FINDINGS

CONTACT TRANSMISSION


An Issue Brief on Infection Control

INSIDE YOU WILL LEARN ABOUT:

High-touch hard and soft surfaces and their effect on antimicrobial behavior.
Different cleaning mechanisms and their impact on surfaces.
An approach for structuring infection prevention teams during the design process.

This issue brief was created as a benefit for the Affiliate+ Program.
Contact Transmission, Part 2: Materials, Design, and Cleaning

March 2019

Executive Summary

As discussed in the accompanying issue brief, Contact Transmission, Part 1: The Role of Surfaces in Healthcare-Associated Infections (HAIs), there are many factors to consider when selecting and specifying materials for healthcare settings. This issue brief will take a closer look at the role of high-touch hard and soft surfaces in infection transmission, including the design features of surfaces that can facilitate or hinder cleanability as well as several emerging cleaning and disinfection technologies.
In 2015, Kaiser Permanente banned the use of 15 antimicrobial chemical treatments that may be toxic to humans or contribute to the development of drug-resistant bacteria.

Figure 1 illustrates some of the research findings on surface contamination. Infection transmission depends on both the frequency of contact and the level of contamination. The Centers for Disease Control and Prevention (CDC) classified surfaces into two categories: minimal hand contact (e.g., floors, ceilings) and high-touch surfaces (Sehulster et al., 2004). The prolonged survival of pathogens on any healthcare surface is undesirable due to the potential risk of cross-contamination. Retention and transmission depend on several variables, including surface and pathogen characteristics, environmental conditions, cleaning methodology, operational factors, and human interaction with the surface (Campoccia, Montanaro, & Arciola, 2013).

Hard surfaces have already been recognized as pathogen reservoirs and potential vehicles of transmission. However, high-touch soft surfaces tend to be overlooked due to a lack of intervention studies demonstrating direct links to infection. Since surface contamination can occur quickly after cleaning, the use of antimicrobial surfaces—those exhibiting prolonged biocidal activity—is seen as a supplemental strategy for controlling contamination through surface treatments, although evidence is still emergent. These include bioactive surfaces of heavy metals or their derivatives (e.g., copper, silver); electrostatic and inhibitory surfaces that repel microbial adhesion; ‘self-cleaning’ coatings that rely upon hydrophilic and hydrophobic properties; and novel coatings (e.g., nanoparticles, micro-patterned surfaces) (Dancer, 2016; Querido, Aguiar, Neves, Pereira, & Teixeira, 2019). Surfaces coated or impregnated with antimicrobial agents or metals can have a prolonged antiseptic effect (Weber & Rutala, 2013a), but there are increasing concerns about potential health risks and antimicrobial stewardship. For example, in 2015, Kaiser Permanente banned the use of 15 antimicrobial chemical treatments that may be toxic to humans or contribute to the development of drug-resistant bacteria (Kaiser Permanente, 2015).

In spite of increased awareness of the challenges associated with cleaning hard and soft surfaces, and the opportunities created by technological advancements to eliminate infectious agents, our understanding of assessing surface disinfection is limited due to lagging regulations that have made objective evaluations difficult (Sattar, 2010). When selecting materials, stakeholders...
should account for both the properties of each surface as well as the epidemiology of infections (as discussed in Part 1). The primary takeaway from the available research is that surface contamination can be reduced by minimizing the number of joints or seams (including counters, flooring, and related transitions between horizontal and vertical surfaces) and by selecting material finishes that are smooth, non-porous (or impervious), durable (that do not get damaged, scratched or pitted easily), stain- and water-resistant, and easy to clean (Malone & Dellinger, 2011).

Traditional cleaning (including terminal cleaning) of surfaces has been found to be episodic rather than continuous in reducing bioburden. As a result, the properties of the materials in question are being investigated as part of a broad approach to tackling HAIs (Esolen et al., 2018). The multifactorial nature of infection prevention demands a systems approach integrating the built environment, organizational values, and behavioral factors. Engaging a multidisciplinary team in the design process is a key strategy to reduce surface contamination and, in turn, HAIs.

Introduction

As summarized in the Perception of Cleanliness issue brief, surfaces in the healthcare setting can be classified as critical, semi-critical, or non-critical according to their potential for infection transmission. Based on these classifications and the level of care required, an individual surface may need to be sterilized, disinfected, or cleaned (Quinn & Henneberger, 2015). The Facility Guidelines Institute (FGI) Guidelines (2018) suggest that finishes should be evaluated for their suitability, life cycle, quality, and safety (for both patients and staff). To achieve this goal, a thorough understanding of both surface characteristics and cleaning methods is necessary.

High-Touch Surfaces as Fomites

Infection transmission depends on both the frequency of contact with the surface and the level of contamination. The CDC has classified surfaces into two categories: those involving minimal hand contact (e.g., floors, ceilings) and those involving frequent hand contact ("high-touch surfaces") (Sehulster et al., 2004). Only one study has quantitatively assessed the frequency of contact between
healthcare workers and surfaces; it defines high-touch surfaces as those sustaining more than three contacts per interaction (Huslage, Rutala, Sickbert-Bennett, & Weber, 2010).

The five high-touch surfaces identified in the immediate vicinity of the patient in the ICU and the medical-surgical floor from this study were bed rails, bed surfaces, supply carts, overbed tables, and intravenous pumps (Figure 2). Curtains, chair cushions, door knobs, public seating, window sills, soap dispensers, elevator buttons, tray tables, room sinks, and medical equipment all fell into the medium-touch category, but these surfaces have shown high levels of contamination in various studies (Pyrek, 2013; Solomon et al., 2018)

Material Selection and Surface Characteristics

Materials are most often selected for comfort and aesthetics. Although these features are important, there are other critical surface properties that should be evaluated before making decisions. Tables 1a and 1b identify some of the most frequently touched and contaminated surfaces in the healthcare setting, the most commonly used material finishes for these surfaces, and the pathogens that have been found to adhere to them.

Table 1a. Frequently touched and contaminated hard surfaces (in no particular order)

<table>
<thead>
<tr>
<th>Hard surfaces</th>
<th>Material finishes</th>
<th>Pathogens</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public seating, tables, information desk</td>
<td>Metal, molded plastic, stone, wood, glass, laminate</td>
<td>Vancomycin-resistant Enterococci (VRE), Methicillin-resistant Staphylococcus aureus (MRSA), Clostridium difficile (C. diff)</td>
</tr>
<tr>
<td>Elevator button</td>
<td>Metal</td>
<td>VRE, C. diff</td>
</tr>
<tr>
<td>Surfaces away from patient in patient room</td>
<td>Stone, wood, prefinished PVC sill</td>
<td></td>
</tr>
<tr>
<td>Sink counter top</td>
<td>Stone, stainless steel, vitreous china (porcelain), enameled cast iron</td>
<td></td>
</tr>
<tr>
<td>Toilet seat</td>
<td>High-impact plastic or plastic coating, vitreous china (porcelain)</td>
<td>VRE, C. diff</td>
</tr>
<tr>
<td>Door knobs</td>
<td>Metal (brass, copper, zinc)</td>
<td>VRE, MRSA, C. diff</td>
</tr>
<tr>
<td>Chair</td>
<td>Metal, molded plastic, stone, wood covered in fabric, leather</td>
<td>VRE, MRSA, C. diff</td>
</tr>
<tr>
<td>Bathroom light switch</td>
<td>Plastic (e.g., Bakelite), antimicrobials (e.g., copper)</td>
<td></td>
</tr>
<tr>
<td>Surfaces near patient in patient room</td>
<td>Polypropene, stainless steel, polyester-coated steel</td>
<td>VRE, MRSA, C. diff</td>
</tr>
<tr>
<td>Bed rail</td>
<td>Polypropene, stainless steel, polyester-coated steel</td>
<td>VRE, MRSA, C. diff</td>
</tr>
<tr>
<td>Bedside table</td>
<td>Metal, molded plastic, stone, wood, glass, laminate</td>
<td>VRE, MRSA</td>
</tr>
<tr>
<td>Tray table and supply cart</td>
<td>Polypropene, stainless steel, polyester-coated steel, molded plastic</td>
<td>VRE, MRSA</td>
</tr>
</tbody>
</table>
### Table 1b. Frequently touched and contaminated soft surfaces (in no particular order)

<table>
<thead>
<tr>
<th>Soft surfaces (e.g., scrubs, drapes, towels, pressure garments, keyboard cover)</th>
<th>Material finishes (e.g., 100% cotton, cotton/polyester blend, olefin, nylon/blend)</th>
<th>Pathogens (e.g., C. diff, MRSA, VRE, Acinetobacter baumannii)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Privacy curtains</td>
<td>100% cotton, cotton/polyester blend, polyethylene plastic, polyurethane, nylon/spandex blend</td>
<td>C. diff, MRSA, VRE, Acinetobacter baumannii</td>
</tr>
<tr>
<td>Furniture upholstery</td>
<td>100% cotton, 100% polyester, cotton/polyester blend</td>
<td>VRE</td>
</tr>
<tr>
<td>Carpets</td>
<td>100% cotton, 100% polyester, cotton/polyester blend, olefin, nylon, olefin/nylon blend</td>
<td>C. diff, MRSA, VRE, Acinetobacter baumannii</td>
</tr>
<tr>
<td>Other textiles (e.g., scrub, drapes, towels, pressure garments, keyboard cover)</td>
<td>100% cotton, cotton/polyester blend, nylon/spandex blend, polyurethane, polyvinyl</td>
<td>MRSA, VRE</td>
</tr>
</tbody>
</table>

### Hard Surfaces

Specifically patterned hard surfaces (or sometimes ad hoc-designed nano-surfaces) can direct the alignment of pathogen cells and reduce the area of contact. This affects the surface properties and should be considered during the design process (Campoccia et al., 2013). As shown in Figure 3, surface features whose dimensions greatly exceed those of the microorganisms will reduce retention because the cells can be washed out fairly easily. Within larger features, however, there could be micro-topographies and nano-topographies that provide attachment points for the microbial cells (Edwards & Rutenberg, 2001; Verran, Packer, Kelly, & Whitehead, 2009). Non-porous surfaces like acrylic, glass, laminates, metals, and plastics may have cracks or crevices making them porous. These increases in porosity can make surfaces rougher, promoting entrapment and immobilization of microorganisms (Ali, Moore, & Wilson, 2012). If they are not adequately cleaned following spills of blood or bodily fluids, porous areas retain moisture and allow pathogens to proliferate (Sehulster et al., 2004). Pitting and degradation of glazed ceramics may also result in porosity, leading to micro-holes that can be difficult to clean (Kronberg et al., 2007).

Some physicochemical properties such as adhesion (i.e., the angle and area of contact between surfaces and soil) and hydrophobicity/hydrophilicity (i.e., the ability to attract or repel water) can also impact the cleanability of a given surface and should be taken into consideration (Decuzzi & Ferrari, 2010; Detry, Sindic, & Deroanne, 2010; Verran et al., 2009).

--- indicates lack or absence of research specific to surface and pathogens.
Soft Surfaces

The survival and transmission of microbes on soft surfaces has proven more complex than their behavior on hard surfaces due to the porous and three-dimensional nature of soft surfaces (Rogina-Car, Budimir, & Katovic, 2017; Yeargin, Buckley, Fraser, & Jiang, 2016). Some soft surfaces are easy to remove and launder (e.g., pillows, bedding, towels, patient gowns, surgical gowns, scrub suits, lab coats, splash aprons, privacy drapes/curtains), while others are less so (e.g., carpet, upholstery, window drapes) (McQueen & Ehnes, 2018; Yeargin et al., 2016). Some hospitals use disposable materials for high-touch soft surfaces like privacy curtains and drapes. Others prefer to wash and reuse materials due to ecological and financial constraints.

In one study, Noskin et al. (2000) found that VRE was recovered from 30% of the seat cushions sampled, and disinfection with quaternary ammonium solution failed to remove VRE from 100% of the fabric chairs. Alternative solutions, such as folding absorbent, non-porous protector sheets in multiple layers over the fabric, were found to prevent contamination of the chairs. The results of this study indicate that evaluating pore size, fabric permeability, and fabric seam type is essential to the reduction of soft surface contamination. Conventional sewing techniques (interlacing or interloping threads) can leave holes in the fabric, making them ineffective microbial barriers (Rogina-Car et al., 2017).

Another factor to consider when selecting fabrics or finishes is location. Carpeting, for example, should be avoided in high-risk and/or high-traffic areas like ICUs, ORs, and burn units, as well as any areas where blood or other bodily fluids may be spilled (e.g., patient unit hallways). Vacuuming or dry cleaning can help temporarily reduce pathogens, but carpeting that remains damp is a perfect setting for microbes to thrive (Sehulster et al., 2014).

Cleaning and Disinfecting Surfaces

Cleaning surfaces is a critical part of infection control. However, the quality and standard of cleaning in a given environment may be compromised due to factors such as the choice of products, manufacturer specifications, inaccessibility, inadequate monitoring because of time crunch or high patient volumes, and staff shortage/turnover in the Environmental Services (EVS) department. Hard
surfaces encountering minimal hand contact may not require as much cleaning as high-touch surfaces (Sehulster et al., 2004; Solomon et al., 2018), but routine cleaning and disinfection (including terminal cleaning) are still recommended.

**Cleaning Challenges**

Unfortunately, less than 50% of surfaces are cleaned during terminal cleaning (Carling et al., 2008). Some launderable surfaces, like privacy curtains, are only cleaned if found visibly soiled and can remain contaminated for long periods (Kukla, 2013; McQueen & Ehnes, 2018).

Surfaces like textured acrylic walls, brushed stainless steel, and fabrics of varying weaves can be challenging to clean. Most hospital furniture is made up of a combination of materials and textiles with various seams, joints, and batten strips, making it difficult (or impossible) to clean between surface materials (Malone & Dellinger, 2011). In some cases, each material requires a different disinfectant and cleaning method, adding to the existing burden of the staff (Lankford et al., 2007) or resulting in damage to the furniture.

When selecting materials, stakeholders should keep the topographical and morphological properties of each surface material in mind, along with the epidemiology of infections (see Part 1 for more information). It is possible to reduce surface contamination by using flush surfaces (or minimizing the number of joints and seams) and by selecting finishes that are smooth, non-porous (or impervious), durable (not easily damaged, scratched, or pitted), stain- and water-resistant, and easy to clean or wipe down (Malone & Dellinger, 2011).

Seepage under assemblies where water is continually present has been shown to encourage layer delamination and invite mold, mildew, and bacteria. Per the 2018 FGI Guidelines, water-resistant materials, sealed-seam construction methods, and moisture-impervious surfaces should be selected for work or sink areas. The location of the surface, frequency of touch, and associated user behavior should be evaluated when determining both surface design and cleaning protocols.

**Cleaning Approaches**

Three approaches to cleaning are described below, including design, selection, and specification considerations. (For more information, see Part 1.)
Manual Cleaning

Some of the most commonly used disinfectants for manual cleaning in healthcare are chlorine-releasing compounds (hypochlorites), hydrogen peroxide liquid disinfectant (accelerated/improved), and quaternary ammonium compounds (Villapún, Dover, Cross, & González, 2016). Only products formulated according to Environmental Protection Agency (EPA) and Food and Drug Administration (FDA) guidance have been cleared for use (Rutala, 2008). Furniture and medical equipment come with cleaning recommendations from the manufacturer. However, the cleaning process is often complicated by unique specifications for various materials and surfaces and the time required for EVS staff to understand them, which can influence turnover and, in turn, cost. The surface material, application method, and choice of applicator (e.g., microfiber/cotton mops or wipes vs. pre-moistened wipes) can also impact the efficiency of manual cleaning efforts. Table 2 summarizes the mixed findings of multiple studies on the use of various disinfectants on healthcare surfaces.

Table 2. Impact of disinfectants on surfaces

<table>
<thead>
<tr>
<th>Chemical disinfectants</th>
<th>Impact on surfaces</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorine (hypochlorites)</td>
<td>While hypochlorites (the most commonly used chlorine-based disinfectants) are bactericidal, fungicidal, virucidal, mycobactericidal, and sporicidal, they are corrosive to metals, can discolor fabrics, may irritate skin and eyes, and are harmful to the environment by developing biocide and antibiotic resistance (Dettenkofer &amp; Block, 2005; Leas et al., 2015).\n Wiping surfaces sprayed with these disinfectants can transfer spores to clean surfaces (Cadnum, Hurless, Kundrapu, &amp; Donskey, 2013).\n Hypochlorous acid (electrolyzed water) is a promising strategy shown to be more effective than quaternary ammonium solutions (Meakin, Bowman, Lewis, &amp; Dancer, 2012). It can be left to dry on surfaces without leaving any toxic residue (Boyce, 2016).\n Chlorine bleach is an economical, broad-spectrum chemical germicide that enhances the effectiveness of the laundering process. Chlorine bleach is not, however, an appropriate laundry additive for all fabrics (Sehulster et al., 2004).</td>
</tr>
<tr>
<td>Accelerated/improved hydrogen peroxide liquid disinfectants</td>
<td>Improved hydrogen peroxide (IHP) disinfectants are EPA-registered and have been shown to reduce bacterial levels on hard surfaces (Rutala, Gergen, &amp; Weber, 2012).\n IHP has also proven effective against multidrug-resistant pathogens on soft surfaces like privacy curtains. It is non-corrosive, unaffected by organic matter, and safe for EVS staff, though discoloration has been observed on upholstery disinfected with IHP (Leas et al., 2015).\n Some limitations of IHP include higher costs (compared with other disinfectants) and a lack of activity against C. diff spores (Cadnum et al., 2015).</td>
</tr>
<tr>
<td>Quaternary ammonium compounds (QACs)</td>
<td>QACs (or quats) are widely used, EPA-registered healthcare disinfectants that are generally regarded as effective when left undisturbed on non-critical surfaces. However, they are not sporicidal.\n Using QACs with materials like cotton has shown diminished microbial activity (Sattar &amp; Maillard, 2013).</td>
</tr>
</tbody>
</table>
**Laundry**

Routine laundering, water cleaning, and vacuuming are assumed to be adequate cleaning procedures for removable upholstery (Malik, Allwood, Hedberg, & Goyal, 2006). Successful laundering depends on factors including the type of linen and microorganism in question; the duration, mechanical action, dosage, filling ratio, and temperature of the cycle; the detergent or disinfectant used; and the conditions surrounding the laundering process, such as drying (Bockmühl, 2017; Fijan & Turk, 2012). If one variable is changed, the others must be adjusted to maintain an optimized effect. Other considerations with design implications are the post-laundering process, including sorting, folding, packing, and delivery (Mitchell, Spencer, & Edmiston, 2015), as well as access to laundry facilities on or off site. The CDC, EPA, and other government agencies have issued guidance on laundering contaminated textiles with registered antimicrobial agents in order to standardize this process. Design decisions must take into account any potential effects on facility operations.

**No-Touch Automated Disinfection Technologies**

Modern no-touch disinfection (NTD) technologies continue to reduce the multitude of challenges that accompany manual cleaning and disinfection. NTD technologies cannot, however, replace routine cleaning procedures; instead, they are best used in terminal or discharge cleaning to reduce staff workload and limit their contact with reservoirs of infection (Otter, Yezli, & French, 2014). Every NTD system differs in its mechanics, efficiency, effectiveness, and usability. Some are designed to target only easily visible surfaces in a single operation and may need to be run more than once. This can affect turnover time, which has cost implications for the system. As such, cleaning tools and strategies should be based on a mindful consideration of the available evidence, proposed applications, cost implications, staff training requirements, and equipment logistics. Table 3 summarizes some increasingly used cleaning technologies and their impact on healthcare surfaces.

<table>
<thead>
<tr>
<th>NTD technologies</th>
<th>Impact on surfaces</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam vapor</td>
<td>Minimal research exists on the effects of steam vapor, but it has been used in routine and outbreak situations.</td>
</tr>
</tbody>
</table>
| Oxidizing agents (e.g., ozone) | Dancer (2014) has summarized the findings of studies in which ozone was successfully incorporated into laundry decontamination, reducing the *E. coli* count.  
  There is not yet any evidence on ozone’s impact on surfaces carrying bacterial and fungal spores. |
Another mechanism used to reduce contamination is introducing antimicrobial agents (heavy metals or germicides) to render a surface “self-disinfecting” or “self-sanitizing.” In theory, treated surfaces have the potential to reduce HAIs (Butler, 2018; McQueen & Ehnes, 2018), but several variables—including coating or impregnation fabrication techniques, surface characteristics, pathogen characteristics, and environmental conditions—can affect the results.

**Surfaces coated or impregnated with heavy metals**

What with the ongoing prevalence of HAIs and a growing movement for antimicrobial stewardship to minimize the development of antimicrobial resistance (Doron & Davidson, 2011; Turner, 2017), there has been an increasing interest in surfaces or textiles impregnated or coated with heavy metals like silver, silver ions, copper, etc. Copper alloys and surfaces containing copper oxide are growing in popularity due to their potential to reduce microorganisms in the environment (Barnes, 2017; Casey et al., 2010; Michels & Michels, 2017; Salgado et al., 2013). Though antimicrobial copper and silver are both EPA-registered, and research on surface treatments with these two metals continues to gain ground (Weber & Rutala, 2013b), other metals like titanium are currently under examination (Villapún et al., 2016; Wojcieszak et al., 2016).

Table 4 summarizes the current evidence from multiple studies on the impact of these strategies on different surfaces.
Table 4. Impact of self-disinfecting surfaces and other advanced technologies on surface contamination

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Commonly includes</th>
<th>Impact on surfaces</th>
</tr>
</thead>
</table>
| Self-disinfecting surfaces| Surfaces coated or impregnated with heavy metal        | Silver • Silver has demonstrated a broad spectrum of antimicrobial activity against bacteria, fungi, and viruses. There have been positive results from the use of silver on medical devices and textile fibers (e.g., uniforms and privacy curtains) (Hicks et al., 2016; Monteiro et al., 2009; Ortí-Lucas & Muñoiz-Miguel, 2017). • It has been suggested that the impregnation of silver into a coating can be more effective than direct surface coating alone.  
Copper • Door knobs impregnated with copper have shown high corrosion resistance. However, actual hand contact has shown high corrosion rates and discoloration (Fredj, Kolar, Prichard, & Burleigh, 2013). • Antimicrobial copper objects were found to reduce microbial burden in a PICU study by Schmidt et al. (2016), but McQueen & Ehnes (2018) expressed concerns about the effects of introducing NTDs in settings with antimicrobial metal surfaces. • Bacterial contamination on standard curtains and complex element compound curtains (i.e., curtains treated with antimicrobial agents like silver) did not differ after 10 days following installation. Research suggests that cleaning and abrasion may render the metal less effective over time, requiring regular replacement (Schweizer et al., 2012). • Copper-oxide-impregnated non-biocidal linens and pillow covers reduced the number of HAI s in a long-term care brain injury ward (Lazary et al., 2014). • 8 types of high-touch items made of copper alloys (e.g., door handles, toilet seats, grab rails, light switches, overbed tables, commodes) had significantly lower microbial counts compared with those made of standard materials (Karpanen et al., 2012). |
| Surfaces coated or impregnated with germicide | • Triclosan, while demonstrating antibacterial efficacy in synthetic polymers (Greenhalgh & Walker, 2017), has recently come under scrutiny as a possible environmental and human health hazard (Dancer, 2014). • Paints with quaternary ammonium compounds have been used to coat textiles, but seem to wear off with continued washing and show no activity against certain pathogens (Schettler, 2016). Quaternary ammonium molecules, combined with organosilanes (silicon chemicals), show conflicting results when applied to textiles or hard surfaces (Boyce, 2016). • High-touch surfaces in patient rooms showed no significant antimicrobial activity after applying two organosilane products (Boyce, Havill, Guercia, Schweon, & Moore, 2014). • A reduction in bacteria and antibiotic-resistant pathogens was found on ICU surfaces coated with similar antimicrobial agents (Tamin, Carlino, & Gerba, 2014). • N-Halamine is another promising broad-spectrum biocide currently being incorporated into textiles and hard surfaces. To date, most testing has been done in laboratories rather than healthcare settings (2017). However, the treated textiles have been found to leave chlorine residue on the surface, resulting in stains and odors (McQueen & Ehnes, 2018; Schettler, 2016). |
| Advanced technologies     | Light-activated microbial surfaces                      | There have been no conclusive findings about the efficacy of this technique on surface finishes (Wang et al., 2017).  
Altered topography         | It is assumed that this technology can be retrofitted to practically any surface in the environment; however, data from real-world applications is not currently available. |

Surfaces coated or impregnated with germicides

It is a common practice to coat or impregnate surfaces with germicides like quaternary ammonium compounds, triclosan, or N-Halamines. One relevant concern, however, is that pathogens might develop resistance to these
treatments. Triclosan has also come under scrutiny as a potential environmental and human health hazard (Dancer, 2014). It is one of the 15 chemical treatments banned by Kaiser Permanente (2015), a list that includes a range of applications such as adhesives; ceilings; wood and wood composites; engineered wood and resilient flooring; floor sealants, coatings, and finishes; high-performance coatings; natural oil wood finishes; toilet seats; carpet and carpet backing; acoustical ceiling components; paint; and high-performance coatings:

- Benzisothiazolin-3-one (BIT)
- 4,4-dimethyloxadizidine
- Diiodomethyl p-tolyl sulfone
- Kathon 886 (CIT/MIT mixture)
- Methylchloroisothiazolinone (CIT, CMIT)
- Methylisothiazolinone (MIT)
- N-octadecyldimethyl [3-(trimethoxysilyl) propyl]
- Quaternary ammonium compounds, benzyl-C8-16-alkylidimethyl, chlorides
- Silver sodium hydrogen zirconium phosphate
- Zinc pyrithione
- Silver (nano)
- Silver zinc zeolites
- Hexamethylenetetramines.

Advanced technologies to create self-disinfecting surfaces

Research into self-disinfecting surfaces has included investigation of reactive radicals: light-activated antimicrobial agents such as surface coatings with titanium-dioxide-based catalyst or an embedded photosensitizer (Dancer, 2014). This approach aims at multiple targets within the microbe instead of just one, reducing the chance that antimicrobial resistance will develop (Wilson, 2003). According to Wilson, these applications are best suited for spaces with higher illumination levels (e.g., treatment areas with exam lights, operating rooms).

Another novel approach to prevent and reduce biofilm formation is engineered altered topography (Leas et al., 2015; Weber, Anderson, & Rutala, 2013). This
approach incorporates a surface that is harder for microbes to attach to, a bio-inspired concept born from the ability of plants and animals to prevent pathogen colonization on their own surfaces (Glinel, Thebault, Humblot, Pradier, & Jouenne, 2012). A similar technique known as "antifouling" has been used in the marine industry to prevent the settlement of microorganisms on ship hulls. One related product currently being promoted in the healthcare industry is an engineered micro-pattern imparted onto the microstructure of the surface to mimic the properties of shark skin (Leas et al., 2015; Platt & Greene, 2017; Weber et al., 2013). More research is necessary to weigh the pros and cons of each of these strategies.

A search of healthcare research in 2017 revealed that copper, silver, and organosilanes were the most commonly studied metal-based antimicrobial surfaces (Ahonen et al., 2017). However, a lack of conclusive evidence suggests that more research on antimicrobial treatment of fabrics and surfaces is required once related cleaning methodologies can be simplified and standardized (Greenhalgh & Walker, 2017; Malone & Dellinger, 2011).

It is important to note that one surface selection or treatment does not eliminate the need for other infection prevention practices. For example, the EPA has established the following standards for labeling bactericidal copper: "Antimicrobial copper containing surface products must be cleaned and disinfected according to standard practice. Health care facilities must maintain the product in accordance with infection control guidelines; users must continue to follow all current infection control practices, including those practices related to disinfection of environmental surfaces. This copper surface material has been shown to reduce microbial contamination, but does not necessarily prevent cross contamination. This product must not be waxed, painted, lacquered, varnished, or otherwise coated by any material" (EPA, 2016).

Engaging a Multidisciplinary Infection Prevention Team

There are many factors to consider in tackling HAI s via contact transmission: surface materials and fabrics, cleaning and disinfection solutions, environmental design, affordable and applicable technologies, staff operations and workflow, and the available research. This means an interdisciplinary approach is the best
way forward. The design team should include experts in infection prevention from diverse backgrounds such as medicine, microbiology, interior design, engineering, and facility management, so that each member can contribute their specialized knowledge to the design process (see the Tool for Engaging Interdisciplinary Teams for more information). The broad range of insights a multidisciplinary team can offer will be crucial in developing a systems approach that examines infection control at the intersection of organizational/operational factors, people and behaviors, and the physical environment (Figure 4).

![Diagram of the interdisciplinary design team](image-url)

**Figure 4. The interdisciplinary design team**
Conclusion

The conditions leading to HAIs can develop when particular pathogens interact in particular ways with particular surfaces. The FGI Guidelines require that an infection control risk assessment (ICRA) is conducted throughout the design process, including an examination of all surfaces in patient care areas that facilitate cleaning and disinfection (Facility Guidelines Institute, 2018). A wide range of products related to surface materials and fabrics, cleaning strategies, and disinfection technologies is available in the marketplace. The Guidelines also provide fundamental requirements for the selection of surfaces (e.g., monolithic flooring) for specific areas of the healthcare setting (e.g., surgery) depending on their individual needs (e.g., the ability to withstand chemical cleaning or scrubbing).

Moreover, there is a need to bridge the gap between existing regulations, expectations, and practices, and our ever-evolving understanding of the epidemiology of infections. It is only by overcoming these obstacles—a limited empirical knowledge of the available products and cleaning methods, the challenges faced by EVS personnel, and shortfalls in organizational infection control policies—that we can work toward better outcomes, from patient and staff safety to overall quality of care (Storr, Wigglesworth, & Kilpatrick, 2013).

For more information on the pros and cons of existing cleaning strategies, refer to the Tool for Selection of Cleaning Methods. The Top Design Strategies can help start the discussion and provide guidance throughout the decision-making process.

For more information on HAIs, refer to Contact Transmission, Part 1: The Role of Surfaces in HAIs.
References


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