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Commentary

Water as a source for colonization and infection with multidrug-resistant pathogens: Focus on sinks

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Water distribution systems have long been known to be reservoirs and occasional sources for healthcare-associated infections (HAIs).[1,2] Recently, hospital-building wastewater systems including sinks and drains have received more attention as potential sources of transmission of multidrug-resistant gram-negative bacilli.[3–7] In this issue of *Infection Control and Hospital Epidemiology*, 2 studies by Dr Curtis Donskey's research group add to our understanding of the importance of sink drains as reservoirs of pathogens and describe potential interventions to reduce contamination of surfaces surrounding sinks.[8,9] This commentary focuses on the growing body of evidence linking sinks to HAIs and discusses strategies to mitigate the risk of transmission of pathogens from sinks to patients.

Sinks as Sources of Transmission of Multidrug-Resistant Organisms

A recent systematic review identified 32 reported outbreaks of carbapenem-resistant organisms (CRO) linked to hospital water supplies since the late 1990s, more than half of which were specifically linked to drains or drainage systems and/or sinks.[7] Likewise, Carling et al[3] recently summarized 23 well-characterized outbreaks of CRO linked to wastewater drains. Common features of the reported outbreaks of CRO associated with wastewater drains include (1) long duration (mean, 37 months), (2) low attack rate (mean, 10.2 months between clinical cases), (3) high prevalence of sink colonization with the outbreak organism strain, and (4) difficult mitigation.[3]

By design, wastewater drains are rich environments for the amplification of microorganisms and the formation of biofilm. Drains consist of a strainer at the interface of the sink bowl and drain pipe, a P trap that contains water to prevent escape of sewer gases, and a tail pipe that connects the strainer to the P trap (Fig. 1). Limited ability to access to the tail pipe and the P trap for routine cleaning purposes makes biofilm removal and disinfection challenging, if not impossible.

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Pathogens may be transmitted from sink drains to patients directly through contamination of healthcare-provider hands or indirectly through contamination of adjacent room surfaces and equipment. A recent *in vitro* study demonstrated that pathogens grow toward the sink strainer from contaminated P traps at a rate of ~2.5 cm (1 inch) per day.[10] Furthermore, contamination of the surrounding sink area with green fluorescent protein (GFP)-expressing *Escherichia coli* occurred only when the growth of the bacteria reached the sink drain but did not occur when the growth of the bacteria was limited to the P trap or tail pipe.[10] At our institution, we documented transmission of KPC-producing *Citrobacter freundii* from a colonized in-room sink P trap and drain to the sink edge during routine use of the sink (Lewis and Smith, unpublished data). Factors including sink design, water flow rates[8] and degree of drain colonization all influence the degree of pathogen transmission from sink drains.

Use of Sinks in Hospitals

In most hospitals, sinks are located in direct patient-care areas (eg, patient rooms) and support areas (eg, corridors, medication preparation areas, soiled utility rooms), and they serve several purposes. First, sinks are used for hand washing by healthcare personnel, patients, and visitors. Hand hygiene is a key intervention to reduce transmission of pathogens in healthcare environments.[11] Although healthcare personnel use waterless alcohol products more frequently than soap and water for hand hygiene, hand hygiene must be performed with soap and water when hands are visibly soiled and for pathogens that are not inactivated by alcohol such as nonenveloped viruses (eg, norovirus) and spore-forming bacteria (eg, *Clostridium difficile*).[12] Second, sinks may be used for the disposal of body fluids (eg, dialysate, urine, gastric residuals) or unused medications or tube feeds. Third, sinks are commonly used during perineal care (both routine care and after bowel movements) and for patient bathing. Finally, sinks may be used for soaking and initial cleaning of equipment that will undergo sterilization or high-level disinfection.

Infection prevention principles dictate separation of clean and dirty areas and tasks. For example, equipment reprocessing areas have separate designated sinks for dirty tasks such as initial equipment cleaning and clean tasks such as handwashing. Some

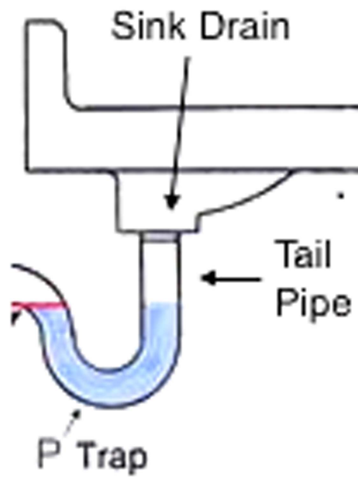

Fig. 1. Diagram of a hospital sink drain.

hospital rooms have clinical sinks (ie, hoppers) dedicated for waste disposal and separate from hand washing sinks. However, in our experience, clinical sinks are not present in all acute-care hospital rooms, and it is common practice for clean and dirty activities, including hand hygiene and waste disposal, to occur in the same in-room sink. Together with properties of sinks that promote colonization and biofilm formation and the proximity of sinks to patient care equipment and room surfaces, this creates a high-risk situation that is underrecognized in most acute-care hospitals.

Potential Mitigation Strategies

Numerous chemical disinfectant strategies have been trialed to disinfect colonized drains with limited success.[3,7,13–15] Biofilms in wastewater plumbing systems are relatively resistant to disinfectants and are not easy to access. Furthermore, disinfectants poured down the drain are diluted by water in the P trap and do not achieve recommended dwell times. Although this can be overcome by blocking, disinfecting, and then draining sinks simultaneously, this approach is logistically challenging and impractical in the long term. Finally, repeated use of corrosive chemicals may lead to degradation of plumbing over time. For all these reasons, strategies to mitigate colonization and/or prevent transmission from colonized drains are needed (Table 1).

Engineering Modifications to Reduce Transmission from Colonized Sinks

Sink design

Ideally, the risk of transmission of pathogens from sink drains to patients could be mitigated through better sink design. Gestrich et al[8] evaluated the association between sink characteristics and dispersion of fluorescent tracer outside the sink bowl in 171 sinks from 4 hospitals. The following sink characteristics were evaluated: depth of sink bowl, diameter of sink bowl, location of faucet relative to strainer (directly over vs offset), distance from faucet to strainer, distance from strainer to sink edge, automatic versus manual operation, and type of material. Of these characteristics, only sink

Table 1. Potential Strategies to Mitigate Transmission of Pathogens from Contaminated Sink Drains

Type of Intervention	Examples	Notes
First Line Strategies Appropriate for All Settings		
Behavioral modifications to minimize drain colonization	• Separation of clean and dirty tasks	• Limitations of physical space or workflow may make this challenging
Engineering modifications to minimize contamination of surrounding surfaces	• Splash guards/ barriers • Dedicated storage space >1 m from sinks • Sink design to reduce splashes	• Consider during design phase for building and remodeling
Secondary Strategies for Mitigation or High-Risk Settings		
Engineering modifications to minimize dispersion from contaminated drains	• Drain covers • Hopper covers	• Requires routine cleaning and maintenance; long-term benefit and feasibility unproven
Engineering modifications to eliminate biofilm formation	• Heater vibrator units • Ozonated water	• Costly; long-term benefit and feasibility unproven

bowl depth was associated with dispersion of the gel outside the bowl, with dispersion occurring in nearly half of sinks with depth ≤19 cm and rarely when depth exceeded 24 cm.[8] Additionally, there are important dynamics between water flow rate and pathogen dispersion that may not be fully mediated by sink design and must be balanced with functionality and the risks of low-flow states.

Modifications to minimize contamination of surrounding objects

Engineering modifications including appropriate use of splash guards and well-designed medication preparation and supply storage areas away from sinks and drains are important interventions to limit contamination of medications and supplies that are subsequently used for patient care. Hota et al[13] reported a prolonged outbreak of multidrug-resistant *Pseudomonas* infections among ICU patients linked to imperfect ICU room design in which handwashing sinks were adjacent to open countertops used for medication preparation. The outbreak was ultimately mitigated when the in-room sinks were closed and remodeled, including installation of a barrier between sinks and adjacent storage areas and ensuring that no patient care items were stored within 1 m of the sink.[13] Despite evidence to support physical separation of sinks from adjacent countertops and storage areas, such safeguards are not recommended in guidelines or mandated by building code requirements for newly constructed hospital buildings.[16]

Modifications to minimize dispersion from contaminated drains

Drain covers that allow passage of water but prevent backsplash and dispersion are straightforward interventions with potential

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utility to minimize transmission of pathogens from wastewater drains. As part of a multifaceted response to ongoing transmission of *Klebsiella pneumoniae* carbapenemase-producing organisms (KPRO) among ICU patients, Mathers et al[17] installed covers on hoppers in ICU rooms and noted a subsequent decrease in acquisition of KPROs following the intervention (odds ratio [OR], 0.51; 95% confidence interval [CI], 0.31–0.81; $P = .003$). Similarly, Livingston et al[18] demonstrated the potential efficacy and feasibility of using a novel drain cover that allows passage of water from sink bowl to drain but prevents dispersion of pathogens from a contaminated sink drain to surrounding surfaces. Compared to no intervention, the drain cover prevented contamination of the sink interior (0 vs 18%) and surrounding surfaces (0 vs 11%) in experiments when water was run for 30 seconds to simulate hand washing.[18]

Questions regarding the long-term feasibility of use, cleaning, and maintenance schedules will need to be answered before drain cover types of interventions are adopted widely for use in hospital patient rooms. Livingston et al[9] used the drain covers in ICU sinks for a 14-day trial period, changing the covers after 7 days of use. When used in this way, the outer surface became colonized with gram-negative bacteria in only 1 of 20 sinks, and there was still no detectable transmission of bacteria from the sink drain or cover when the cover had been in place for 7 days.[18] Still, a 7-day replacement schedule might present challenges for real-world implementation of such a device, particularly when ICU patient lengths of stay are highly variable, making it infeasible to rely on a standardized point in time (eg, terminal clean following patient discharge) for replacement.

Engineering modifications to reduce biofilm formation

As previously discussed, attempts to disinfect sinks drains once biofilms become colonized with multidrug-resistant organisms have typically failed.[3] Novel disinfectant strategies that can successfully penetrate or mechanically disrupt biofilms may be more effective than typical chemical disinfectants. Additionally, technologies that do not require manual application but instead provide continuous disinfection are appealing. Mathers et al[17] reported a decrease in KPRO acquisition following the installation of devices that heat and vibrate on the exterior of P traps. However, because this intervention coincided with the installation of hopper covers in the same ICU rooms, the impact of the vibrator and heater units could not be determined.[17] In this issue, Livingston et al[9] demonstrate potential efficacy of ozone to disinfect contaminated sink drains in an experimental setting. We anticipate that many similar technologies will enter the marketplace; however, additional study is needed to demonstrate their efficacy and cost-effectiveness.

In summary, recent studies provide mounting evidence that in-room sink drains are an important and underrecognized reservoir for pathogens in the chain of hospital-acquired infection. While published epidemiologic investigations have linked sink drains to transmission of multidrug-resistant organisms, we suspect that multidrug-resistant pathogens only represent the "tip of the iceberg" and that sink drains are also a source of transmission of susceptible gram-negative pathogens that has not yet been quantified. Multifaceted prevention and mitigation strategies are needed to minimize the risk of pathogen transmission from contaminated sinks. At a minimum, we need to return to the basics of infection prevention with clear separation of clean and dirty tasks. As such, sinks used for clean tasks such as hand washing should not be used for disposal of body fluids. The most promising adjunctive solutions include (1) design modifications of sinks and hospital rooms that minimize dispersion of pathogens from the drain and contamination of surrounding surfaces and (2) technologies that provide continuous disinfection of sink drains.

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