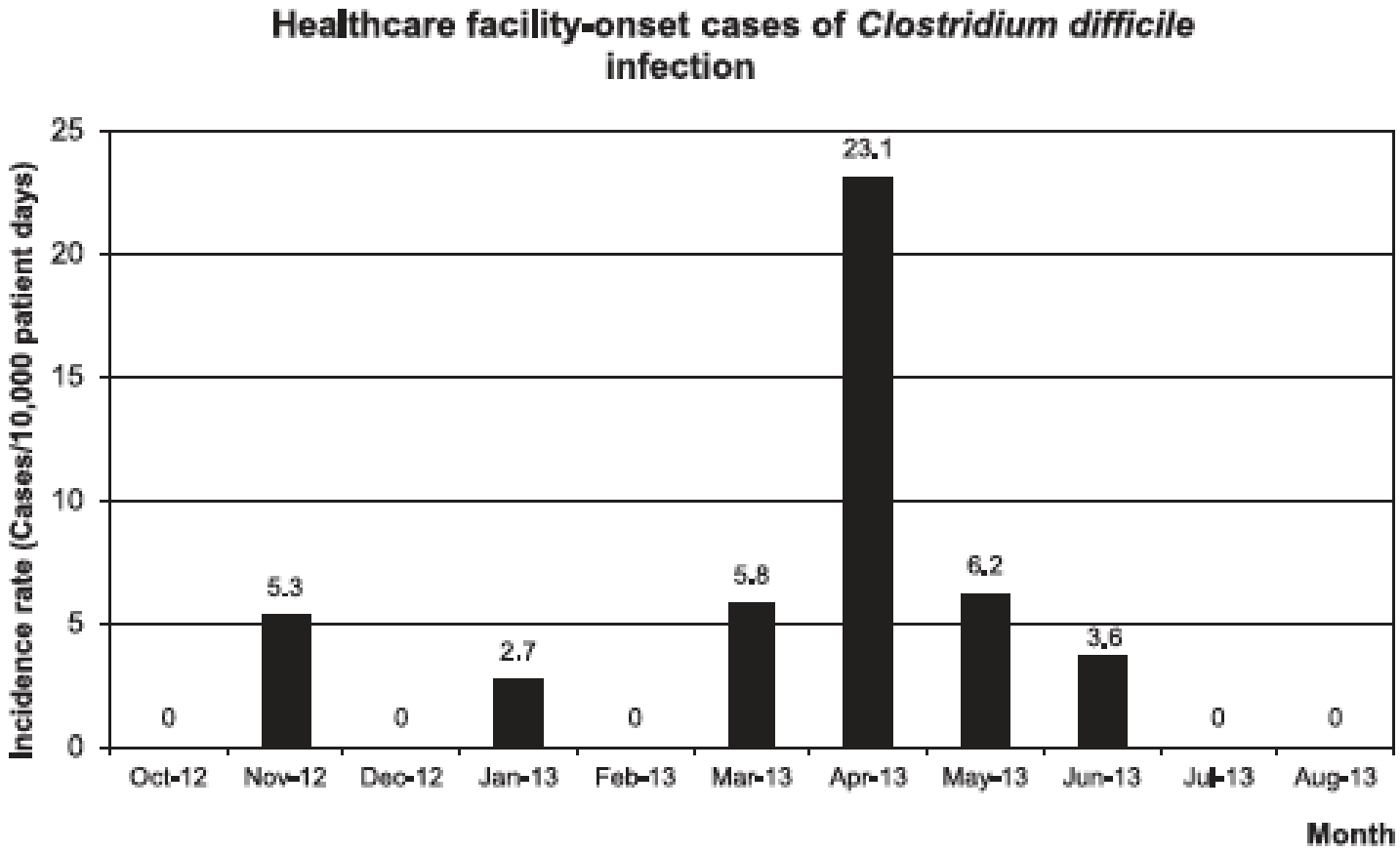
- Systematic review (30 studies)
  - Rashid, T., et al., Epidemiol Infect, 2016: p. 1-11
- Pathways of transmission
  - Human contact studies showed activities like walking, touching or contact with floor surfaces as important factors
  - Aerosolisation methods included airborne dispersal, and aerial and dust dissemination
    - sporadic airborne dissemination of C. difficile in the hospital environment was identified during routine cleaning procedures
      - Roberts K, et al. BMC Infectious Disease 2008; 8: 7.

Walk the walk

- Walking leads to the highest dispersal of Staph. aureus and other microorganisms at levels 3x higher than found with heating, ventilation and air conditioning ventilation, and 17x higher than with floor mopping
  - Hambraeus A, et al. Journal of Hygiene (London) 1978; 80: 169–174
- So, do we clean the floor, the feet or the patient?

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 we are always told that floors are not a risk?

Limited Transmission in hospitals?

Walker AS, Eyre DW,, et al. (2012) PLoS Med

- Large multicentre study looking for molecular evidence of transmission of C. difficile
  - No more than 25% of cases could be linked with a ward-based source
- Problem: Role of asymptomatic carriage
  - In a study of 56 cases, 30% were associated with a symptomatic case and 29% were with an asymptomatic case
    - Curry SR, Muto CA, et al. Clin Infect Dis 2013;57:1094-102

Environmental contamination and C. difficile

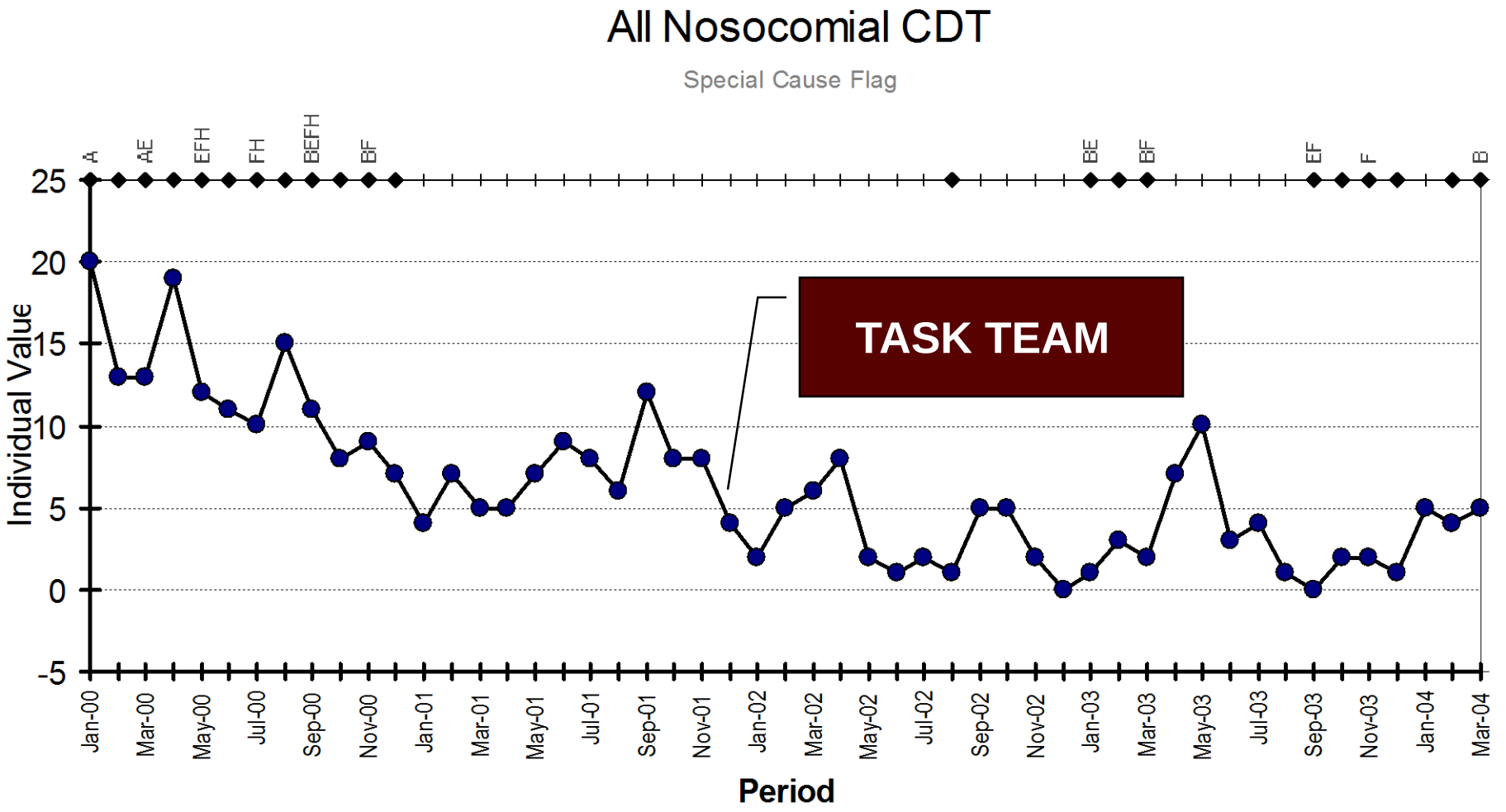
- Contamination of the environment spores more common in symptomatic cases than asymptomatic carriers: 49% v 29%
  - Kim et al *J. Infect Dis* 1981
- Range from 10%-50% of sites positive; correlates with frequency of C. difficile acquisition
  - Weber DJ et al, AJIC 2013; S105-S110
- BP cuffs 10% contamination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

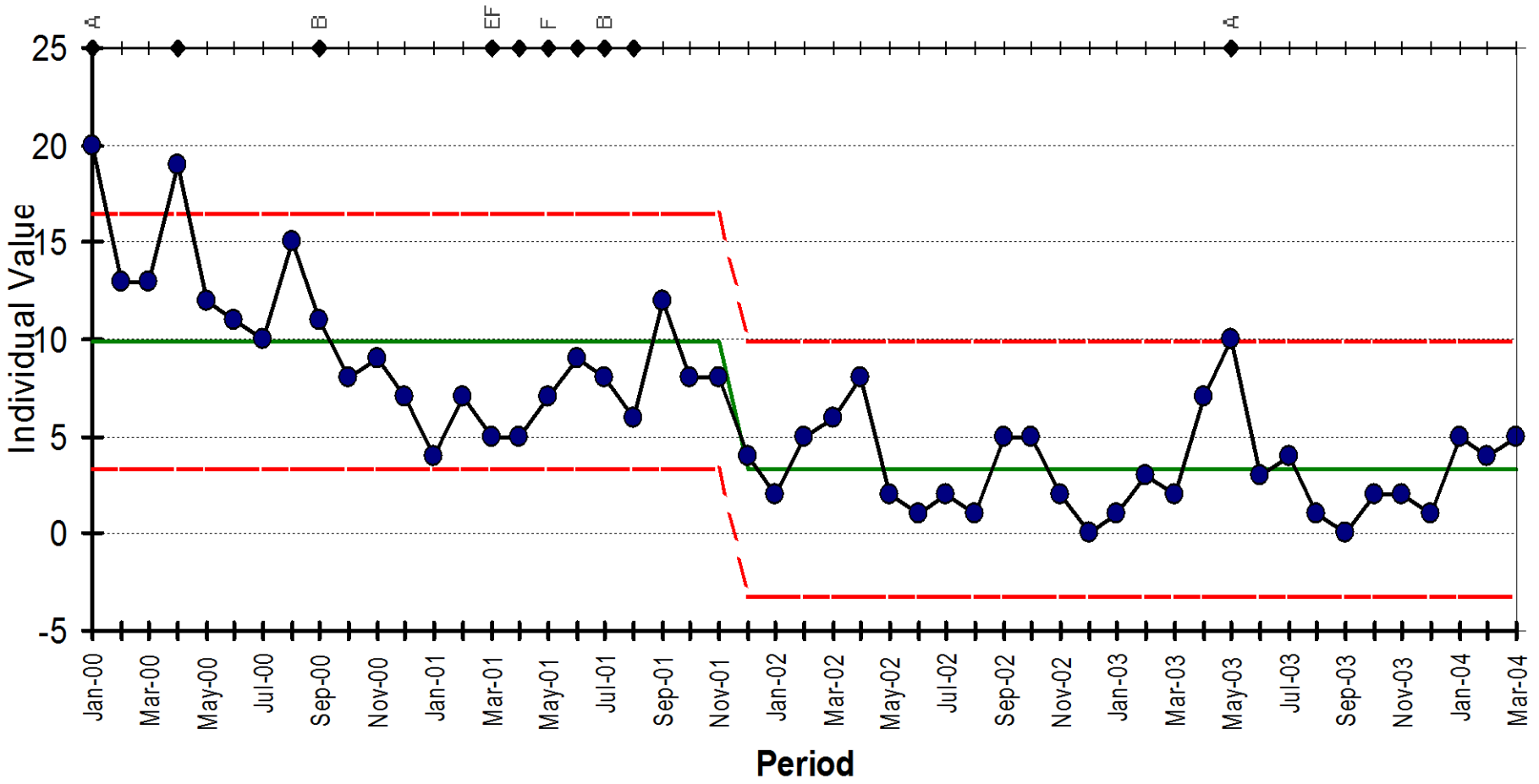
UV-visible marker demonstrates lack of compliance with cleaning

Alfa M, Duek C et al. BMC Infectious Diseases 8:64 (2008)

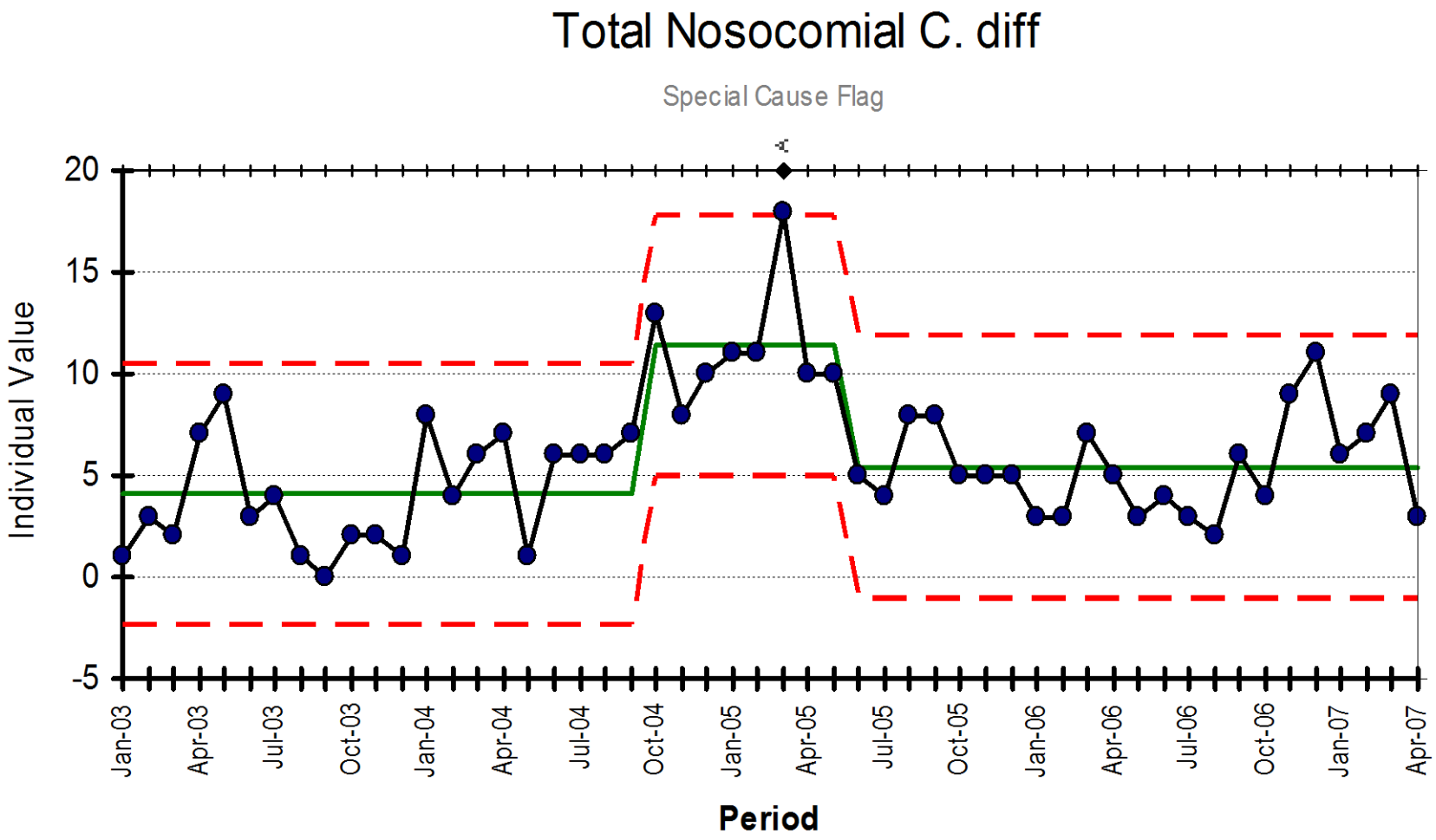
- Canadian study centring on NAP1 (027) strain
- Marker applied to toilets and commodes
  - Inspected daily; sampled for C. difficile
  - UV marker in 50% toilets and 75% commodes
    - Commodes not cleaned at all on 3 in 4 days
  - Toxigenic C. difficile found on 33.3% of toilets and 62.5% of commodes

Effect of Task Team on CDT



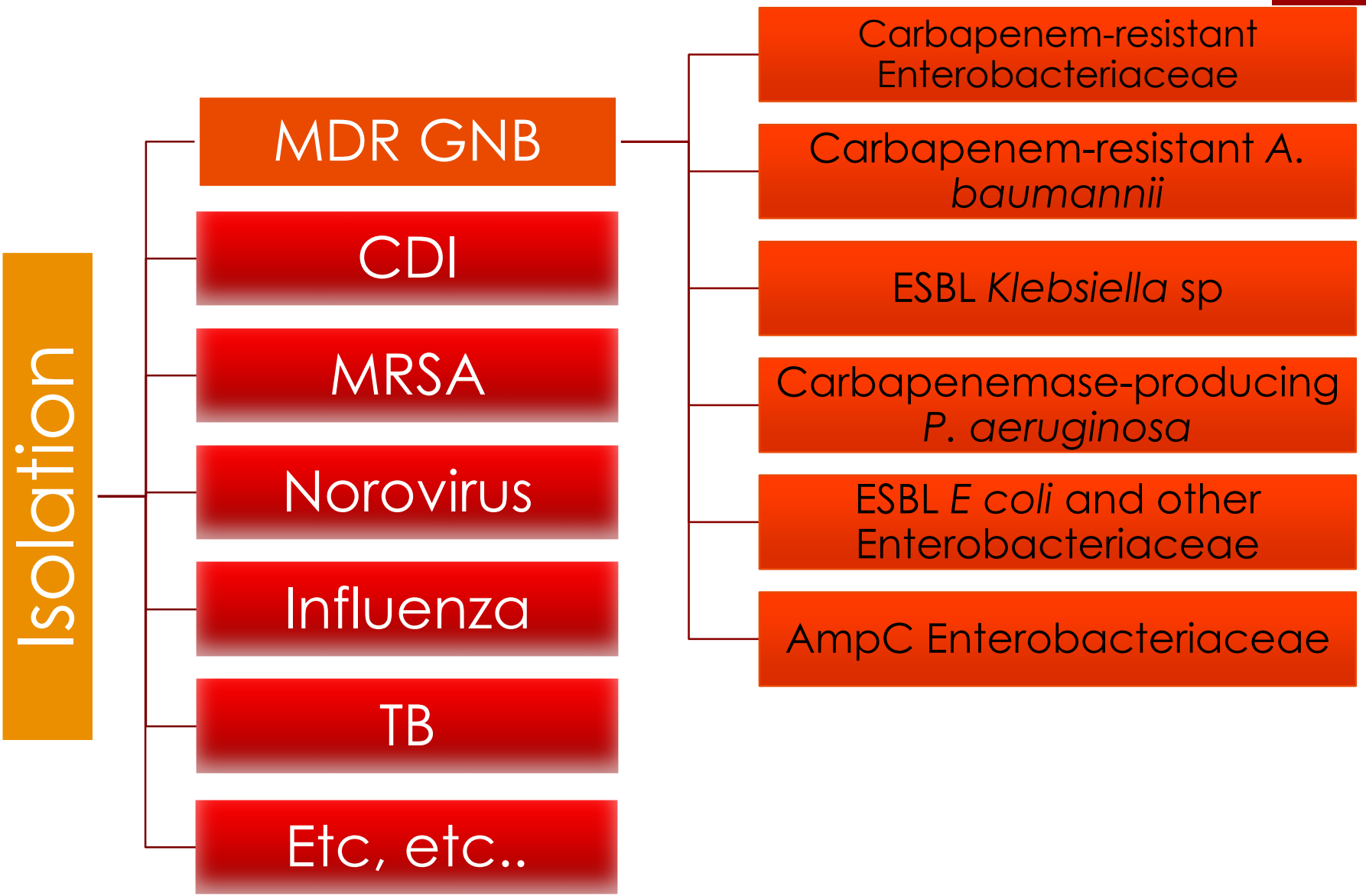

All Nosocomial CDT
Special Cause Flag
A
B
EF
F
B
A
25
20
15
10
5
0
-5
Individual Value
Jan-00
Mar-00
May-00
Jul-00
Sep-00
Nov-00
Jan-01
Mar-01
May-01
Jul-01
Sep-01
Nov-01
Jan-02
Mar-02
May-02
Jul-02
Sep-02
Nov-02
Jan-03
Mar-03
May-03
Jul-03
Sep-03
Nov-03
Jan-04
Mar-04
Period

Temporary Removal of the Team



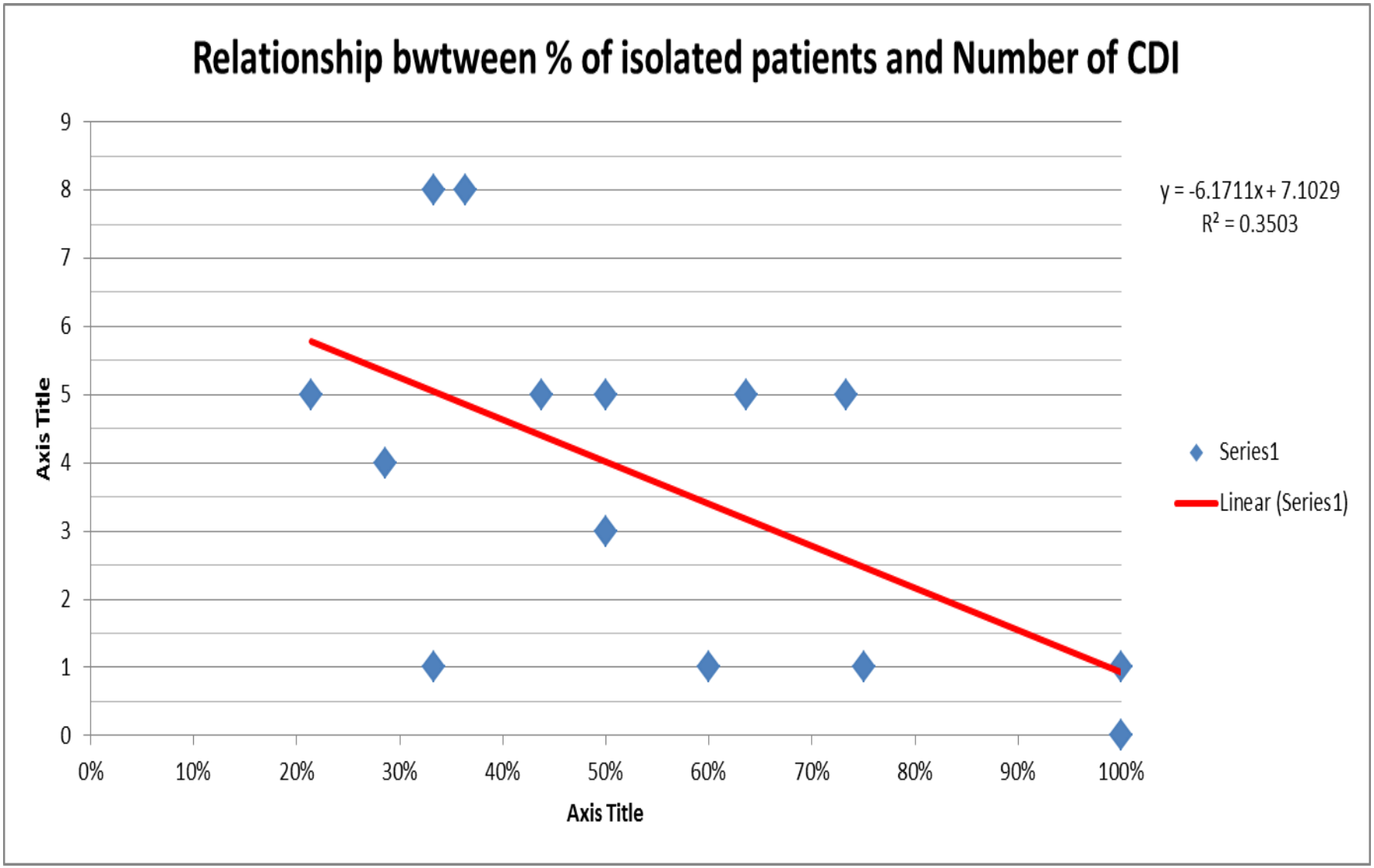
Environmental Contamination after the patient gets better

- High contamination rate before treatment and at the time of resolution of diarrhoea (37%), lower after treatment, but increased again at 1-4 weeks after treatment (50%)
  - ‘It’s Ok, they are 48 hours clear…’
    - Sethi AK et al. ICHE 2010;31:21-7
- So, we need to clean well and consistently well
  - Elbow grease is the most expensive cleaning agent


Isolation
MDR GNB
CDI
MRSA
Norovirus
Influenza
TB
Etc, etc..
Carbapenem-resistant Enterobacteriaceae
Carbapenem-resistant *A. baumannii*
ESBL *Klebsiella* sp
Carbapenemase-producing *P. aeruginosa*
ESBL *E coli* and other Enterobacteriaceae
AmpC Enterobacteriaceae

Isolation - Let’s play Trumps..

- You have competing priorities, so who gets the side room?
  - Standard for C. difficile is that patients with diarrhoea “**not clearly attributable to an underlying condition (e.g. inflammatory colitis, overflow) or therapy (e.g. laxatives, enteral feeding)“** are isolated within 2 hr
  - So, what if you have a ‘cause’?

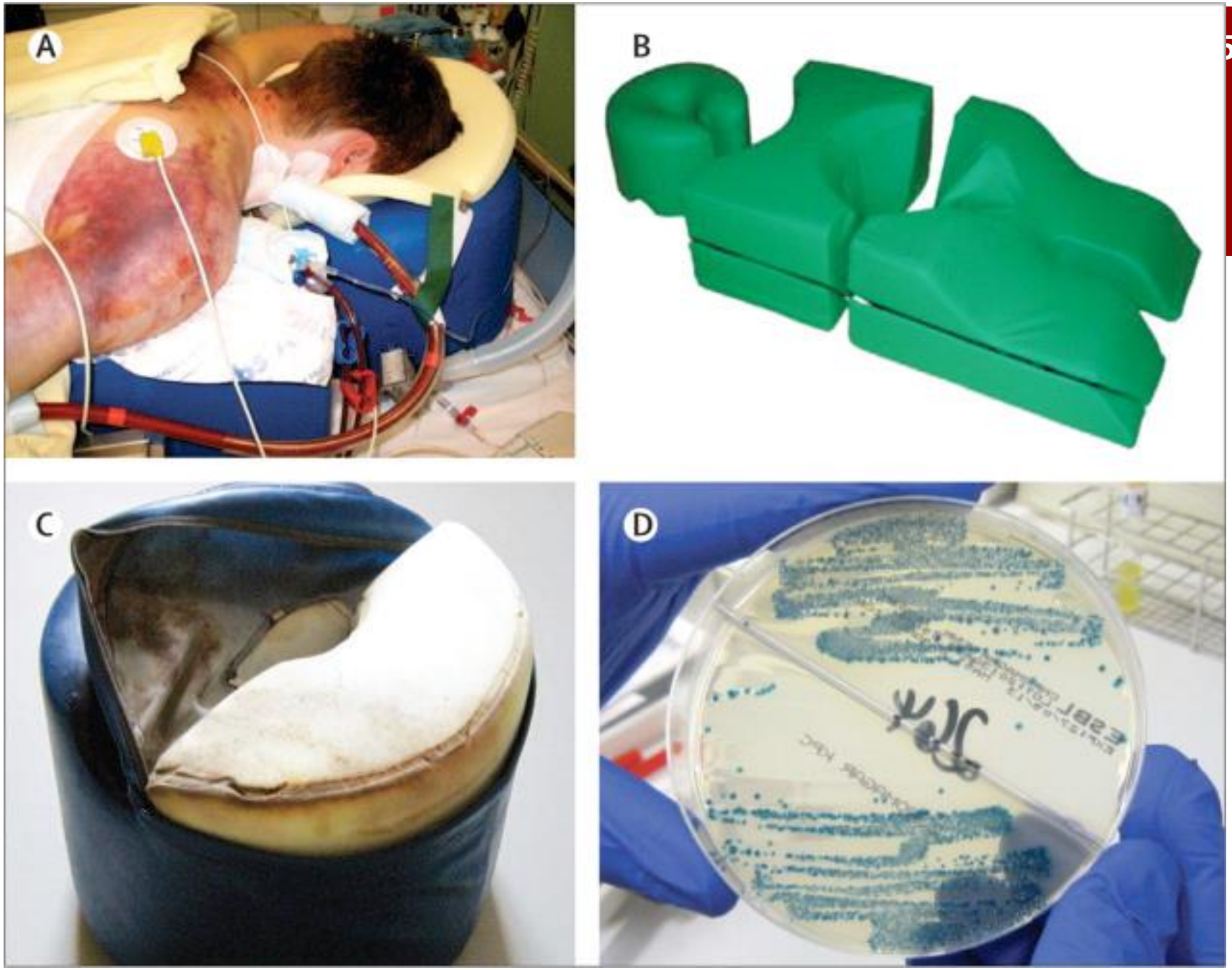

Relationship bwtween % of isolated patients and Number of CDI
Axis Title
Axis Title
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
0
1
2
3
4
5
6
7
8
9
y = -6.1711x + 7.1029
R² = 0.3503
Series1
Linear (Series1)


Prima
with ESPRIT
CONDEMNED
28-1-08
Prima

CPE contamination

Lippmann N., Lubbert C et al Lancet ID (2014)

- Large outbreak of KPC in Germany
- Environmental reservoir sought
  - Positioning pillows for ARDS internally contaminated and remained so for 6 months
  - Ward pillows and mattresses not externally positive
    - Attributed to frequent steam cleaning of pillows and mattresses
- Concluded that the search for environmental contamination should leave no stone unturned


A
B
C
D

Risk of Transmission of Gram-negatives from the previous room occupant

- Meta-analysis of all studies looking for evidence of transmission
  - Mitchell BG, et al. Risk of organism acquisition from prior room occupants: a systematic review and meta-analysis. J Hosp Infect. 2015;91(3):211-7.
- Pooled acquisition odds for the study pathogens Meticillin-resistant Staphylococcus aureus (MRSA), Vancomycin-resistant enterococci (VRE), Clostridium difficile and Acinetobacter baumanii 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 greatest effect; 4.53 (95% CI: 2.32-8.86)

Seasonal peaks in Gram-negatives

- Estimated 7% increase in monthly BSI incidence for every 10˚ F increase in average monthly temperature
  - Al-Hasan M, et al. Clin Microbiol Infect 2009; 15
- Incidence of E. coli from clinical specimens (including blood) in a Baltimore hospital increased by 12% during the summer
  - Perencevich E et al. ICHE 2008; 29: 1124–1131.

Seasonal peaks in Gram-negatives

- Increases in the mean monthly rates of infection caused by P. aeruginosa, E. cloacae, E. coli, and A. baumannii
  - Perencevich EN et al. ICHE 2008;29(12):1124-31
- Higher temperatures associated with higher infection rates, independent of seasonality
  - For each 10˚ F increase, observed a 17% increase in the monthly rates of infection caused by P. aeruginosa ($P<0.01$) and A. baumanii ($P<0.05$)
  - Hottest month also the wettest
- Importantly there was no change in Gram-positives, reducing the risk of practice variable confounding

The Effect of Temperature

Perencevich EN et al. ICHE 2008;29(12):1124-31

TABLE 2. Incidences of Infection Among Hospitalized Patients at the University of Maryland Medical Center, 1998–2005, Stratified by Warm and Cold Months, For Each 10°F Increase in Mean Monthly Temperature

	May–September		October–April	
Infecting organism, by class	IRR (95% CI)	*P*[a]	IRR (95% CI)	*P*[a]
Gram-positive bacteria				
Enterococcus species	1.00 (0.92–1.08)	.95	0.95 (0.91–0.99)	.02
Staphylococcus aureus	1.06 (0.97–1.16)	.19	1.00 (0.95–1.04)	.88
Gram-negative bacteria				
Acinetobacter baumannii	1.17 (1.00–1.04)	.05	1.00 (0.92–1.09)	.94
Pseudomonas aeruginosa	1.17 (1.04–1.31)	.01	1.03 (0.97–1.09)	.81
Enterobacter cloacae	1.03 (0.90–1.18)	.67	1.09 (1.01–1.18)	.03
Escherichia coli	1.06 (0.97–1.15)	.21	1.02 (0.97–1.07)	.46

Worldwide seasonality of Klebsiella pneumoniae

- Analysis of 5 yrs surveillance data from hospitals in 4 continents
  - Anderson DJ, et al. J Infect Dis. 2008;197(5):752-6.
- IR of K. pneumoniae BSI during the 4 warmest months of the year 2.23/10,000 patient-days
  - for the other 8 months was 1.55/10,000 patient-days (IRR, 1.46 [95% confidence interval, 1.04 –2.06]; P<.03)
- Poisson regression showed that temperature (P<.0001) and dewpoint (marker for relative humidity; P <.0001) were both linearly predictive of increasing rates of K. pneumoniae BSI

Speculative explanations

- Environmental
  - K. pneumoniae is the most heat tolerant of all enteric pathogens
    - specific growth rate maximal at temperatures approaching 36.9˚ C
      - Esener AA, et al. Biotechnol Bioeng 1981 23: 1401-1405
  - K. pneumoniae survives better at higher humidity, as experimental models have shown that dehydration is an important factor in inactivating the organism
    - Esener AA, et al Biotechnol Bioeng 1983 25: 2093-2098.

Additionally

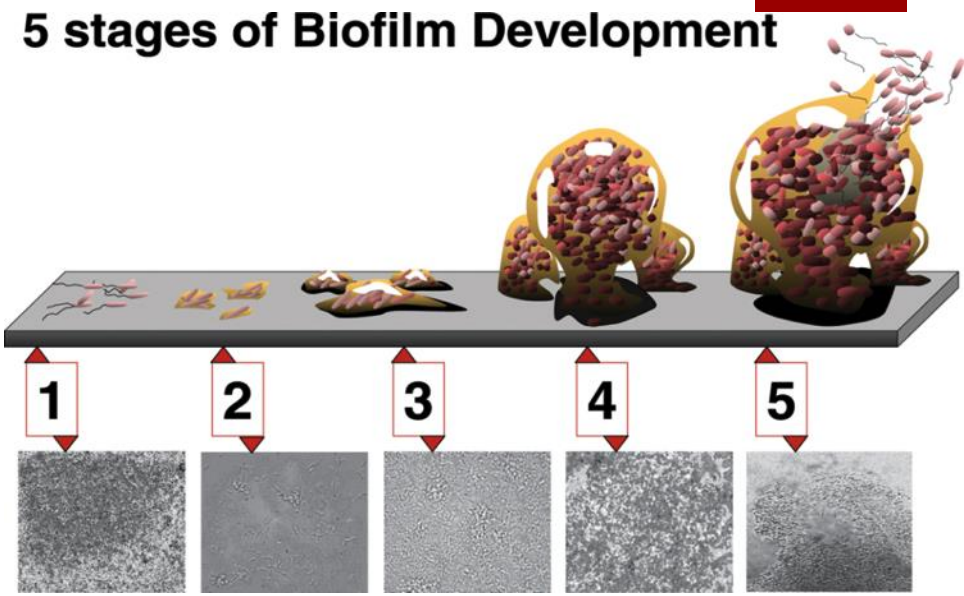
- Density of K. pneumoniae in the environment (e.g. freshwater ponds) higher during warm months
  - Al-Harbi, AH Aquaculture Res 2003; 34:517–24
- Density higher in cow faeces during the summer
  - Munoz MA et al. J Dairy Sci 2006; 89:3425–30.
- Humans higher environmental K. pneumoniae colonisation levels during warm months?
  - Environmental strains are as virulent as clinical strains
    - Struve C, et al. Environ Microbiol 2004; 6:584 –90.
    - Podschun R, et al . Appl Environ Microbiol 2001; 67:3325–7

Additionally

- Evidence suggests that elevated temperatures may be associated with increased virulence of Gram-negatives
  - Lipid A part of lipopolysaccharide, which forms the outer monolayer of the outermost membrane of most Gram-negatives, is regulated by environmental conditions and modulates virulence
    - Raetz CR, et al (2007) Annu Rev Biochem 76: 295–329

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



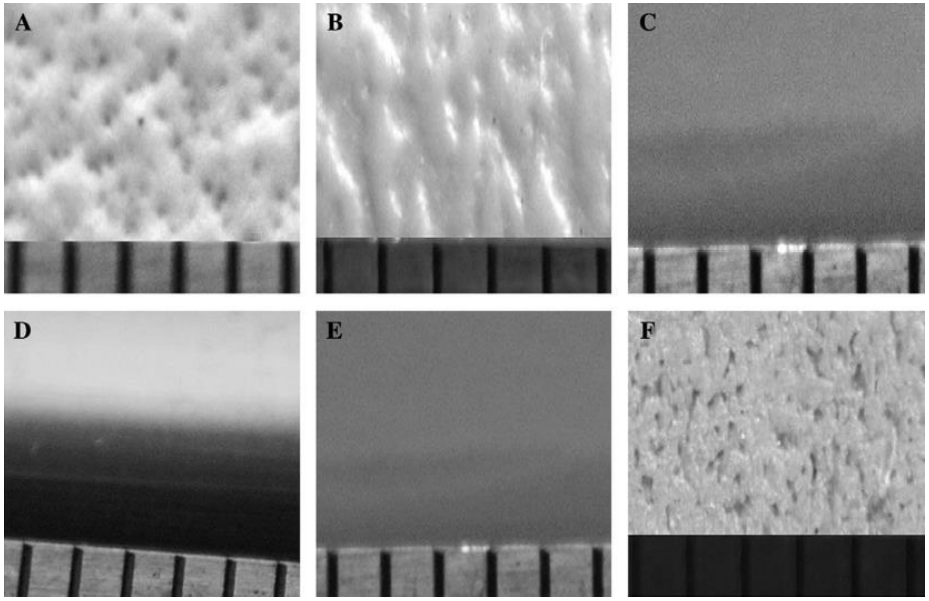
Biofilm survival
Hu et al, JHI (2015)

- ITU decommissioned, two terminal cleans with hypochlorite
  - Parts of the ITU stored and tested
  - At least one MDRO grew from 52% of cultures – a year later

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

Surface Type Matters

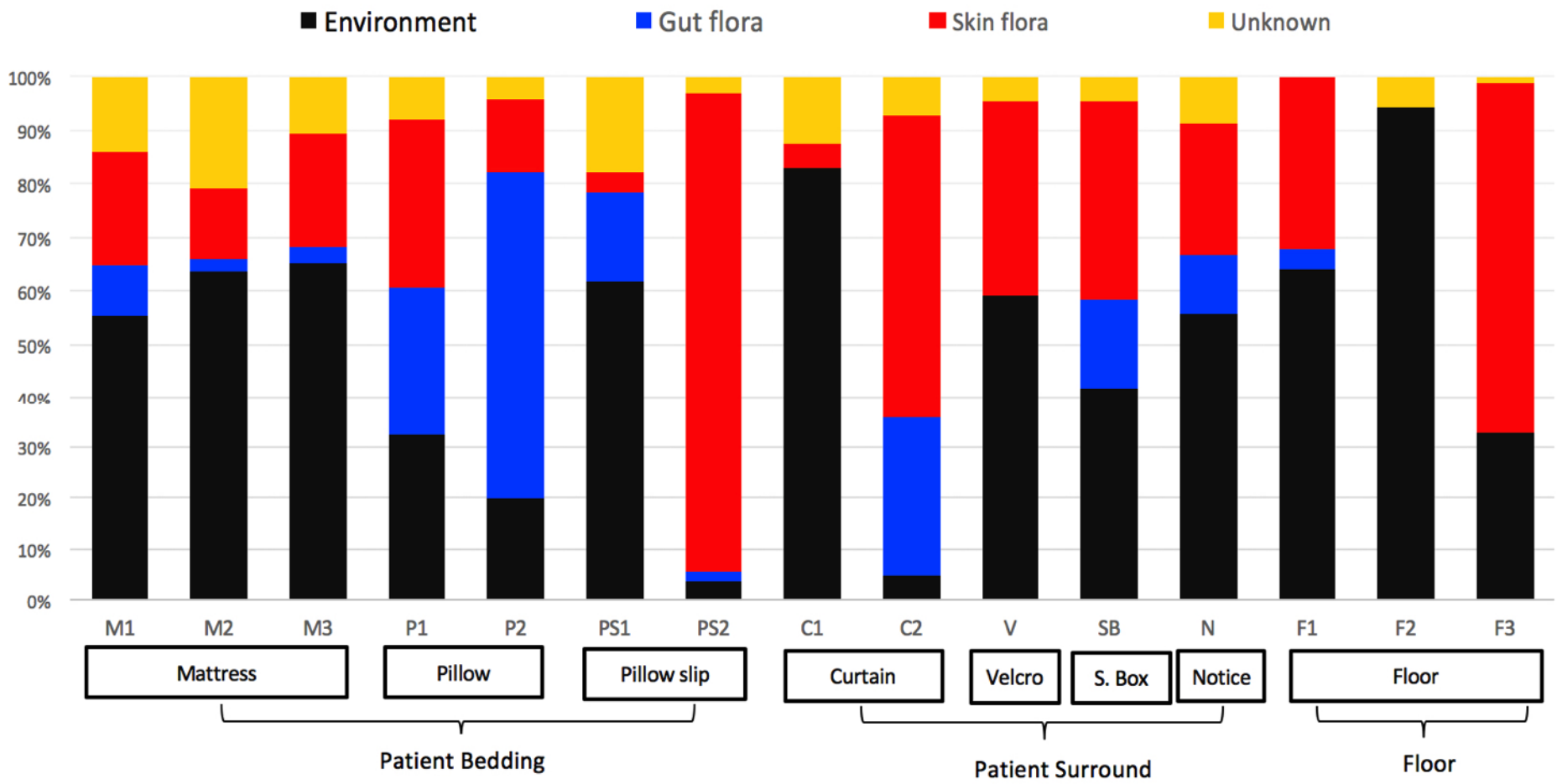
Ali et al. J Hosp Infect 2012;80:192-198.



- 6 hospital bedrails - very different surfaces
  - ease of cleaning inversely proportional to transfer of S. aureus from surfaces
  - Surfaces become rapidly contaminated
    - should be cleaned twice daily with an disinfectant wipe with efficacy against the target organism

Prevalent Species in Biofilms

Hu et al, JHI (2015)



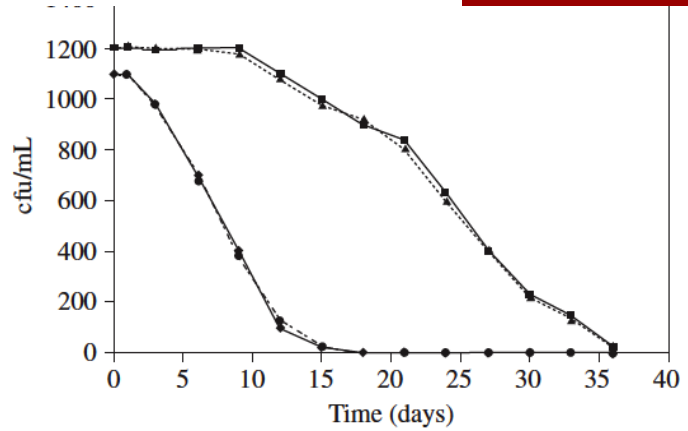
Acinetobacter – a born survivor

- A. radioresistens found to be extremely desiccation resistant, survived for an average of 157 days at 31% RH
  - Jawad et al, (1998) JHI 39 235-40
  - Two strains of A. iwoffi and three strains of A. baumannii survived for an average of three and 20 days respectively, at 31% RH
- A. radioresistens identified as a silent source of the blaOXA-23 gene
  - Poirel, L. et al (2008) Antimicrob Agents Chemother 52(4): 1252-1256.
- This is the most common environmental isolate detected in hospitals but is never looked for clinically
  - Webster, C. A. et al (1998) Eur J Clin Microbiol Infect Dis 17(3): 171-176.

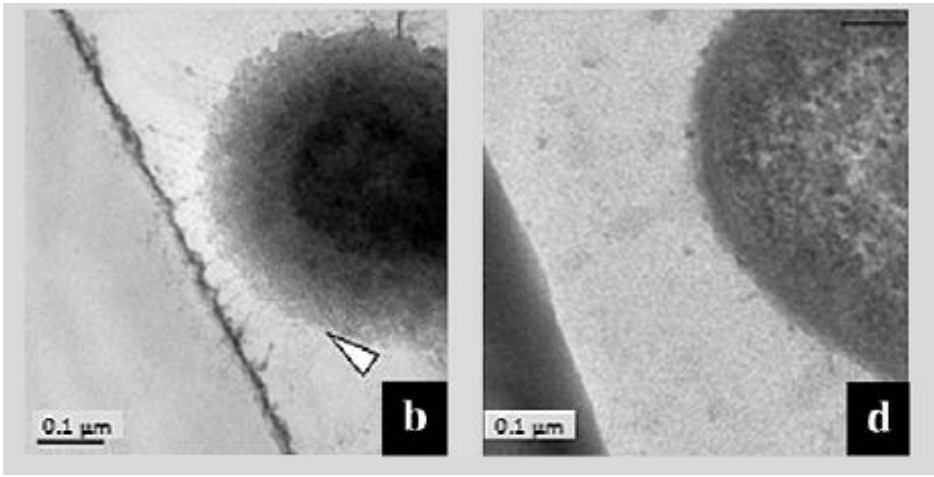
Biofilms and Gram-negatives

- Biofilm-producing strains of Acinetobacter baumanii survive more than twice as long in the environment
- Electron microscopy showed a polysaccharide layer and appendages in the biofilm-forming strains, not in the non-biofilm forming ones

  Espinal et al, JHI (2012) 80; 56-60



igure 1. Survival curve. Comparison between biofilm-forming
\b033, ■; Ab053, ▲) and non-biofilm-forming (Ab001, ◆; Ab143,



Acinetobacter, resistance and biofilm

- Studied 72 clinical isolates of A. baumanii
  - 45 (62.5% of isolates produced biofilm)
    - Biofilm formers showed greater resistance to ampicillin- sulbactam, amikacin, ciprofloxacin and ceftazidime as compared to imipenem and piperacillin
    - concluded that there a positive correlation between biofilm formation and multiple drug resistance in A. baumannii
    - Badave, G.K. and D. Kulkarni J Clin Diagn Res, 2015. 9(1): p. DC08-10
- Biofilm-forming strains were responsible for longer duration of colonisation (18 days vs. 12 days, $p < 0.05$)
  - Simultaneous colonization with other bacteria was more common for biofilm-producing isolates than that for the non-biofilm producing isolates
    - Ryu, S.Y., et al, Korean J Intern Med, 2016 (in press)

What's going on in a Biofilm?

- New paper demonstrating resistance transfer in environmental gram-negatives in biofilms (waste outlets in this case)
  - Muzslay et al, J Hosp Inf (2016)
  - Antimicrobial resistance genes could be easily imported from the hospital environmental microbiota and be disseminated via conjugation with pathogenic species
- What about Chronic wounds?

Environmental Investigation

- Study examined the epidemiology of a long Acinetobacter baumanii outbreak
  - Halachev et al (2014) Genome Medicine 6:70
  - Combined Whole Genome Sequencing and epidemiological 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 a contaminated bed and a burns operating room as sources of transmission
- Other studies have suggested that airborne transmission is significant
  - Allen KD, Green HT. Hospital outbreak of multi-resistant Acinetobacter anitratus: an airborne mode of spread? J Hosp Infect. 1987;9(2):110-9.

Environmental contamination with CRAB

- Study evaluating sensitivity of surveillance cultures for carbapenem-resistant Acinetobacter baumannii (CRAB) in patients and in their environment
  - Nutman, A., et al. Clin Microbiol Infect, 2016
  - Thirty-four patients included
    - Screening sensitivity 28/34 (82%) for buccal mucosa, 30/34 (88%) for skin, and 25/34 (74%) for rectum
    - Combined sensitivity was 32/34 (94%)

CRAB and the Environment

Nutman, A., et al. Clin Microbiol Infect, 2016

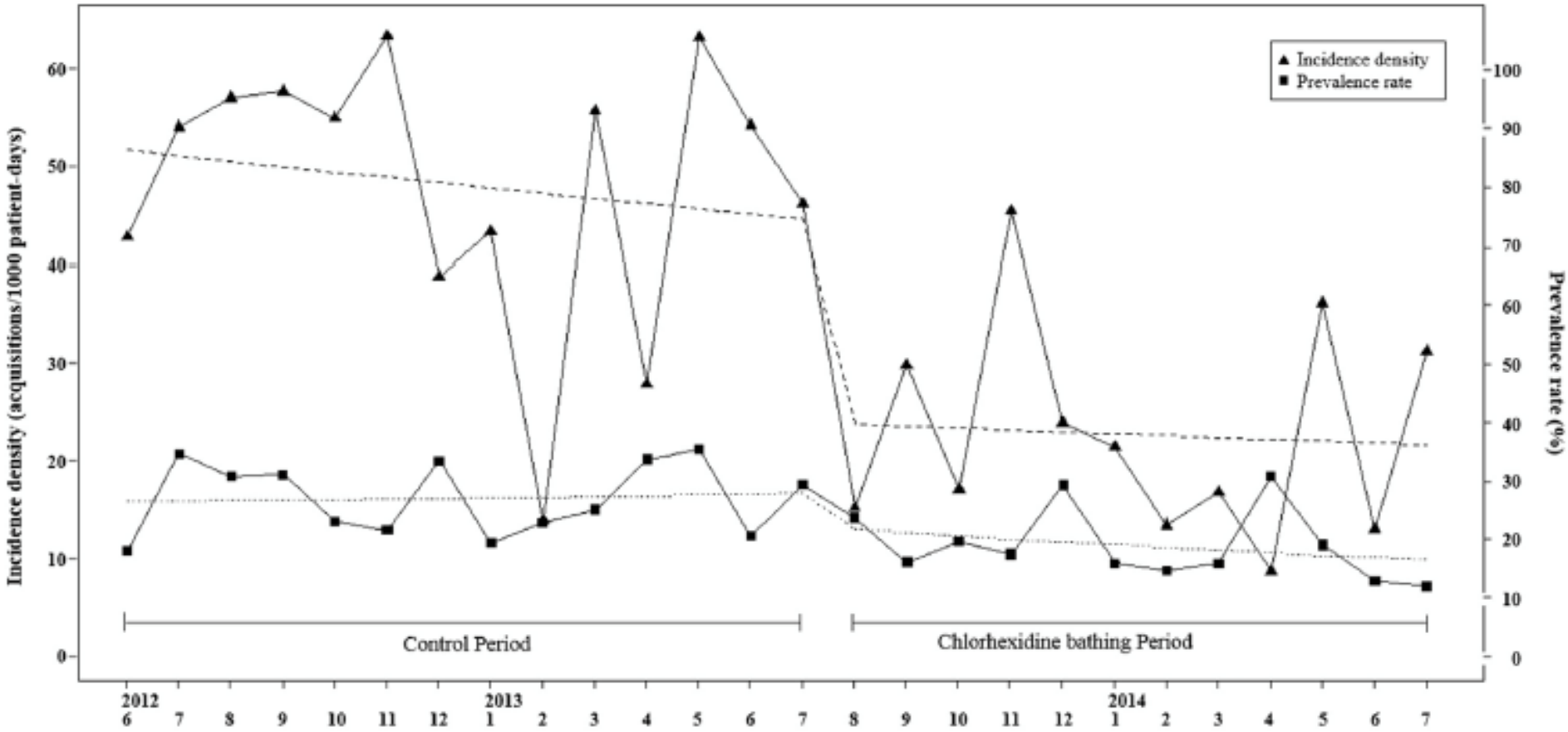
- The environment of all patients was contaminated
  - Correlation between the patient colonisation score and the environmental contamination score
    - (r=0.63, p<0.001; 0.4 (p=0.04) for buccal mucosa, 0.7 (p<0.001) for skin, and 0.46 (p=0.14) for rectum)
- Limitation is that these were all ventilated patients with a positive clinical culture
  - Asymptomatic patients not included
  - However, many high touch surfaces were contaminated, and not by the patient..

Can wipes reduce transmission

- Study from S. Korea in Carbapenem-Resistant Acinetobacter baumanii (CRAB) endemic area
  - Chung YK, et al. Effect of daily chlorhexidine bathing on acquisition of carbapenem-resistant Acinetobacter baumannii (CRAB) in the medical intensive care unit with CRAB endemicity. Am J Infect Control. 2015;43(11):1171-7.
  - Control period: Screening, isolation and enhanced environmental control with Universal wipes for twice-daily high-touch area cleaning by environmental staff and cleaning critical medical equipment three times a day by nurses
    - Incidence density did fall over this period (p=NS)
  - 51.8% reduction in CRAB acquisition after introduction of daily patient cleansing with CHG wipes (P<0.001)

Do CHG patient wipes affect the environment?

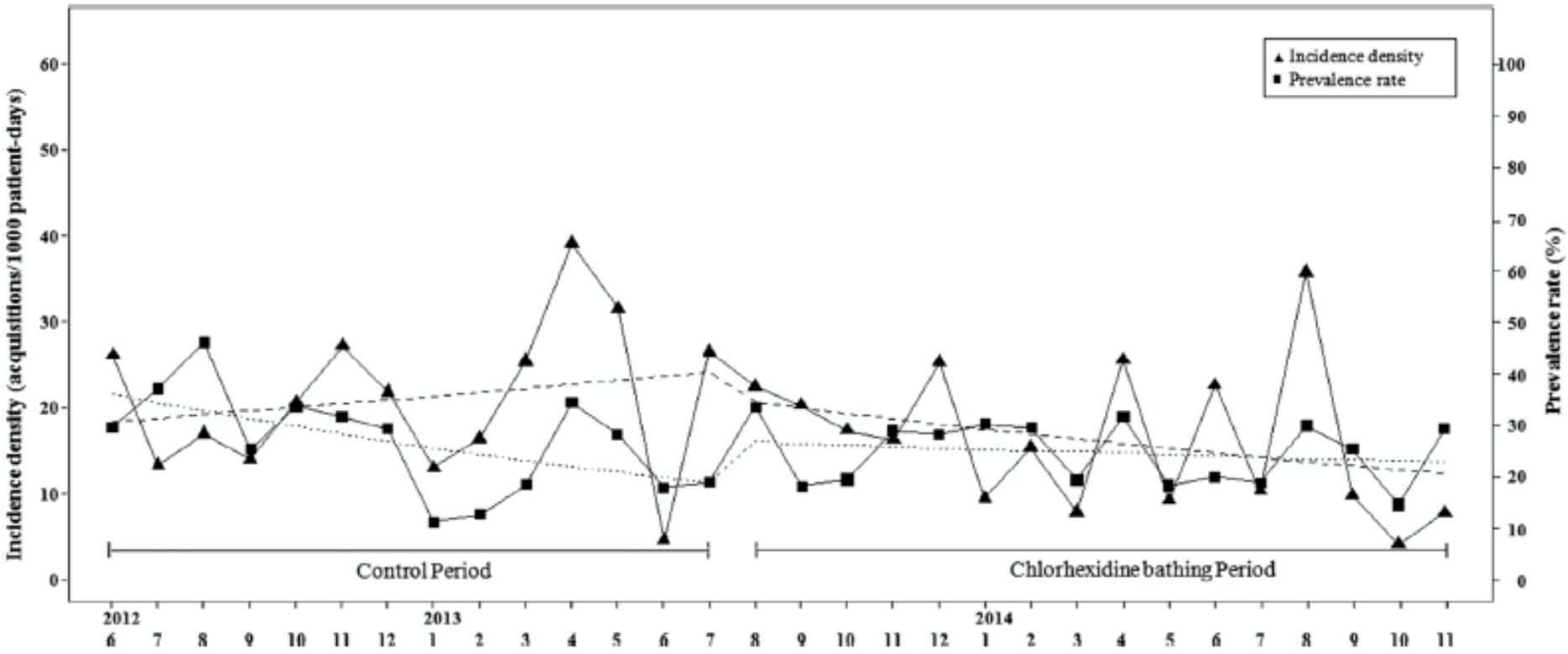
- Study also looked at levels of environmental contamination
- CRAB Environment contamination rate in the Medical ICU was 30.7% (39/127) before daily CHG bathing
  - Reduced to 9.6% (52/540) during intervention period ($P < 0.001$)
- Contamination of patient and staff gowns, bed rails, keyboards and monitors all significantly reduced during the CHG bathing period
  - All high-touch surfaces


Incidence density
Prevalence rate
Incidence density (acquisitions/1000 patient-days)
Prevalence rate (%)
Control Period
Chlorhexidine bathing Period
2012
2013
2014

MRSA Reduction

Kim et al, AJIC (2016) in Press

- An interrupted time series study was performed to evaluate the effect of daily Chlorhexidine bathing on the acquisition of MRSA in a medical ICU with endemic MRSA
- Daily bathing with no-rinse 2% Chlorhexidine gluconate–impregnated washcloths (Clinell Chlorhexidine Wash Cloths; GAMA Healthcare, London, UK) showed a significantly decreasing trend of MRSA acquisition rates irrespective of increased MRSA prevalence rates
  - Rate of MRSA acquisition 23.4% lower during the intervention period (21.0 vs 16.1 cases per 1,000 patient days, P = .101)
- No shift in Chlorhexidine-resistant MRSA strains


Incidence density
Prevalence rate
Incidence density (acquisitions/1000 patient-days)
Prevalence rate (%)
Control Period
Chlorhexidine bathing Period
2012
2013
2014

MRSA and 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 never touched 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.

THE MOP OF DEATH

EXCLUSIVE

By GRAHAM JOHNSON
Investigations Editor

THIS is the hospital so dirty even the cleaners' mops are crawling with deadly bugs.

News

Hospital bans flowers in wards

Flowers have been banned from wards at St Richard's Hospital, as the battle against MRSA superbugs continues across the country.

The policy is being introduced this month for 'tidiness, cleanliness and infection control reasons'.

Visits by children under 13 are also being restricted, as part of the action.

MRSA figures for St Richard's increased slightly, from 22 infections to 25, with an infection rate of 0.160 per 1,000 bed days for the period between April, 2004, and March, 2005.

No more ward flowers - St Richard's volunteer Rita Rose outside the hospital shop. 060173-1

Acting director of nursing Ruth Williams said critical care areas such as high dependency, intensive care and Boxgrove ward had not been allowed patients' flowers for some time.

Flowers are dangerous?

- Two papers looked at Pseudomonas
  - Contaminated flower vases
    - The Lancet, 1973;302:568-569. A. L. Rosenzweig
  - Flower vases in hospitals as reservoirs of pathogens
    - The Lancet 1973;302:1279-1281. D. Taplin, PM. Mertz
- Protecting chrysanthemums from hospital infection
  - The Lancet 1974;303:267-268. W. Howard Hughes

BBC NEWS UK EDITION

Last Updated: Thursday, 2 June, 2005, 14:28 GMT 15:28 UK

Bedside Bibles could be removed

Hospital bosses may remove Bibles from the bedsides of patients amid concerns over offending non-Christians and spreading the superbug, MRSA.

Leics-based Gideons International, which distributes Bibles, described the move as "outrageous".

University Hospitals of Leicester NHS Trust said it was committed to equality and religious diversity.

It is to meet on Friday to discuss whether the tradition should continue at the city's three main hospitals.

Gideons International's UK headquarters, which is based in the county, commissioned reports from medical consultants about the potential risk and found there was no danger.

> **"They say it's discriminating against people of other faiths. It's outrageous, political correctness gone mad"**
>
> Iain Mair, Gideons

Daily Record

News

KILLER RAPIST HAS MRSA IN PERVS' JAIL

Oct 16 2004

Superbug scare

By Amy Devine

A NOTORIOUS murderer and serial rapist is carrying the deadly superbug MRSA in jail.

Thomas Young has been moved to the hospital wing at Peterhead prison where bosses have reminded cons to wash their hands and have placed extra soap and paper towels in its halls.

But a source at the jail, where some of Scotland's worst sex offenders are held, said: 'Inmates and staff are scared to go near the health centre in case they catch this horrible bug.

Candida auris

- Candida auris is an emerging fungal pathogen
  - a yeast species first isolated from the external ear canal of a patient in Japan in 2009
    - Satoh K, et al.Microbiology and immunology (2009) 53(1):41-4.
  - since then has been associated with bloodstream infections, wound infections and otitis reported from South Korea, South Africa, and Kuwait
  - C. auris has caused hospital outbreaks in India, Pakistan, Venezuela, Colombia
  - Now in the UK – Royal Brompton ICU

Why is it an issue?

- Commonly resistant to first-line drug fluconazole, may also be resistant to other antifungals, including amphotericin B and the echinocandins (not in current UK strains)
  - evolves rapidly to develop resistance, specific susceptibility testing is recommended
- Prolonged hospital outbreaks reported globally, leading to large numbers of colonised patients (skin, respiratory tract, urine) and clinical infections (wound, urinary tract, candidaemia), which may be fatal
  - Biofilm capacity unknown; the types that caused ear infections did not form biofilms, however if there are line-associated infections this may mean a different subtype

Is it under-recognised?

- In UK laboratories, *Candida* spp isolated from superficial sites are not routinely identified to species level or tested for antifungal susceptibility
  - Even if species identification is undertaken (e.g. for invasive infections), isolates can be misidentified by some commercial kits as *Candida haemulonii*, *Rhodotorula glutinis* or *Saccharomyces cerevisiae*

What else?

- Scientific understanding of transmissibility and pathogenicity is in its infancy, although widespread environmental contamination has been described
- Although sporadic cases of C. auris have been identified throughout England in 2013 and 2014, since April 2015 a critical care unit in England has been managing an outbreak with over 40 patients either colonised or infected. Around 20% of these patients have had candidaemia
  - outbreak has been difficult to control, despite enhanced infection control interventions, including regular patient screening, environmental decontamination and ward closure

Are contact times of surface disinfectants achievable?

- Oral paper delivered at CHICA conference in 2008
  - Omidbakhsh N. Surface Disinfectants and label claims: Realistically can contact times be met to achieve antimicrobial efficacy ? Canadian Journal of Infection Control. 2008;23(1):49.
  - Small study carried out by a Virox employee that was never published except in abstract form
- Aim to determine efficacy of different disinfectant chemistries against common pathogens using a realistic contact time for each based on its evaporation rate, compare results to efficacy claims listed on product labels

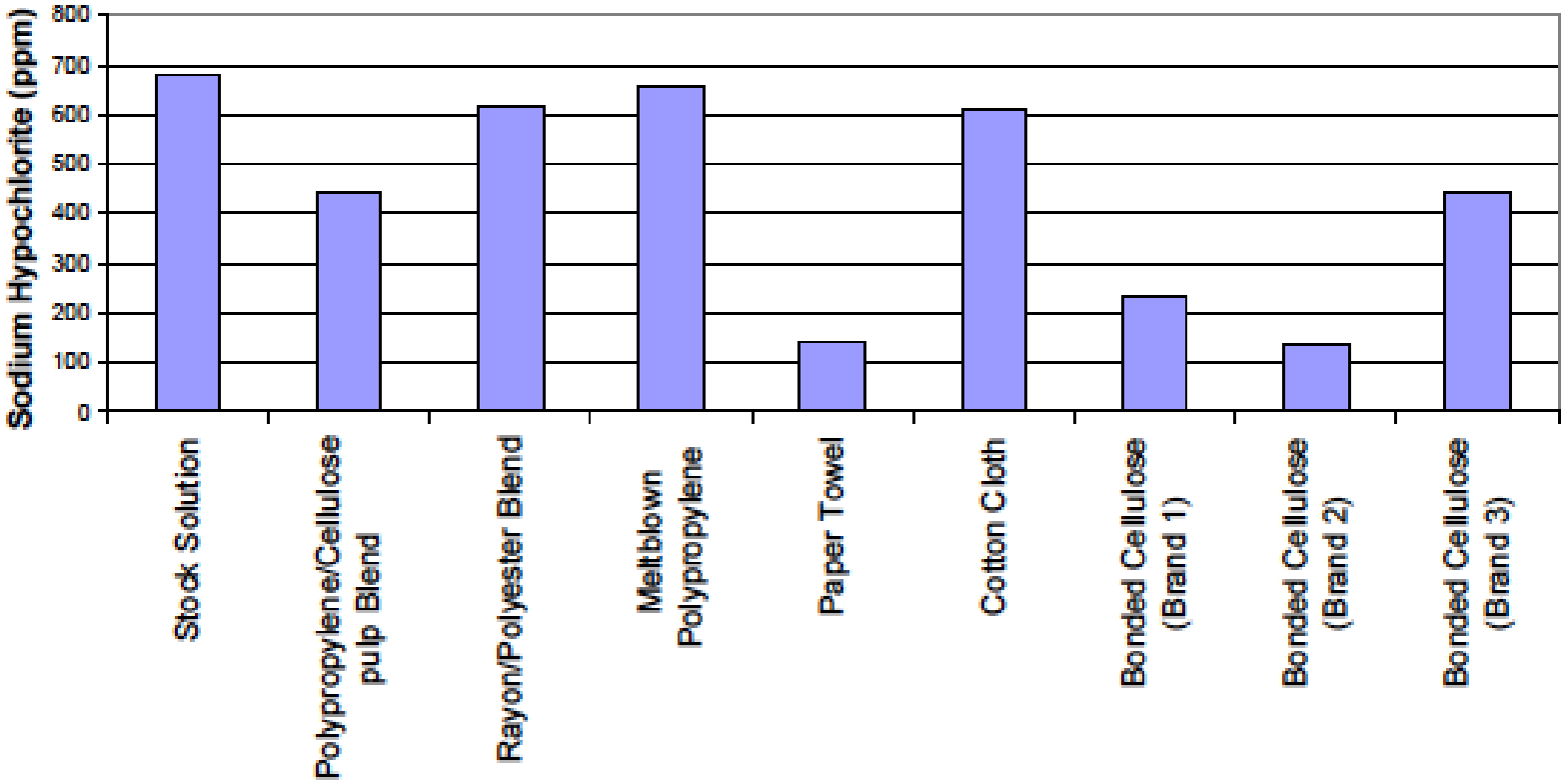
Results

- All tested products dried in less than 5 min contact time with alcohol-based products drying significantly faster than any other chemistry (p-value of 0.000)
  - Quat and phenol carried a label claim of 10 min, but dried at less than 2-3 min, and those contact times, they were found ineffective
  - AHP dried at 3-4 min, regardless it was still efficacious
  - Bleach dried at less than 2 min, and it was not efficacious
  - Quat/alcohol dried at less than 30 seconds, and was not effective

Effect of delivery method

Schultz, J. Advances in Disinfection Technologies (2007) 1: 1-4

Figure 5: Effect of Towel Material on Sodium Hypochlorite Concentration



S. aureus biofilms not killed by Sodium hypochlorite

- Hypochlorite exposure reduced plate counts by a factor of 7 $\log^{10}$, and reduced biofilm biomass by a factor of 100; however, staining of residual biofilm showed that live S. aureus cells remained
- Organism grew from the biofilm
  - WGS demonstrated identical organism
    - Almatroudi, A., et al (2016). "Staphylococcus aureus dry-surface biofilms are not killed by sodium hypochlorite: implications for infection control." Journal of Hospital Infection.

Evaluation of Environment Burden

Shams, A.M., et al., ICHE 2016: p. 1-7.

- Prospective 2.5-yr survey of large surface areas (>1,000 cm^2), 11 facilities, 4 states
  - MDRO contact precaution rooms
- 2 composite (1 sponge) samples from each room
  - Third sample was collected from each C. difficile room
  - Composite 1 - TV remote, telephone, call button, and bed rails
  - Composite 2 - room door handle, IV pole, and overbed table
  - Composite 3 - toileting surfaces
  - Composites based on a max. area of 2,258.06 cm^2
    - composed of 1 large surface-area site (bed rails or overbed table) and 2– 3 smaller sites

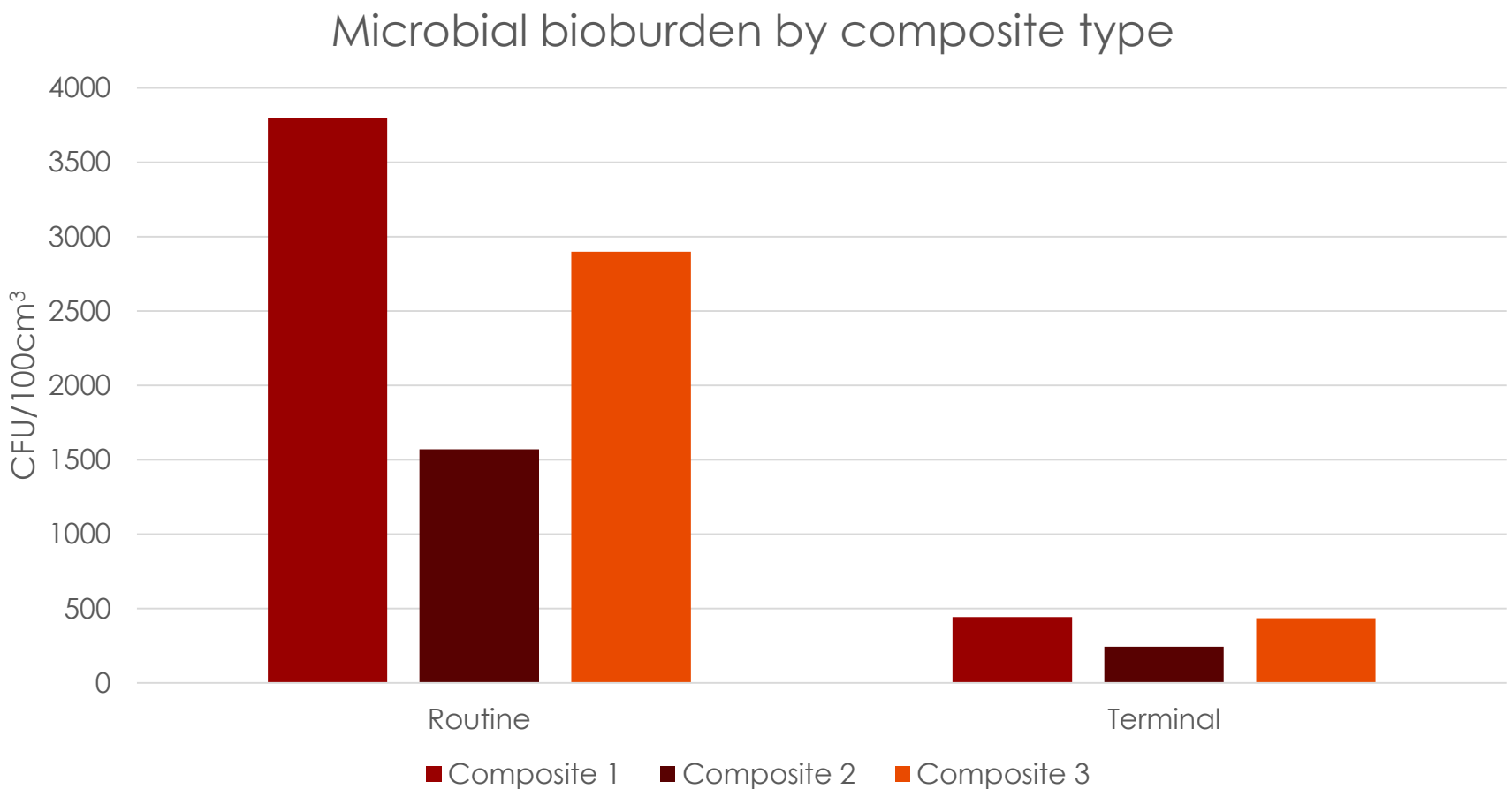
Evaluation of Environment Burden

Shams, A.M., et al., ICHE 2016: p. 1-7.

- Distinction between ‘routine’ and ‘terminal’ cleaning – varied by facility..
  - Effectiveness of cleaning not assessed
  - Some automated systems in use
- Preliminary study determined sites for composites
  - highest counts from room door handles (7,546 CFU/100 cm^2), telephone (2,350 CFU/100 cm^2), remote/call button (1353 CFU/100 cm^2)
  - overbed table most common MDRO-positive site (53.9%)

Evaluation of Environment Burden

Shams, A.M., et al., ICHE 2016: p. 1-7



Evaluation of Environment Burden

Shams, A.M., et al., ICHE 2016: p. 1-7

- MDROs recovered from 39.8% of rooms
  - 75.8% routine; 24.2% terminal
  - VRE was the predominantly recovered MDRO from all rooms (19.3%) and from routine cleaned rooms (23.9%)
    - recovered more often from discordant contact precaution rooms (n=20) than from concordant VRE contact precaution rooms (n= 12)
    - all rooms positive for K. pneumoniae were discordant contact precaution rooms
  - C. difficile recovered from 11.3% terminal rooms
  - Discordance – undetected carriage/previous occupant?

Transmission MDR Organisms

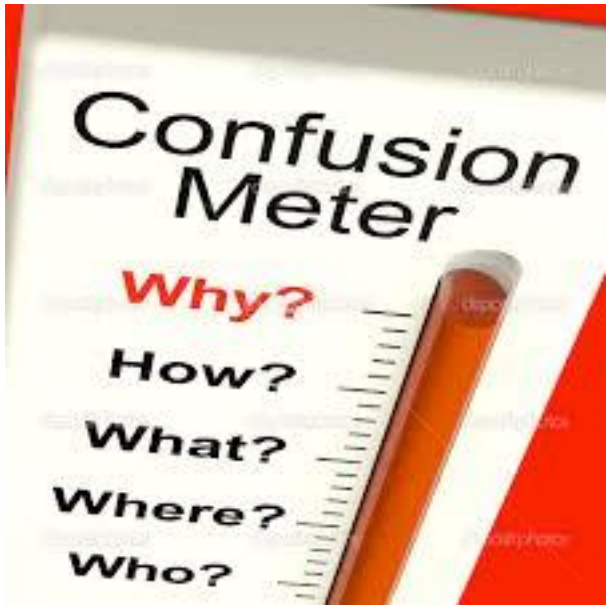
Nseir S, Blazejewski C, Lubret F et al. Clinical Microbiology and Infection 17(2) pp1201-8 (2010)

- Prospective cohort study in ICU
  - successive occupiers of a room at risk from organisms from previous occupants
    - Pseudomonas aeruginosa
    - Acinetobacter baumanii
- 'Quality' audits showed that 56% of rooms were not cleaned correctly
  - Failure in room door knobs (45%), monitor screens (27%) and bedside tables (16%)

Who is really caring for your environment of care?

Dumigan DG, Boyce JM et al AJIC 38:387-92 (2010)

- Procedures for cleaning patient care environments
  - Confusion about division of labour over cleaning responsibilities
- Systems to monitor cleaning are often ineffective
  - ‘Housekeeping’ yes; ‘Clinical’ No



Audit of Equipment

Anderson RE, Young V et al, JHI 78(3) 2011

- Many items of *clinical* equipment do not receive appropriate cleaning attention
  - ATP score showed surfaces cleaned by professional cleaning staff 64% lower than those by other staff (P=0.019)
- Nurses don't clean very well – of 27 items cleaned by clinical staff, 89% failed the benchmark
  - We need to be concerned about important areas, not on items that present no risk

Wipes can help

Lopez GU, et al. Evaluation of a disinfectant wipe intervention on fomite-to-finger microbial transfer. Appl Environ Microbiol. 2014;80(10):3113-8.

- Evaluated the impact of surface disinfection on the level of pathogen transfer from fomites to fingers
  - The mean $\log^{10}$ reduction of the test microorganisms on fomites by the disinfectant wipe treatment varied from 1.9 to 5.0, depending on the microorganism and the fomite
- Microbial transfer from disinfectant-wipe treated fomites was lower (up to<0.1% on average) than from non-treated surfaces (up to 36.3% on average for all types of microorganisms and fomites

Using wipes for cleaning

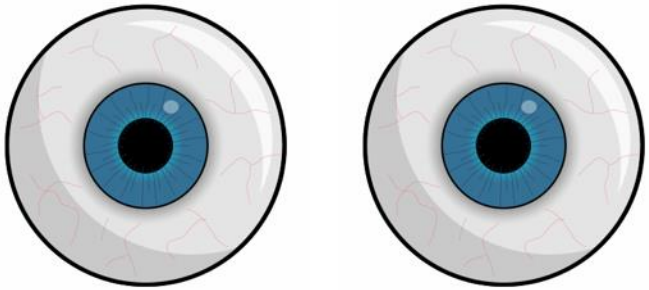
- Common use but label claims may be misleading
  - Mode of action, technique, absorbtion etc etc
    - Sattar SA, Maillard JY. AJIC 2013;41(5 Suppl):S97-104.
- Repeatedly using a wipe transfers organisms and C. difficile spores from contaminated to clean areas in significant numbers
    - Siani H, Cooper C et al. AJIC 2011;39(3):212–218

Transfer of C. difficile between surfaces

- Study examining the effect of using hypochlorite wipes on the transfer of C. difficile spores
  - Cadnum J, Hurless K et al, ICHE 2013; 34(4) 441-2
- Used wipes transferred spores to four sequential surfaces (although in low quantities on the fourth site)
- If used incorrectly, hypochlorite wipes can transfer spores to multiple surfaces
  - Use on multiple surfaces is frequent
  - Users not allowing insufficient contact time for the disinfectant

A lesson repeatedly learnt

- Go, stand there and watch what people are *really* doing
  - If I had $1 for every time that I found that they aren't doing what I thought they were
  - Disinfectant contact times in the real world are nowhere near what the manufacturer recommends
  - Staff develop their own system to circumvent 'problems'



Observation of wipes in use

Williams et al. J Hosp Infect 2007

Surface initially wiped	Time applied (seconds)	Number of consecutive surfaces wiped (other surfaces)
Bed Rail	4	5 (bedside table, monitor X2, monitor stand)
Steel Trolley	6	2 (both shelves on the trolley wiped)
Monitor	4	5 (monitors, two keypads, monitor stand)
Bed rail	7	4 (table, monitor, keypad)
Bedside table	10	4 (folder, two bed rails)

Hospital Hygiene in the News

BBC | Sign in | News | Sport | Weather | iPlayer | TV | Radio

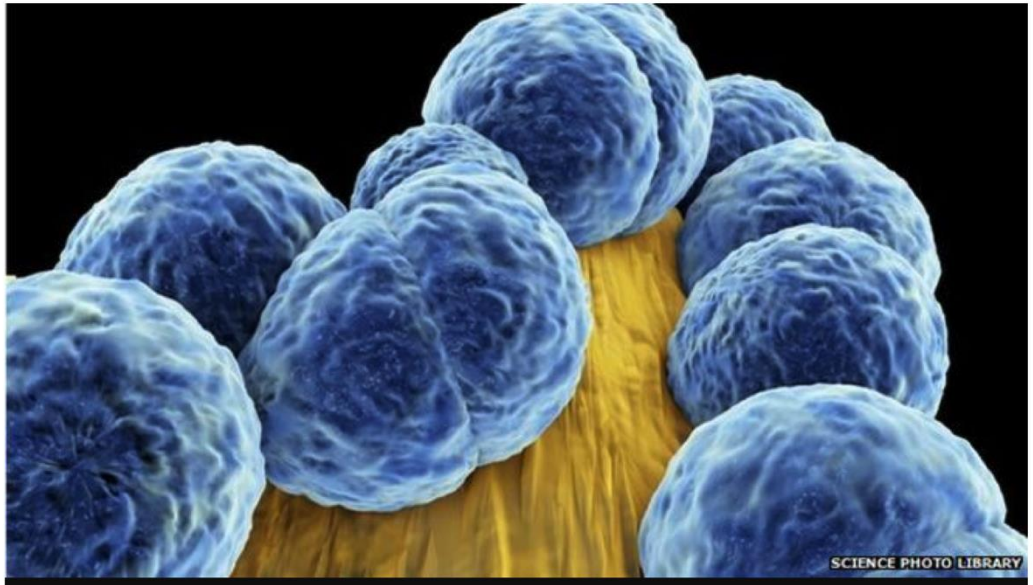
NEWS

Home | UK | World | Business | Politics | Tech | Science | Health | Education | Entertain

Wales | Wales Politics | North West | North East | Mid | South West | South East | Cymru

Superbugs 'spread by hospital wet wipes'

8 June 2015 | Wales



MRSA bacteria can cause skin, blood, lung and heart infections

Use of Detergent Wipes

Ramm, Siani et al (2015) AJIC in press

- Efficacy of removal of bioburden from surfaces by detergent wipes was variable between products
  - Efficacy of the wipes to remove A. baumannii from surfaces was appropriate, but not satisfactory with S. aureus and spores of C. difficile
- All wipes repeatedly transferred bacteria and spores onto multiple surfaces
  - Detergent cleaning is advocated in many national guidelines
    - it is imperative that such recommendations and guidance take into account the limitations found in this study

Research is still needed….

- Does daily disinfection of high-touch surfaces and increased attention to portable equipment add significant benefit to terminal room cleaning?
- What is the optimal frequency of disinfection?
- Is it beneficial to include all rooms on high-risk wards or the whole facility in interventions?

More disinfection questions

- Should interventions strive to “get to zero” positive cultures, or can we obtain similar results if contamination is reduced to an as-yet undetermined ‘safe’ level?
- Interesting that we seem to need evidence +++ when implementing ‘technical’ interventions, yet none when we change ‘convenience’ items such as wipes
  - Even though the total annual spend may be similar..

Final Points

- Cleaning is a Science and time to recognise it as such
- Technology can help but it needs to be able to fit in with the way that the organisation functions
- Change the language
  - Don’t say ‘Has that been cleaned?’, say “is that room/piece of equipment safe?”
- Value those that do the cleaning