THE HIDDEN THREATS OF PLASMIDS AND BIOFILMS A CALL FOR ENHANCED

DECONTAMINATION

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THE HISTORICAL CONTEXT

Our findings strongly suggest that microorganisms in the inanimate hospital environment — particularly on surfaces and in the air, but also in water, faucets, and sink drains — contribute negligibly to nosocomial infections occurring endemically in hospitalized patients.

Maki, D. G., C. J. Alvarado, C. A. Hassemer and M.A. Zilz (1982). "Relation of the inanimate hospital environment to endemic nosocomial infection." <u>N Engl J Med</u> **307**(25): 1562-1566.

THE FOUNDATION OF ENVIRONMENTAL HYGIENE IN THE UK

- Dates from this document
 - Hoffman P, Bradley C, Ayliffe G. Disinfection in Healthcare. 3rd Edition ed.: Blackwell; 2004

Low risk	Items in contact with normal and intact skin	Stethoscopes, washing bowls	Cleaning and drying usually adequate
Minimal risk	Items not in close contact with patients or their immediate surroundings	Floors, walls, ceilings and sinks	Cleaning and drying usually adequate



TIMES HAVE CHANGED

- Increased Complexity
 - Higher patient morbidity, rapid turnover and shorter hospital stays
 - 1990 Knee replacement meant 14 days in hospital; 2025 Day case surgery
- Emerging threats from antibiotic-resistant organisms
- Ever more complex medical interventions
- Hand Hygiene is not the be-all and end-all of IPC
- Need for effective hygiene
 - Adaptation to these challenges necessitates robust cleaning and disinfection protocols

WHO CONTAMINATES SURFACES?

- Evaluation of MRSA contamination relating to patient activity
- At baseline, 30% of hands and 20% of high-touch surfaces positive for MRSA
 - At each follow-up, 27% of patient hands, and 6% of environmental sites were positive
 - Patient activity explains 70% of contaminations
 - Wolfensberger, A., et al., Understanding short-term transmission dynamics of methicillin-resistant
 Staphylococcus aureus in the patient room. Infect
 Control Hosp Epidemiol, 2022. 43(9): p. 1147-1154.



WE KNOW THAT FAILURE TO DECONTAMINATE 'LOW-RISK' EQUIPMENT LEADS TO TRANSMISSIONS

- Clonal outbreaks of pathogens contaminating the room surfaces of colonised or infected patients are demonstrated to be due to person-to-person transmission or use of shared medical equipment
 - C. auris on a axillary skin temperature probe that was impossible to decontaminate due to age and no evidence that the staff actually did it between patients
 - Eyre DW, et al. A Candida auris Outbreak and Its Control in an Intensive Care Setting. N Engl J Med 2018;379(14):1322-31



WE KNOW THAT WE DO NOT KNOW EVERYONE CARRYING A PATHOGEN

- Environments are contaminated with pathogens in the absence of patients known to be colonised/infected with alert organisms, leading to a lack of awareness of the extent of contamination
 - 80% of socks with VRE; I 2% with MRSA
 - No known patients of either
 - Mahida N, Boswell T. Non-slip socks: a potential reservoir for transmitting multidrug-resistant organisms in hospitals? J Hosp Infect 2016;94(3):273-5



RISK OF C. DIFF TO THE NEXT OCCUPANT OF A BED

- CDI patients exposed to a potentially "contaminated" bed if, within the preceding 7 days from their HO-CDI diagnosis, they resided in a bed that held an occupant with C. difficile in the previous 90 days
 - Beds tracked with RFID stickers; cleaned with BruTab (Sodium dichloro-striazinetrione (NaDCC)
 - 4306ppm/4 minute or 2153ppm/10 minute minimum contact time
 - Exposure to a contaminated bed associated with HO-CDI in unadjusted analyses (OR 1.8; 95% CI 1.4-2.31)
 - Witt LS, et al The role of the hospital bed in hospital-onset Clostridioides difficile: A retrospective study with mediation analysis. Infect Control Hosp Epidemiol 2023:1-5. https://doi.org/10.1017/ice.2023.254.







HOW DO PEOPLE BECOME COLONISED?

- Skin organisms Staph. aureus etc
 - Organism acquired onto the skin through hand contact or a contaminated environment
- Gut organisms C. difficile and Gramnegatives
 - There are only two entrances





■ Patient ■ Visitor ■ Nursing ■ Medical Staff ■ Blood ■ Physio ■ Hostess ■ Cleaner ■ Porter

Sweeney, C. et al. IPS Conference Birmingham, 2024

KEY TRANSMISSION PATHWAY

- We need to effectively interrupt transmission from orifice to orifice
 - Ingestion of spores, gram-negatives
- Patient hand hygiene is terrible
 - 13% pre-intervention; 59% post
 - Loveday HP, Tingle A, Wilson JA. Using a multimodal strategy to improve patient hand hygiene. Am J Infect Control 2021;49(6):740-5



RETHINKING TRANSMISSION

- A 5-year investigation of the transmission dynamics of carbapenemase-producing Enterobacterales (CPE) in Singapore
- Transmission considered to have occurred if a source isolate from a different patient with an earlier or same date of culture (source patient) could be genomically-linked
 - Marimuthu K, et al. Whole genome sequencing reveals hidden transmission of carbapenemase-producing Enterobacterales. Nat Commun. 2022;13:3052 https://www.ncbi.nlm.nih.gov/pubmed/35650193

Clonal transmission

Bacteria spread by replicating themsselves

Plasmid transmission

Bacteria share resistance genes with each other through mobile DNA



CLONAL VS PLASMID

- 42% met criteria for clonal transmission
 - Mostly associated with direct ward contact, decreased in the latter half of the study period with the 'usual' interventions
- 44.8% met criteria for plasmid-mediated transmission
 - Associated with indirect ward and hospital contact, I.e., no association with time/space
 - Did not decrease over time
- I 3.2% were unlinked

ORGANISMS AND CLUSTERS

Transmission Clusters

- 58 clonal local transmission clusters
 - Median: 3 per cluster; first to last case 97 days (IQR 12.5-246)
- 16 plasmid-mediated transmission clusters
 - Median: 5 per cluster; first to last case was 667 days (IQR 373-908)
 - Majority involved multiple hospitals and species
 - Patients in 14 clusters were admitted to more than one hospital

Interquartile Range (IQR)



OUTBREAKS YOU NEVER KNEW YOU HAD

- Three patients underwent ERCP with the same duodenoscope infected
 - Two patients infected with Citrobacter freundii, one experiencing BSI, the other UTI
 - Another patient had BSI caused by Klebsiella pneumoniae
 - Screening of patients who had the implicated scope found three more colonised patients
- Scope negative on eight conventional tests but biofilm found under forceps elevator during destructive testing
 - Cimen C, et al. Uncovering the spread of drug-resistant bacteria through next-generation sequencing based surveillance: transmission of extendedspectrum beta-lactamase-producing Enterobacterales by a contaminated duodenoscope. Antimicrob Resist Infect Control 2024;13(1):31 doi: 10.1186/s13756-024-01386-5



BIOFILMS IN HOSPITALS





RELEASE OF S.AUREUS ORGANISMS FROM DRY BIOFILM

- Biofilms enhance persistence of microorganisms on dry clinical surfaces
 - Viable cells from biofilms significantly more virulent and transferrable a single touch with a gloved finger can transmit up to 30 cfu
 - Transfer higher when biofilms were wet with detergent than dry
 - Amaeze NJ. et al. Transfer of micro-organisms from dry surface biofilms and the influence of long survival under conditions of poor nutrition and moisture on the virulence of Staphylococcus aureus. J Hosp Infect 2024; 150:34-9.
 - 20 cfu can cause skin lesions in humans

 Elek SD. Experimental staphylococcal infections in the skin of man. Ann NY Acad Sci 1956;65(3):85-90



A 4-YEAR OUTBREAK OF MDR GRAM-NEGATIVES

- Plasmid mediated; 37 ICU patients colonised or infected with hospitalacquired CPE-NDM and/ or PA-VIM
 - 19 PA-VIM and 25 CPE-NDM detected
 - I3 Enterobacter cloacae, 5 Citrobacter freundii, 4 Escherichia coli, one Klebsiella oxytoca, one Proteus mirabilis and one K. pneumoniae
 - >50% mortality



22

• Anantharajah A, et al. Long-term intensive care unit outbreak of carbapenemase-producing organisms associated with contaminated sink drains. J Hosp Infect 2024;143:38-47. https://doi.org/10.1016/j.jhin.2023.10.010.

WHAT'S GOING ON IN A SINK?



RESISTANCE TRANSFER

- ESBL resistance gene transfer demonstrated from environmental gramnegatives (Pantoea calida, Raoultella ornithinolytica) to E. coli in waste outlet biofilms
 - Muzslay et al, J Hosp Inf (2017) 95(1) 59-64
- Common antibiotics detected in 33% of sink traps
 - Rodger G, et al. Survey of healthcare-associated sink infrastructure, and sink trap antibiotic residues and biochemistry, in 29 UK hospitals. J Hosp Infect 2025 (in press)



SEXUAL HEALTH EDUCATION



SINKS IN ICU

- 100 beds, 231 water outlets, 130 hand hygiene
- Determined splash radius from sinks
 - laid absorbent paper sheeting on the floor and ran a tap, observing for visible moisture marks
 - Up to 2 metres, dependent on faucet/strainer placement, water pressure, speed of drainage
- Recorded equipment within the radius
 - Garvey MI, et al. The sink splash zone. J Hosp Infect 2023;135:154-6



WITHIN THE SPLASH RADIUS?

Group	In Zone
Personal care items such as mouth care items, toiletries and washbowls	68%
IV access equipment e.g. IV ANTT ™ trays and phlebotomy equipment	65%
Alcohol hand rub and Personal Protective Equipment	57%
Computers on wheels	48%
Moving/handling equipment	43%
Nutrition/enteral feeding equipment, food, drinks, oral medication tubes	33%
Respiratory Equipment: O2 masks, humidification devices and Yankauer suckers	27%
Ventilator equipment	18%
Haemofiltration and dialysis equipment and outlets	12%
Patients with their invasive devices within the zone	12%

WHAT GOES DOWN, COMES UP!



Garvey, M.I., et al., The sink splash zone. J Hosp Infect, 2023 Vol. 135 Pages 154-6







THE SPAULDING CLASSIFICATION

- Patient care items divided into 3 categories based on degree of risk of infection in use
 - critical (enters sterile tissue and must be sterile)
 - semi-critical (contacts mucous membranes or non-intact skin and requires high-level disinfection)
 - noncritical (comes in contact with intact skin and requires low-level disinfection)
- Therefore, low level disinfectants should be used for hospital surfaces and frequently reused portable equipment (e.g., wheelchairs, patient vital signs monitoring equipment)
 - in the UK, detergent cleaning has been deemed acceptable for low-risk items based on recommendations dating back at least 20 years
 - Hoffman P, Bradley C, Ayliffe G. Disinfection in Healthcare. 3rd Edition ed.: Blackwell; 2004

PROBLEM

- Low risk = No risk
- Outbreak of CPE in Germany traced to 'low risk' equipment
 - Lippmann N, et al . Clinical epidemiology of Klebsiella pneumoniae carbapenemases. Lancet Infect Dis 2014;14(4):271-2. https://doi.org/10.1016/S1473-3099(14)70705-4.
- And who is doing it anyway?



ARE OUR POLICIES UP TO SCRATCH?

- 279 decontamination protocols regarding 283 different shared non-critical objects examined for decontamination method, decontamination frequency, and person responsible for decontamination
 - 54% did not indicate the person responsible
 - 33% were complete, giving indications for all three parameters analysed
 - Castelli A, Norville P, Kiernan M, Maillard JY, Evans SL. Review of decontamination protocols for shared non-critical objects in 35 policies of UK NHS acute care organizations. J Hosp Infect 2022; 120:65-72

UK NATIONAL IPC MANUAL

- Started in Scotland
- Imposed on England where it is mandatory
- Ignored by Wales and Northern Ireland
- Also ignored in Scotland
 - Shepherd E, Leitch A, Curran E, Infection Prevention Control Team NHS Lanarkshire. A quality improvement project to standardise decontamination procedures in a single NHS board in Scotland. J Infect Prev 2020;21(6):241-6. https://doi.org/10.1177/1757177420947477.

ENGLAND'S NATIONAL INFECTION AND PREVENTION AND CONTROL MANUAL (NIPCM)

- NIPCM (England) provides recommendations for "safe management of the care environment", including:
- The environment should be routinely cleaned in accordance with the National Cleaning Standards and Manual
 - Detergent is recommended for routine cleaning
 - A fresh solution of general-purpose neutral detergent in warm water is recommended for routine cleaning. This should be changed when dirty or when changing tasks
 - Routine disinfection of the environment is not recommended however, 1,000ppm available chlorine should be used routinely on sanitary fittings



NHS NATIONAL CLEANING STANDARDS

- Not evidence-based (no literature review)
- Only used in England; Scotland, Wales and Northern Ireland ignore it
- Not supported by IPS, HIS, RCN (all of who were involved in the development but withdrew support)

NIPCM AND THE INFECTED PATIENT

- NIPCM recommends the use of "environmental decontamination: enhanced cleaning" for such patients
- This includes the following: patient isolation/cohort rooms/area must be decontaminated at least daily; this may be increased on the advice of Infection Prevention and Control (IPC) Teams
- These areas must be decontaminated using either
 - a combined detergent/disinfectant solution at a dilution of 1,000 parts per million available chlorine); or
 - general-purpose neutral detergent in warm water followed by solution of 1,000ppm av Cl
 - NIPCM also notes that "Alternative cleaning agents/disinfectant products may be used with agreement of the local IPC team
- Detail on technique is absent

ISSUES WITH THIS – YOU ONLY KNOW WHAT YOU KNOW

- Guidance does not take into account undetected carriers of MDROs who cannot reliably be predicted by traditional risk categories or other organisms such as VRE and C. difficile
 - Goodman KE, et al. Predicting probability of perirectal colonization with carbapenem-resistant Enterobacteriaceae (CRE) and other carbapenemresistant organisms (CROs) at hospital unit admission. Infect Control Hosp Epidemiol 2019;40(5):541-50.



THINGS MOVE AROUND

- Detergents don't have any direct biocidal activity, so do not inactivate microbes
 - There is a risk of transferring microbes from one surface to another if practice is poor
 - Ramm L et al. Pathogen transfer and high variability in pathogen removal by detergent wipes. Am J Infect Control 2015;43(7):724-8.



OTHER ISSUES

- Guidance on low-risk items was written when antibiotic resistance was not an issue
- Biofilms were not even though to be a problem in wet areas, let alone recognising the risk from dry biofilms
- Equipment has become far more complex
- Nurses do not have the time to clean any more (Students nurses used to do it)
 - Moore G, Barry A, Carter J, Ready J, Wan Y, Elsayed M, et al. Detection, survival, and persistence of Staphylococcus capitis NRCS-A in neonatal units in England. J Hosp Infect 2023;140:8-14.

CHLORINE AND C. DIFFICILE

- Examined spore response to in-use concentration of 1,000 ppm NaDCC for 10 minutes liquid contact time on a surface
 - Hydrophobicity and surface structure influence spore transmission and that outer spore surface structures play a part in spore adhesion
 - Spores possessing an exosporium-like structure (e.g., strains DS1813 and R20291) demonstrated increased adherence to surfaces compared to exosporium-negative spores (e.g., strain DS1748)
 - Viable spores were recovered from treated surgical gowns, stainless steel, and vinyl flooring, demonstrating ineffectual sporicidal action
 - Dyer, C., et al., Biocide Resistance and Transmission of Clostridium difficile Spores Spiked onto Clinical Surfaces from an American Health Care Facility. Appl Environ Microbiol, 2019. 85(17)

ORGANIC MATTER AND CHLORINE

- I,000 ppm NaDCC gave a 5.26-log₁₀ reduction after 9 minutes in the absence of a test soil
 - in the presence of test soil, 9 minutes contact time resulted in only a 1.16-log₁₀ reduction in spore count
 - Wheeldon LJ, et al . Sporicidal activity of two disinfectants against Clostridium difficile spores. Br J Nurs 2008;17(5):316-20 https://doi.org/10.12968/bjon.2008.17.5.28827.



Ungurs M, et al. The effectiveness of sodium dichloroisocyanurate treatments against Clostridium difficile spores contaminating stainless steel. Am J Infect Control 2011;39(3):199-205. https://doi.org/10.1016/j.ajic.2010.07.015

CHLORINE USE BY NURSES

- Have they adequate access to necessary equipment?
- Someone has to make it up, label it and discard at 24 hr
- This is not always reliable...
 - Garvey MI, et al Chlorine in cleaning - are we concentrating enough? J Hosp Infect 2024. https://doi.org/10.1016/j.jhin.20 24.09.015.



IS CHLORINE TOLERANCE AN ISSUE?

- Pork wholesale market surfaces in China disinfected (sprayed) with sodium hypochlorite at 500ppm
- Main Findings:
 - Limited reduction of pathogens (Salmonella, E. coli, Klebsiella, P. aeruginosa)
 - Increase in disinfectant tolerance genes (e.g., emrA, mdtABC, qacG) and efflux pump-related ARGs
 - NaClO-tolerant Salmonella showed 100% multidrug resistance; E. coli 95.2%.
 - Xiao X, et al. Insights into microbial contamination and antibiotic resistome traits in pork wholesale market: an evaluation of the disinfection effect of sodium hypochlorite. Journal of Hazardous Materials 2024;468. https://doi.org/10.1016/j.jhazmat.2024.133811.

ENHANCING ENVIRONMENTAL DECONTAMINATION FOR C. AURIS

- Microfibre and/or cotton mops transferred C. auris to uninoculated tiles when used with water and detergent
 - Sporicidal disinfectants and UV-C light achieved the highest reduction of C. auris with no cross-contamination
 - Non-sporicidal cleaners allowed transfer of *C*. *auris* to adjacent tiles
 - Rutala WA, et al. Inactivation and/or physical removal of Candida auris from floors by detergent cleaner, disinfectants, microfiber, and ultraviolet C light (UV-C). Infect Control Hosp Epidemiol 2024;45(3):390-2.



CONCLUSION

- Times have changed
 - England's recommendations in the NICPM for routine detergent-based cleaning of surfaces in hospitals are not in keeping with current evidence
 - There are a range of effective agents that can be used to decontaminate surfaces, each with strengths and limitations to take into account compatibility etc etc
 - Local procedures should be related to local issues and risks
 - Kiernan MA, Garvey MI, Norville P, Otter JA, Weber DJ. Is detergent-only cleaning paired with chlorine disinfection the best approach for cleaning? J Hosp Infect 2024;148:58-61. https://doi.org/10.1016/j.jhin.2024.03.018.