What strategies are in place to control microbial burden in hospital environments and how could these change in the future?

“There is mounting evidence that microbial burden in the hospital environment plays a central role in the development of hospital-acquired infection...”

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More than 150 years ago, Soren Kierkegaard stated, “Life can only be understood backwards; but it must be lived forwards.” It was around this time in history that the scientific study of hospital infections was beginning and by the mid-20th century the first full-time infection control position was created in the UK. Modern infection control programs have learned from looking backwards and are now complex, multi-disciplinary efforts designed to better understand the epidemiology of hospital infections to provide effective, safe care to vulnerable patients.

There is renewed interest in defining the role of environmental contamination in transmission of nosocomial pathogens and development of hospital-acquired infection (HAI). Patients shed microorganisms into their environment and despite methodological variability among studies attempting to quantitate this burden, there is high-quality evidence for the presence of organisms, especially on high-touch surfaces [1]. Other factors, for example, the body site of colonization or infection and the fact that infected patients shed more organisms into the environment compared with colonized patients, are also important when assessing environmental contamination. Additionally, organisms may persist in the patient care environment from hours to months under certain conditions [2]. This has been documented for worrisome Gram-positive pathogens (*Staphylococcus aureus*, including methicillin-resistant strains, *Enterococcus*, including vancomycin-resistant strains and *Clostridium difficile*) and Gram-negative pathogens (*Pseudomonas*, *Klebsiella* and *Acinetobacter* sp.), as well as viruses [2]. Transmission of pathogens in hospitals is complex; however, most

often, patients acquire organisms via the contaminated hands of the healthcare worker, use of contaminated equipment or contamination of the room from a prior occupant [3,4]. Hence, the CDC has issued guidelines for hand hygiene and personal protective equipment use as well as for cleaning and disinfection of the environment of care [101].

Decreasing the level of environmental contamination through CDC-recommended routine cleaning and disinfection has been shown to reduce transmission of nosocomial pathogens and the rate of HAIs; however, multiple studies have reported that this is frequently inadequate [5]. It is also noted that the effectiveness of routine cleaning and disinfection techniques depends on several factors, such as location, number, intrinsic resistance of organisms and biofilm formation, as well as the concentration and potency of products and compliance with recommended use, such as application and contact time. All of these characteristics have been used to recommend the most appropriate method to reduce microbial burden (MB) in the environment as well as to estimate what level of contamination is acceptable to mitigate risk of HAI. A quantitative aerobic colony count of less than 500–250 CFU/100 cm² on high-touch surfaces has been proposed as an acceptable threshold above which environmental cleaning is considered inadequate [6]. The average MB of common surfaces within the patient intensive care unit room was recently described. Bed rails harbored 17,336 CFU/100 cm², over bed tray tables harbored 3925 CFU/100 cm² and the nurses call button harbored 7118 CFU/100 cm² [7]. Few data exist that directly relate the risk of

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- hydrogen peroxide vapor
- UV light

infection to MB; however, another recent study that prospectively followed infection rates in the intensive care unit among patients in rooms that were sampled weekly found that the risk of HAI significantly increased as MB increased [8]. The same research group also demonstrated that, as expected, cleaning was effective at significantly reducing MB by 82% on traditional plastic bed rails; however, within 6.5 h, this burden had returned to nearly precleaning levels [9]. The CDC does not recommend routine microbiological sampling and thus most facilities rely on visual inspection alone, but new novel techniques such as adenosine-triphosphate bioluminescence analysis or UV light markers are attractive options to assess the effectiveness of environmental cleaning and disinfection when used as an adjunct to visual inspection and checklists [10,11].

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Routine and terminal environmental cleaning followed by disinfection are the mainstay of environmental bioburden control and multiple studies have demonstrated that measures to increase the efficacy of cleaning and disinfection have reduced environmental contamination. For example, an educational intervention to enforce environmental cleaning demonstrated reduction in acquisition of vancomycin-resistant *Enterococcus* (VRE) and *C. difficile* [12]. Another study showed that increasing the volume of disinfectant along with an educational intervention and feedback decreased the frequency of VRE and *S. aureus* [11]. The CDC recommends use of disinfectants such as alcohols, chlorine, aldehydes, quaternary ammonium compounds, hydrogen peroxide, iodophors, peracetic acid and phenolics, alone or in combination. Liquid disinfectants, use of microfiber cleaning materials and steam cleaning, while still controversial, may be more effective than traditional methods and underscore technological developments in hospital environmental cleaning [13].

The methods described above are typically bundled as infection control practices to enhance and optimize environmental cleaning and disinfection; however, failure to comply with all processes every time may limit the benefit. In an attempt to limit human variability in cleaning practices, novel disinfecting agents, no-touch delivery systems and antimicrobial surfaces have

been developed. These include, but are not limited to, hydrogen peroxide vapor (HPV), UV light decontamination units, antibiotic impregnated surfaces and copper-surfaced objects.

HPV via microcondensation or dry-gas delivery systems has reportedly been very effective in decreasing the MB of pathogens such as *S. aureus*, VRE and *C. difficile* but there is also evidence for decreasing HAI, specifically *C. difficile*-associated diarrhea [14,15]. Strict safety measures must be complied with during the use of HPV and this requires additional training of environmental services personnel. Additionally, cost-effective analyses must be conducted that take into account the extra time necessary for use after terminal cleaning.

Several studies have also documented effective MB reduction using UV light units; up to 93% for methicillin-resistant *S. aureus* and VRE and 80% for vegetative *C. difficile* and up to 99.8% for *C. difficile* spores [16]. Robust studies of the impact of UV light on HAI are lacking; however, these devices have the advantage of being completely automated, easy to use, do not require monitoring or supervision by an operator and have virtually no risk for personnel when appropriate precautions are utilized. Like HPV, it is important to recognize that precleaning of rooms to remove visible contamination is needed as this has been shown to decrease effectiveness [17]. Additionally, efficacy may be lower in shadowed areas of the room, thus adding additional time and effort [18]. Recent data comparing HPV and UV light confirms the effective reduction of microbial and spore burden in patient rooms for both methods, but finds significantly better effect for HPV when considering out-of-sight areas [19].

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Another emerging technology for reduction of MB is self-disinfecting surfaces. Metallic silver and copper have intrinsic broad-spectrum antimicrobial activity and have the advantage of being continuously active in a patient room when incorporated into medical devices or onto the surfaces of objects such as bedrails, doorknobs

and furniture. *In vitro*, hospital-based studies have consistently shown that copper alloy-surfaced materials reduce MB, which is maintained for hours following standard disinfection [7,9]. Schmidt and colleagues reported that copper-alloy surfaces placed into patient rooms reduced the average MB significantly by 83% during regular use and routine cleaning conditions [7]. Furthermore, a reduction of more than 50% in the composite outcome measure of HAI or methicillin-resistant *S. aureus*/VRE colonization in patients treated in hospital rooms with these copper alloy-surfaced objects was realized [8]. Antimicrobial polymers in solution or on surfaces, such as silicone polymers containing light-activated methylene blue with or without gold nanoparticles, have also shown promising results regarding MB reduction; however, their clinical utility in reducing HAI has yet to be demonstrated [20]. The advantages of antimicrobial surfaces include the fact that they do not require active participation or compliance from health-care workers (except that they should be kept in the room and need to be cleaned routinely) and they do not appear to be associated with serious long-term adverse effects on humans who come into contact with them. Like HPV and UV light, the use of these novel surfaces must be studied with respect to cost-effectiveness.

There is mounting evidence that MB in the hospital environment plays a central role in the development of HAI, and that controlling it may

significantly reduce these deadly consequences of healthcare. Therefore, let us learn from the work of the recent past to describe what future measures hospitals could employ for enhanced environmental control of MB. Certainly, a facility will employ recommended cleaning and disinfection measures and perhaps utilize newer technology, such as ATP bioluminescence, to guide the frequency by which this needs to occur. Furthermore, the use of enhanced cleaning measures, including novel no-touch HPV and UV light, would be employed for use in areas where patients with epidemiologically important organisms are receiving care and the use of antimicrobial surfaces, specifically copper-alloy surfaces, for those patient populations at highest risk (those in intensive care). Further research is needed to establish the optimal combination or bundling of these methods, feasibility of implementation and the cost-effectiveness required for large-scale usage.

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