prof. Dr. Payman A.Hamaseed PhD. In Medical Microbiology

Cleaning and decontamination of the healthcare environment.

1- Introduction

A visual experience of dirty hospitals is automatically linked with infection risk [Microbes are invisible and they are not associated with visual dirt], but there are already several known risks for patients acquiring infection in hospital :

1- Antimicrobial consumption
2- Insufficient isolation rooms
3- Poor hand hygiene
4- Verify whether a hospital is truly clean and safe.
5- There is confusion between nursing and domestic personnel over allocation of cleaning responsibilities.
6- Established cleaning regimens do not target high-risk reservoirs due to a lack of evidence and education.
7- The impression of cleanliness is confounded by clutter, excess equipment; cramped wards and fabric deficits.

2- Pathogen survival time in the hospital environment

If a microbial pathogen can retain viability on surfaces outside the human body, there is a risk that it could be picked up by hands or air currents and transmitted to a patient. The longer it survives, the more likely it will ultimately reach a patient at a vulnerable site and cause infection. Robust pathogens will persist in an appropriate environmental niche for days unless removed through some cleaning process.

Organisms that are particularly good at resisting drying or desiccation are more likely to be associated with epidemic spread.8.

Whilst the ability of bacterial spores to withstand intemperate environments is well known, survival patterns of vegetative bacteria and viruses in healthcare institutions are less.

It has been assumed that **Gram-negative bacilli** are more vulnerable to exposure on surfaces, many studies that detail prolonged survival periods for some Gram-negative species. For example, Escherichia coli and Klebsiella spp. have been shown to survive more than a year under certain conditions, and Serratia marcescens up to 2 months. In contrast, methicillin-resistant Staphylococcus aureus (MRSA) has been shown to survive for a year in hospital dust, the spores of Clostridium difficile for five months and epidemic vancomycin-resistant enterococci (VRE) for up to four years.. Acinetobacter can survive in surface dust for at least a month, with some strains reportedly surviving for up to 3 years.8 Pseudomonas aeruginosa usually only survives for a couple of days but will persist for five weeks on a dry floor. Along with Stenotrophomonas maltophilia, Pseudomonas spp. demonstrate long-term persistence within biofilm adherent to hospital plumbing components and other water-exposed sites.

Most respiratory viruses such as coronavirus, rhinovirus and influenza can survive on dry surfaces for a few days, with gastrointestinal viruses retaining viability for a couple of months. Norovirus is found in the hospital environment for days after an outbreak, demonstrating survivability despite terminal cleaning with bleach-based products.

Fungi such as Candida spp. may persist in hospitals for up to four months, although there are very few reports detailing the risk of cross-infection from an environmental source.

Given the proven ability of these microorganisms to survive on surfaces for relatively long periods of time, it is obvious that the healthcare environment facilitates cross-transmission and outbreaks of many hospital pathogens. The risks of cross-transmission are:

1- heavy workload
2- understaffing
3- high bed occupancy rates and rapid bed turnover.
4- Furthermore, in an era of cost cutting, those with cleaning responsibilities cannot hope to decontaminate all high-risk surfaces as often as required when a hospital is full to capacity and patients with attendant microorganisms are transferred between wards day and night.

3- Identifying the main reservoirs of microorganisms

Pathogens can be recovered from the environment using a variety of microbiological techniques. Most organisms can be found in the air and ultimately on the floors, but almost any surface can host a range of microbes for differing lengths of time. These include general surfaces such as shelves ,curtains , linen and clothes; furniture and computers, telephones, patients' beds and items of clinical equipment.

Gram-negative organisms such as Pseudomonas spp. and Stenotrophomonas are associated with damp places such as taps, sinks, showers and baths.

Coliforms such as Klebsiella and Serratia have been identified from buckets, bowls, mops and liquids. Thus, traditional sites for Gram-negative microbes have been sites constantly or intermittently exposed to water, but this is not always the case. Dry sites, e.g. patient charts, can also host a range of Gram-negative organisms.

About 5% of near-patient sites demonstrate presence of Gram-negative bacilli indistinguishable to those from the patient. Organisms identified included *E.coli*, *Enterobacter, Serratia and Klebsiella,* and these organisms were recovered from a range of sites including linen and nightwear; bedside table, bed rail and chair; door handle; infusion pump and respirator; and expected bathroom sites. The most prevalent site for the patients' own isolate was the perineal region of the patients themselves, thus demonstrating the major reservoir for Gram-negative bacteria. The perineum has already been highlighted as an important source of environmental contamination for hands of both patients and staff.

Pathogens normally resident in the gastrointestinal system, such as norovirus, C. difficile and VRE, are predominantly recovered from bathrooms, toilets or commodes, although the propensity for survival of these particular organisms means that they can be found from many other sites in the healthcare environment.

Indeed, spores of C. difficile persist on hands and under fingernails, and could be carried between wards on the soles of shoes. Spores may disseminate through the air, confounding attempts at controlling infection and invalidating terminal cleaning protocols.

Norovirus easily spreads in air and on surfaces throughout an entire ward, although this usually reflects the situation during seasonal outbreaks. Dust-loving MRSA and Acinetobacter contaminate rarely cleaned and/or inaccessible surfaces, such as shelves, tops of monitors, patient notes and computer keyboards. The most frequently contaminated sites for MRSA on an acute ward are top of the bedside locker; overbed table and bed frame. Airborne spread of MRSA and Acinetobacter has also been documented but remains poorly investigated.

The more traditional airborne pathogens, ubiquitous Aspergillus and Bacillus spp., are dispersed through the hospital particularly during hot dry weather, and often associated with construction or renovation.

Coliforms and Pseudomonas may frequent ‘wet’ sites such as sinks and baths, with differences between the recovery rate from sinks on separate wards within the same hospital.

Few coliforms persisted in intensive care unit (ICU) sinks, as opposed to sinks on medical wards, with Pseudomonas-type bacteria more frequently isolated from ICU sinks than those on the medical wards. This was attributed to more frequent dispensing of alcohol and chlorhexidine for the purposes of hand disinfection in ICU. All environmental bacteria recovered from ICU were significantly more resistant to antibiotics than those from the medical wards. Antibiotic consumption appears to influence the resistance profiles of organisms on floors and other surfaces within a defined local environment such as a hospital ward.

Prior room occupancy has been shown to be a risk for acquisition of both Gram-negative and Gram-positive organisms. A patient admitted into a room previously occupied by an infected patient remains at risk of acquiring the same organism, regardless of hand hygiene compliance rates by attendant clinical staff. The greatest risk for infection for most patients emanates from surfaces beside or on beds, e.g. linen, bed frames, lockers and overbed tables. Contamination of near-patient bedside sites provides an opportunity for everyone’s hands, including those of the patient, to acquire pathogens and/or transfer them elsewhere.

4- Transmission of contaminants by hands during healthcare

Items or surfaces that are frequently touched provide the largest risk of contamination by pathogens spread on hands. Researchers track the movement and spread of the viral marker around the unit, from hand-touch site to hand-touch site over the course of hours and days.

In addition, the community study showed how direct hand-to-hand contact, as occurs during handshaking.

About 40% nurses' hands yield coliforms without prior disinfection, although rates depend upon the type of unit in which sampling takes place.

Another study showed that 17% ICU staff carried Klebsiella on their hands, and that these strains were probably related to those colonising or infecting patients resident on the unit.

clinical staff caring for patients with C. difficile, 59% had positive cultures for C. difficile from their hands. About of contacts between a healthcare worker and an MRSA-colonised patient result in transmission of MRSA from a patient to the gloves of a healthcare worker.

Staff also acquire pathogens after touching environmental sites as they are after caring for patients. Coliforms can be recovered from the hands of nurses after touching patients' washing materials and clothing, as well as after bed making, handling bedlinen and curtains, and even after a drug round. Once acquired, hands may then be responsible for contaminating additional environmental sites.

Contamination of hands or gloves with hospital organisms provides a highly plausible route of transmission between patients on a ward. hand hygiene compliance is still only about 50%. It is also possible that hand hygiene is insufficient to stop pathogen transmission. Neither chlorhexidine, alcohol, nor soap and water necessarily remove contamination from hands, and some hand cleansing products are ineffective against specific pathogens.

5- The role of cleaning in reducing the infection risk for patients

Numerous reports detail cleaning as a major control component for outbreaks of MRSA; VRE; C. difficile; norovirus; and drug-resistant Acinetobacter. These pathogens thrive in dust and dirt in the temperate hospital environment and contaminate numerous sites on surfaces and equipment, particularly during an outbreak.

5.1- Cleaning and MRSA

There is some evidence that cleaning removes MRSA from the ward environment with benefit for patients. MRSA was isolated from 13 patients on the dermatology ward over a 14-month period. Extensive environmental culturing revealed that a **blood pressure cuff** and the patients' **communal shower** were positive for MRSA, with pulsed field gel electrophoresis (PFGE) demonstrating identical DNA typing patterns from the majority of patient isolates and both environmental sources. Control was achieved after changing of blood pressure cuffs between patients and more stringent cleaning of communal areas.

Another MRSA outbreak on a urological ward .After the outbreak strain was isolated from the ward environment, the number of domestic cleaning hours was doubled from 60 to 120 hours per week and the number of patients affected immediately decreased. The cleaning intervention was thought to have played a significant role in the termination of the outbreak .

So extra cleaning, notably targeting hand-touch sites and clinical equipment using detergent wipes and water could be effective mechanism of reducing MRSA infections.

5.2- Cleaning and VRE

Environmental cleaning important for controlling VRE. One study describes the impact of improved cleaning on the spread of VRE in a medical ICU, with and without promotion of hand hygiene compliance. Enforcing cleaning measures along with improved hand hygiene was associated with less surface contamination with VRE, cleaner healthcare worker hands and a significant reduction in VRE cross-transmission among patients. Introducing an educational programme, use of bleach for bathroom surfaces and 70% alcohol for furniture and patient equipment.

5.3- Cleaning and *C. difficile*

The benefits of cleaning for control of *C. difficile* are well established, one hospital introduced enhanced **cleaning with hypochlorite** into two ICUs. One of the ICUs applied the extra cleaning to all areas, including rooms used solely by staff, and sensitive clinical equipment was wiped over twice daily using hypochlorite-impregnated cloths. The other unit introduced the intensive hypochlorite clean into isolation rooms housing patients already infected with C. difficile. Rates of infection decreased in both units over several months and appeared to be maintained at a lower rate for at least 2 years after the cleaning intervention.

Increased rates of C. difficile infection (CDI) in three American hospitals prompted terminal room cleaning of those affected with dilute bleach instead of the usual quaternary ammonium compound, dilute bleach led to significant reduction on the rate of nosocomial CDI.

5.4- Cleaning and Acinetobacter

The importance of cleaning in controlling outbreaks caused by multiply resistant strains of *A. baumannii* involving more than 30 patients in two ICUs. both ICUs were closed for terminal cleaning and disinfection. The high standards of cleaning play an integral role in controlling outbreaks of Acinetobacter in the intensive care setting, .

A further study describes what happened following the introduction of bedside computers in a paediatric burns ward. There was a sudden increase in the number of patients acquiring Acinetobacter and environmental screening demonstrated the organism on various surfaces in the patients' rooms, especially the **plastic covers on the computer** keyboards. Targeted infection control measures that included the use of **gloves before using the computer and thorough disinfection of the plastic covers effectively terminated the outbreak.** Before the outbreak occurred, no one had thought to include the computers in a routine cleaning specification.

A 3-year prospective study was conducted in intensive care and coronary care units to evaluate interventions including contact isolation precautions, hand hygiene, active surveillance, cohorting patients colonised or infected with pandrug-resistant A. baumannii and environmental cleaning with 1:100 sodium hypochlorite. The rate of A. baumannii colonisation and/or infection was 3.6 cases per 1000 patient-days before the intervention. One year after the intervention, the rate of A. baumannii colonization and/or infection decreased by to 1.2 cases per 1000 patient-days ($p < .001$) and two years later by to 0.85 cases per 1000 patient-days ($p < .001$).

5.5- Cleaning and multi-drug-resistant coliforms

The importance of cleaning in controlling outbreaks of Gram-negative microorganisms other than Acinetobacter is difficult to ascertain outbreaks of coliforms traced to discrete pieces of equipment, specific environmental site or particular product or practice. This is probably because terminating an outbreak caused by single source contamination is a lot easier than implementing a routine cleaning regimen that prevents infection from a multitude of general surfaces. Identification of a single reservoir and eradicating it usually curtails the outbreak.

Persistent reservoirs of resistant Klebsiella pneumoniae with extended-spectrum β-lactamase-(ESBC)-producing was source of this outbreak in a contaminated sink. By replacing the sink and its plumbing and improving routines regarding sink usage and cleaning, the outbreak was terminated.

5.6-Cleaning and Pseudomonas/Stenotrophomonas

5.7. Cleaning and norovirus

The importance of environmental cleaning in the control of outbreaks of norovirus is widely accepted. All general cleaning, especially toilet and bathroom areas, should use a chlorine-containing disinfectant or bleach at a specified concentration. norovirusn can be seen near toilets in bathrooms but also on numerous types of clinical equipment, e.g. pulse and blood pressure machine; alcohol gel containers, and near-patient sites.

Outside hospitals, norovirus outbreaks can be devastating in closed or semi-closed communities. These include sudden and extensive outbreaks in hotels or prisons, but outbreaks can also occur in nursing and residential homes, cruise-ships and schools. An outbreak reported recently in a primary school involved 79 pupils and 24 members of staff. Subsequent investigation of the outbreak showed that **person-to-person contact** was Public health officials recommended hand hygiene, exclusion of symptomatic persons and thorough environmental disinfection with a diluted (1:50 concentration) bleach solution, to include sites that were not commonly cleaned.

6- Contaminated cleaning equipment and fluids

Cleaning equipment may also become contaminated with hospital pathogens and disperse these into the hospital environment. Disinfectants are more effective at killing pathogens than in-use detergents but some hospital pathogens can resist bactericidal effect of a particular agent [Both multi-drug resistant S. marcescens and extremely-drug-resistant strains of K. pneumonia] have demonstrated increasing tolerance to chlorhexidine. Other cleaning fluids can become contaminated with Gram-negative bacilli during use; indeed, some formulations may encourage acquisition of resistance elements by Gram-negative organisms.

7- Assessment of environmental cleanliness

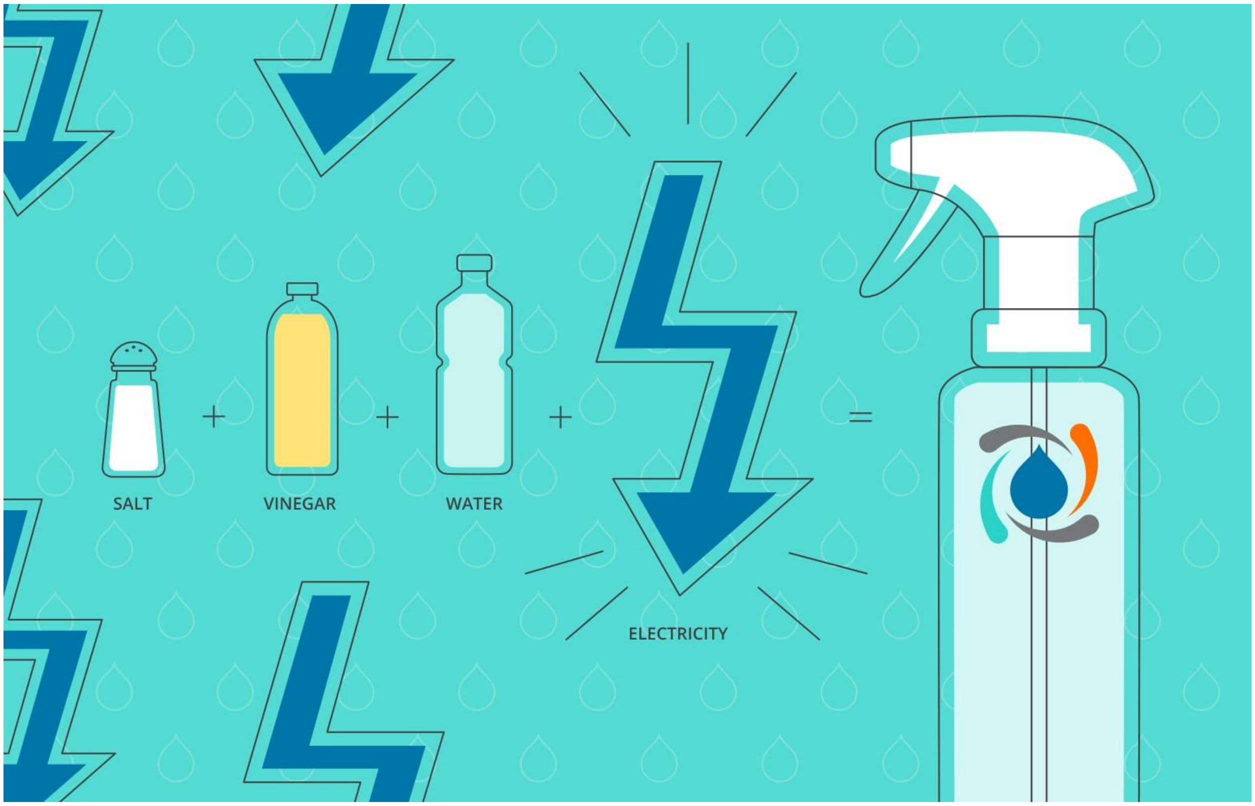
Hospital staff need to know exactly which levels are acceptable for patient safety purposes. Currently coagulase-positive staphylococci provide a reliable indicator of environmental hygiene, studies examining the utility of microbiological standards in hospitals have chosen both Staph. aureus and MRSA to help monitor cleanliness. Routine monitoring should be able to indicate trends in hospital cleanliness and workload, and, most importantly, when enhanced cleaning activity is required before patients are exposed to serious risk of infection or even an outbreak.

Further studies have demonstrated differing effects between direct observation, supervision and education of staff as they clean, again showing reduction of important hospital pathogens. There is a concern that these interventions might lose impact over time, since cleaning is physically demanding, poorly paid and subject to inadequate staffing. Hence training and continual evidence-based reassessment are required as part of staff development.

8- Current and future trends

New methods for environmental decontamination are constantly appearing on the market. Disinfectants tend to be expensive and environmentally unfriendly. This has encouraged ‘greener’[GREENER proposes the development of green, sustainable, efficient, and low-cost solutions for soil/sediment and water bioremediation[Bioremediation is a waste management technique that includes the use of living organisms to eradicate or neutralize pollutants from a contaminated site.]]

electrolysed water; The process starts with the correct concentrations of salt, water and vinegar. You may remember that a salt molecule is made up of the elements sodium and chloride (NaCl) and a water molecule is made up of hydrogen and oxygen (H2O). When an electrical current is applied to the solution, the molecules break apart and the elements form two new molecules: Sodium hydroxide (NaOH), a common detergent used at different concentrations in products ranging from toothpastes and skin moisturizers to sunscreens, and hypochlorous acid (HOCl), a natural disinfectant & sanitizer that’s as powerful as bleach. Hypochlorous acid is actually the same substance your immune system produces to fight infection.



Examples include ultra-heated steam; ozone and hydrogen peroxide, amongst others.

In addition to these, are novel cleaning materials and equipment such as microfiber[It has been said that microfiber technology is arguably the most significant product innovation to the cleaning industry in the last century. Not only has microfiber proven to reduce time and energy on certain tasks, it is environmentally friendly and rarely requires the use of chemicals.] ; scrubbing machines; microbicidal gases, bioactive veneer ultraviolet (UV) light-emitting devices; air ionisers; and a range of high-pressure steam cleaners.

A recent study describes the effect of a newly developed portable pulsed ultraviolet (UV) radiation device on bactericidal activity and its impact on the labour burden when implemented in a hospital ward.

There are new types of antimicrobial coatings available for linen, equipment, furniture and general surfaces such floors, walls and doors. Practically anything that can be impregnated with chemicals, or coated with microbicidal paint, could potentially be marketed as ‘antibacterial’ for healthcare environments. Bioactive surfaces or coatings can contain heavy metals (or their derivatives) such as copper, zinc, silver or titanium, or antiseptics and biocides. There is evidence that coating near-patient hand-touch sites with copper reduces organisms such as MRSA and consequently, the risk of HAI.