

Antimicrobial Copper Surfaces for the Reduction of Health Care–Associated Infections in Intensive Care Settings

Summary

- ✓ **Antimicrobial copper surfaces are an emerging new approach to supplement standard infection control practices for the prevention of health care–associated infections (HAIs).**
- ✓ **Antimicrobial copper surfaces have been shown to have intrinsic and continuous broad-spectrum antimicrobial activity that is expected to remain in effect for the product’s lifetime.**
- ✓ **A literature search identified a multi-centre, single-blinded, randomized controlled trial (RCT) that showed that replacing standard surfaces with antimicrobial copper surfaces on six commonly touched objects in intensive care unit (ICU) rooms over one year reduced the risk of HAIs by 58% and microbial burden by 83%. Results suggested an association between the level of bacterial contamination and HAI risk. No negative health effects associated with patient exposure to antimicrobial copper surfaces were observed.**
- ✓ **A single-centre, double-blinded RCT is currently being conducted to determine whether reducing surface bacteria through the use of antimicrobial copper surfaces over four years decreases HAI rates, improves treatment outcomes, and reduces costs when compared with plastic and sham stainless-steel surfaces. Study completion is expected in April 2017.**
- ✓ **Health Canada granted full registration for the sale and use of six different groups of antimicrobial copper alloys in July 2014 but, to date, no Canadian health care facilities have installed antimicrobial copper surfaces.**
- ✓ **Confirmation of a sustained reduction in HAI rates over time with antimicrobial copper surfaces and the cost-effectiveness of replacing existing surfaces with antimicrobial copper surfaces in Canadian health care facilities will need to be determined before its widespread adoption as an infection control practice in intensive care settings.**

Background

Health care–associated infections (HAIs) are infections that are caused by a wide variety of bacteria, fungi, and viruses during the course of receiving medical treatment or surgical procedures in a health care facility.¹ Bacterial contamination on various surfaces in the patient’s environment, such as door handles, tables, intravenous (IV) poles, bed rails, or sinks, can be a source of transmission.² Pathogens that cause HAIs — including methicillin-resistant *Staphylococcus aureus* (MRSA), *Acinetobacter* spp., vancomycin-resistant *Enterococcus* spp. (VRE), and norovirus — can survive on environmental surfaces for days to weeks.³ *Clostridium difficile* (CDI) spores may survive on surfaces for months.³ Treating HAIs has become more difficult as antimicrobial resistance has increased and the number of effective antibiotics has declined.^{4,5} More than 50% of HAIs are caused by bacteria that are resistant to at least one type of antibiotic.⁶ However, fewer pharmaceutical companies are developing new antibiotics. The US FDA has approved only two new antibiotics in the past five years — an 88% decrease from the mid-1980s.⁷

Regular surfaces made of plastic, stainless steel, coated metal, and wood are quickly re-contaminated after cleaning.⁸ Studies have shown that fewer than 50% of hospital room surfaces are adequately cleaned when



Image courtesy of Copper Development Association, Publication 196 (2014) Reducing the Risk of Healthcare Associated Infections – The Role of Antimicrobial Copper Touch Surfaces

standard chemical disinfectants are used.^{9,10} Similarly, inadequate cleaning of portable medical equipment has also been demonstrated.¹¹ There is evidence that the risk of hand or glove contamination with antibiotic-resistant organisms is high after contact with the surfaces in a patient's environment.¹² Furthermore, a lower compliance with hand hygiene has been observed when health care professionals have contact with the patient's environment but not with the patient.¹³ Hence, despite efforts to promote infection control practices, HAIs are a common complication of hospital care, resulting in prolonged hospitalization, higher readmission rates, and increased mortality.¹⁴ An estimated 10% of adults in Canadian hospitals have an HAI at any given time.¹⁵ One in every 12 patients in Canadian hospitals are colonized or infected by CDI, MRSA, or VRE — the antibiotic-resistant organisms that currently pose the biggest challenge to Canadian health institutions.¹⁶ In Alberta, the Department of Health estimates that the cost of caring for a patient with an HAI ranges from \$2,000 to \$20,000.¹⁷

Intensive care unit (ICU) patients are at higher risk for HAIs due to the severity of their illness, compromised immune systems, higher frequency of invasive procedures, increased requirement for portable medical equipment, and their frequent interaction with health care workers.¹⁸ Implementing additional strategies to reduce bacterial contamination, in addition to standard infection control practices, could reduce patient exposure to pathogens, improve patient outcomes, and decrease health care costs associated with HAIs. Such strategies may be particularly beneficial to patients acutely vulnerable to infection, such as those in the ICU.

The Technology

Surfaces made of copper and copper alloys offer a new approach for reducing bacterial contamination, transmission, and rates of HAIs.¹⁹ Metallic copper has been shown to have intrinsic and continuous broad-spectrum antimicrobial activity.²⁰ While using pure copper results in the fastest killing of pathogens, many of its alloys consisting of at least 60% copper (including brasses and bronzes) are also effective and offer a range of enhanced properties, such as strength, durability, several colours, and tarnish resistance.¹⁹ Collectively termed “antimicrobial copper,” surfaces manufactured from copper and its alloys are intended to provide supplemental antimicrobial action between periods of routine cleaning of environmental or touch surfaces. Most standard hospital detergents and disinfectants will not affect the efficacy of antimicrobial copper, with the

exception of products containing metal ion chelators, such as ethylenediaminetetraacetic acid (EDTA).¹⁹

Laboratory tests show that antimicrobial copper surfaces kill 99.9% of specific infectious bacteria (including *S. aureus*, *Enterobacter aerogenes*, *Escherichia coli* O157:H7, *Pseudomonas aeruginosa*, MRSA, and VRE) within two hours or less and continuously kill more than 99% of bacteria even after repeated contamination.²⁰ Additional data suggest copper might also be effective against other bacteria, viruses, and fungal pathogens.^{19,21} Although the mechanism of action has not been confirmed, it is postulated that the toxicity of copper involves the rupture of the cell membrane, the generation of reactive oxygen species, and the breakdown of bacterial DNA, resulting in cell death.^{19,22,23} Due to this multi-targeted mode of action and the rapid degradation of bacterial DNA, the development of copper resistance and the spread of antibiotic-resistant organisms is considered unlikely.²⁴ Copper's antimicrobial properties are expected to remain in effect for the product's lifetime, as they do not rely on coatings or impregnated surfaces that can wear off or wash away.¹⁹ Some natural tarnishing may take place, depending on the alloy, but this does not appear to affect efficacy.¹⁹

Antimicrobial copper can be incorporated into a wide variety of components, including bed rails, overbed tables, door handles, IV poles, lavatory components, and work surfaces.¹⁹ Antimicrobial copper products are available from both primary manufacturers and stockists.²⁵ Globally, there are thousands of suppliers of both raw materials and semi-finished products. CuVerro Bactericidal Copper Surfaces (Olin Brass, GBC Metals, LLC, Louisville, Kentucky) is a leading manufacturer and distributor of antimicrobial copper alloys in North America and one of the largest in the world.²⁶ Products made with CuVerro Antimicrobial Copper, such as IV poles, tables, and stretcher rails, are available across the US through various manufacturers, including Midbrook Medical (Jackson, Michigan) and Pedigo Products, Inc. (Vancouver, Washington).²⁵

Regulatory Status

Health Canada's Pest Management Regulatory Agency (PMRA), which regulates public health claims for antimicrobial products, granted full registration for the sale and use of six different groups of antimicrobial copper alloys in July 2014.²⁷ In February 2008, the US Environmental Protection Agency (EPA) approved five different groups of copper alloys to be marketed as antimicrobial materials to supplement standard infection

control practices.²⁰ There are now 479 EPA-registered alloys available in the US.²⁸ Copper alloys are the first class of solid surface materials to be approved for public health use in the US.¹⁹ Before these registrations were granted, only antimicrobial gases, liquids, sprays, and concentrated powders, including sterilizers, disinfectants, and antiseptics, were registered for antimicrobial public health use.¹⁹

Patient Group

It is estimated that 220,000 Canadians acquire an HAI each year and between 8,000 and 12,000 of them die as a result.²⁹ The 30-day mortality rate attributable to CDI more than quadrupled from 1.5% in 1997 to 6.4% in 2011.³⁰⁻³² Since then, there has been a decreasing trend in 30-day mortality attributable to CDI, with a rate of 3.1% recorded in 2013.³² The incidence of MRSA infections in Canada remained fairly stable between 2009 and 2013 (1.96 versus 1.44 cases per 1,000 patient admissions, respectively), and mortality rates have also remained similar (24.4 versus 25.0 all-cause mortality per 100 MRSA bacteremia cases).³² However, the rate of VRE infections almost doubled between 2009 and 2013 (0.24 versus 0.44 cases per 1,000 patient admissions).³²

Current Practice

Infection Prevention and Control Canada has provided access to a number of evidence-based guidelines for the prevention of HAIs.³³ Preventing HAIs involves the implementation of infection control practices that include maintaining proper hand hygiene, cleaning patient environments and equipment, sterilizing instruments, implementing additional contact precautions (gloves and gowns) when caring for a patient infected or colonized with an HAI, placing colonized or infected patients in isolation areas, screening new patients and identifying outbreaks of infection with continuous surveillance, and regularly reporting infection rates to frontline and hospital leaders. There is currently no transparent or standardized system in place for reporting HAI outbreaks in Canada.³⁴ The Canadian Nosocomial Infection Surveillance Program (CNISP) uses a network of 54 health care facilities in 10 provinces to monitor rates and trends of HAI infections in Canada.³⁵ HAIs currently monitored by CNISP include infections caused by CDI, MRSA, VRE, carbapenem-resistant gram-negative bacilli, and central venous catheter-associated bloodstream infections.

Methods

A peer-reviewed literature search was conducted using the following bibliographic databases: MEDLINE, PubMed, Embase, and the Cochrane Library (2014, Issue 12). Grey literature was identified by searching relevant sections of the Grey Matters checklist (<http://www.cadth.ca/resources/grey-matters>). No methodological filters were applied. The search was limited to English language documents published between January 1, 2004, and December 10, 2014. Regular alerts were established to update the search until March 1, 2014. Conference abstracts were excluded from the search results. Peer-reviewed published studies evaluating the clinical efficacy and safety of antimicrobial copper surfaces for the reduction of HAIs in intensive care settings were considered for inclusion in the evidence section of this bulletin. Unpublished data, case reports, editorials, letters, and literature reviews were excluded.

The Evidence

Clinical data to support the use of antimicrobial copper surfaces for the reduction of HAIs in the ICU have been reported in one trial.¹⁸ The US Department of Defense funded a multi-centre, single-blinded, randomized controlled trial (RCT) to determine whether placement of six copper alloy-surfaced objects in the ICU reduced the risk of HAIs.¹⁸ The institutions replaced stainless-steel, aluminum, and plastic surfaces with antimicrobial copper within selected rooms in each of the ICUs. The following four items were replaced with antimicrobial copper components at all hospitals: bed rails, overbed tables, IV poles, and arms of the visitor's chair. The other two items that were replaced varied slightly between centres: nurses' call button, computer mouse, monitor bezel, or laptop keyboard. No changes were made to clinical practices or cleaning protocols in the study rooms. During the trial period, the level of bacterial contamination (microbial burden) on matched copper and non-copper surfaces was determined weekly. The primary outcome was incident rate of HAI and/or MRSA or VRE colonization. HAI or colonization was attributed to the ICU if it occurred more than 48 hours after ICU admission or within 48 hours after ICU discharge.

The trial was executed in three stages. The first stage of the trial established the baseline microbial burden on the frequently touched objects in the ICU rooms before installation of the antimicrobial copper products.³⁶ The second stage of the trial was the replacement of the most

contaminated touch surfaces with antimicrobial copper. The average microbial burden observed on antimicrobial copper surfaces was 83% less than on the non-copper surfaces (465 colony-forming units (CFU)/100 cm² versus 2,674 CFU/100 cm²; $P < 0.0001$). Standard bed rails became re-contaminated more rapidly than antimicrobial copper bed rails after disinfection (at 6.5 hours, 424 CFU/100 cm² versus 5,198 CFU/100 cm²; $P = 0.002$).³⁷ The third stage of the trial evaluated the incidence of HAIs in ICU rooms with and without antimicrobial copper components. A total of 650 patients admitted to the ICU between July 12, 2010, and June 14, 2011 were randomly assigned to eight rooms with antimicrobial copper surfaces or eight standard rooms, and monitored until hospital discharge. To control for bias toward objects being cleaned differently in copper versus standard rooms, the burden from a standard-surfaced object (bed footboard) was sampled in each room, unbeknownst to study clinicians, environmental services, or health care teams.

Results were available for 614 of the 650 patients admitted to the ICU (12 were excluded due to missing primary outcome, three due to missing study room information, and 21 due to missing both primary outcome and study room information). Demographic and clinical characteristics between groups were comparable. The rate of HAI and/or MRSA or VRE colonization in ICU rooms with antimicrobial copper surfaces was statistically significantly lower than that in standard ICU rooms (21/294 [7.14%] versus 41/320 [12.81%]; $P = 0.020$). Results showed a 58% reduction in HAIs in patients cared for in antimicrobial copper rooms versus in standard rooms (10/294 [3.40%] versus 26/320 [8.12%]; $P = 0.013$). Forty-two different micro-organisms were identified among the 36 patients who developed an HAI. There were no important differences between the distribution of types of HAIs or associated microbiology between patients treated in antimicrobial copper and non-copper rooms. Regardless of the presence or absence of antimicrobial copper, there was a statistically significant association between the level of contamination and HAI risk based on microbial burden ($P = 0.038$), with 89% of HAIs occurring among patients cared for in a room with a microbial burden greater than 500 CFU/100 cm².

Colonization with MRSA or VRE was lower among patients admitted to antimicrobial copper rooms, but the difference was not statistically significant (4/294 [1.36%] versus 12/320 [3.75%]; $P = 0.063$). The burden from the bed footboard did not differ between

the antimicrobial copper and standard rooms (2,786 CFU/100 cm² versus 2,388 CFU/100 cm²), making it less likely that the effect of antimicrobial copper on microbial burden and HAI rates was due to differences in health care worker cleaning behaviours. ICU length of stay was comparable between groups (median of four days for both; $P = 0.74$). Mortality did not differ between groups (42/294 [14.29%] in antimicrobial copper rooms versus 50/320 [15.63%] in standard rooms; $P = 0.64$).

Due to the need to move furniture for patient care, 53.4% of patients assigned to antimicrobial copper rooms had at least one copper item removed from the room during their ICU stay. In contrast, 13.4% of those assigned to non-copper rooms were exposed to a copper item during their stay. These events may have led to an underestimation of the effect of copper on HAI infection rates and colonization. The study also failed to assess the frequency of hand hygiene by health care personnel and the effectiveness of discharge disinfection, potentially biasing the study results.³⁸ The trial was not adequately powered to detect differences in mortality or which HAIs are more likely to be influenced by microbial burden reduction. Further evaluation is required to confirm a sustained reduction in HAI rates with antimicrobial copper surfaces beyond a one-year time period and whether there are potential limitations in efficacy with soiling, exposure to chemicals, or the presence of surface defects that may act as microbial reservoirs.^{24,39-41} The ability of antimicrobial copper surfaces to kill pathogens that are more resistant to conventional cleaning methods, such as CDI spores and norovirus, also requires further assessment.^{24,42}

In July 2012, the Agency for Healthcare Research and Quality awarded a US\$2.5 million interdisciplinary research grant to the University of California, Los Angeles (UCLA) to conduct a four-year, single-centre, double-blinded RCT to determine whether reducing surface bacteria with the use of antimicrobial copper surfaces decreases HAI rates, improves treatment outcomes, and reduces costs.^{43,44} Two ICUs at the Ronald Reagan UCLA Medical Center will evaluate copper, plastic, and sham stainless-steel surfaces to determine their role in HAI transmission. Hospital surfaces selected for the study will include bed rails, chairs, overbed tables, and mobile nursing cart-tops that include a handle, keyboard, and mouse. The estimated enrolment has not been specified. The study is expected to conclude in April 2017.

Adverse Effects

No negative health effects associated with patient exposure to antimicrobial copper surfaces were observed during the one-year time period of the trial.¹⁸

Cost

Cost estimates for the installation of antimicrobial copper surfaces in Canadian health care facilities are currently unavailable. An economic assessment undertaken by the York Health Economics Consortium in the UK investigated the cost-effectiveness of installing antimicrobial copper touch surfaces as part of a newly built or planned refurbishment in ICUs.⁴⁵ A cost-benefit model was developed to compare expenditure on antimicrobial copper surfaces with improvements in patient outcomes. Data from the US trial,¹⁸ component cost data from installations in European hospitals, and cost-of-care figures from the UK were applied to calculate the cost of replacing six frequently touched surfaces with antimicrobial copper equivalents in a 20-bed ICU. The model predicted that the cost to install antimicrobial copper components would be recouped in less than two months, based on 20% fewer infections and the resulting shorter length of stay. While the total cost of the copper installation was £30,600 higher than traditional components, a savings of almost £2 million over five years was estimated because of the reduction of HAIs.⁴⁶

An economic assessment from the Copper Development Association estimates that the cost to install antimicrobial surfaces in the US ranges from US\$7,700 to US\$15,000 per room.⁴⁷ Based on a cost to outfit a 420-bed hospital of between US\$3 million and US\$6 million, a 20% reduction in HAIs could translate into an annual cost savings of US\$7.2 million and operating expense savings of US\$66 million over a 10-year period.

Concurrent Developments

Several other novel approaches are currently under investigation for the prevention of HAIs.^{40,48,49} The following are emerging technologies that have been evaluated in a clinical setting.

Copper Textiles

In addition to the use of copper as a material for contact surfaces, the antimicrobial effects of copper oxide-impregnated textiles are also being investigated.⁵⁰ One study examined whether the HAI

rates in a long-term care brain injury ward in Israel could be reduced when the textile products used in the ward were replaced with biocidal copper oxide-containing linens, including bedsheets, pillowcases, shirts, pants, gowns, towels, underpads, and personnel robes.⁵¹ Data were gathered from two patient cohorts during two six-month parallel periods before ($n = 57$) and after ($n = 51$) the replacement of all regular linens and personnel robes with copper oxide-impregnated biocidal products. Results showed a 24% reduction in HAI per 1,000 hospitalization days ($P = 0.046$) and a 32.8% reduction in total number of days of antibiotic administration per 1,000 hospitalization days ($P < 0.0001$) after the introduction of biocidal copper oxide linens.

Copper Alloy Coatings

At the University of Toronto, a Canadian company recently developed Aereus Shield (Aereus Technologies, Toronto, Ontario), a copper alloy coating consisting of 70% copper.⁵² Aereus Shield is applied using a patented thermal spray process and can coat nearly all solid surfaces, including metals, polymers, plastics, and wood composites. A study conducted in a waiting room at the Toronto General Hospital reported that outfitting 16 chairs with Aereus Shield resulted in a 68% reduction in overall microbial burden when compared with 16 chairs with standard plastic arms (0.87 CFU/cm² versus 2.71 CFU/cm²; $P < 0.0001$).⁵³ Copper alloy coatings are anticipated to be cheaper to install than solid copper alloys. Aereus Technologies claims that its proprietary combination of alloys makes Aereus Shield non-tarnishing, wear-resistant, and durable. Techlem Medical Corp. (Mississauga, Ontario) is one of the first Canadian manufacturers to work with Aereus Technologies to produce stretchers and IV stands coated in Aereus Shield. However, the product is still in the early stages of development and sales projections are not yet available. Aereus Technologies is currently in the process of acquiring registration with Health Canada's PMRA and the US EPA.⁵²

No-Touch Methods of Surface Disinfection

Automated environmental disinfection systems that use ultraviolet light (UV-C) or hydrogen peroxide vapour (HPV) have been investigated to complement standard cleaning and disinfection protocols after patient discharge (terminal cleaning).^{48,54} They are activated remotely and disinfect via a portable, stand-alone machine instead of the manual application of cleaning agents. The TRU-D SmartUVC system (Lumalier Corp., Memphis, Tennessee) calculates the UV time and dose required based on room size, geometry, surface

reflectivity to UV-C, and equipment in the room.⁵⁵ Disinfection of a single-patient room requires approximately 25 minutes for MRSA decontamination and 45 minutes for CDI decontamination. Another UV-C device, the Xenex (Xenex Disinfection Services, San Antonio, Texas), uses five-minute cycles of pulsed xenon in multiple positions in a patient room for decontamination.⁵⁶ Disinfection for pathogens, including CDI, MRSA, and VRE, takes approximately 15 minutes in a typical patient room. The Q-10 robot system (Bioquell Inc., Horsham, Pennsylvania) uses HPV for disinfection.⁵⁷ A single-patient room without a bathroom takes approximately 90 minutes to decontaminate. Although none of these devices are currently licensed for sale in Canada, the TRU-D SmartUVC and Xenex systems have been trialled at the Vancouver General Hospital in British Columbia and the Juravinski Hospital in Ontario, respectively.^{58,59}

Several studies have shown that the UV-C disinfection systems reduce microbial burden.^{42,60-63} There is also evidence that UV-C systems significantly reduce CDI infection rates⁶⁴ and overall multidrug-resistant organism infection rates.⁶⁵ Recent data comparing UV-C with HPV systems confirm the effective reduction of microbial burden in patient rooms using both methods, but indicate that HPV is superior to UV-C for the ability to disinfect sites out of direct line of sight, such as a bathroom with a closed door or drawers.⁶⁶ Studies evaluating HPV systems report reductions in bacterial levels,^{67,68} reductions in MRSA contamination,⁶⁹ reductions in CDI-associated diarrhea rates,⁷⁰ and reduced environmental contamination and risk of acquiring multidrug-resistant organisms compared with standard cleaning.⁷¹ The Centers for Disease Control (CDC) Prevention Epicenter Program awarded researchers at Duke University and the University of North Carolina US\$2 million to fund an ongoing, multi-centre cluster-randomized trial to determine the impact of environmental decontamination on HAI rates and the acquisition of multidrug-resistant pathogens among hospitalized patients after disinfection with the TRU-D SmartUVC system compared with standard chemical cleaning.⁷² Four strategies for terminal room disinfection will be assessed over 28 months in an estimated 50,000 patients: cleaning with quaternary ammonium alone, with quaternary ammonium followed by UV-C disinfection, with bleach alone, and with bleach followed by UV-C disinfection. The primary outcome of the study is the clinical incidence of MRSA, VRE, multidrug-resistant *Acinetobacter* spp., and CDI.

Current no-touch systems can be used only for terminal room disinfection after the room has been vacated, because UV-C and HPV are hazardous to patients.^{48,54} A significant amount of time may also be required for effective disinfection, which may affect bed turnaround time. UV-C systems cannot disinfect areas without a direct or indirect line of sight, meaning that all equipment and furniture must be moved away from the walls prior to use. These systems may be relatively expensive in terms of the cost to purchase and maintain the device. According to ECRI Institute's pricing database, the average prices for the Q-10, Xenex, and TRU-D SmartUVC systems are US\$47,000, US\$81,000, and US\$125,000, respectively.⁵⁴ Staff will also require training on proper use during the terminal cleaning process.

Rate of Technology Diffusion

Replacing standard surfaces with antimicrobial copper surfaces has also been shown to reduce microbial burden in other health care settings, including an acute medical ward in the UK;^{73,74} an outpatient infectious disease clinic in the US;⁷⁵ an oncology, respiratory, and geriatric ward in Germany;⁷⁶ and a walk-in clinic in South Africa.⁷⁷ One study has reported that the microbial burden of a non-copper surface within the general vicinity of a copper surface was also significantly reduced (also known as an antimicrobial "halo" effect).⁷⁵ Antimicrobial copper surfaces have been installed in more than 90 health care facilities in 26 countries in Europe, North America, South America, Africa, Asia, and the Pacific.⁷⁸ Installations have predominantly taken place in clinical settings where the most high-risk patients are treated, such as ICUs, pediatric and neonatal units, and cancer centres. Thirteen of these facilities are located in the US. There are currently no antimicrobial copper installations listed in Canada.

Implementation Issues

Introducing antimicrobial copper surfaces could have positive implications for infection prevention practices and health care budgets in Canada. Antimicrobial copper surfaces have been shown to work in tandem with standard infection control practices to reduce microbial burden and HAIs in the ICU.¹⁹ Although installation of antimicrobial surfaces would mean that hospital rooms may have to temporarily close, the intervention would not require any special training, additional cleaning, ongoing maintenance, or hospital room disruption after installation.¹⁹ Implementing antimicrobial copper surfaces into new infrastructure

and equipment is expected to be easier than retrofitting existing surfaces. There is currently no consensus on which surface areas should be targeted.²¹ Based on a review of the available evidence, the CDC has published a checklist of key surfaces that could be targeted for upgrade based on the likelihood of touch and contamination.⁷⁹ However, input should also be sought from the local infection control team, health care staff, and other experts to ensure that replacing existing surfaces with antimicrobial copper surfaces is cost-effective and all high-risk touch surfaces specific to the clinical setting of interest are identified.¹⁹

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