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Communication

Diminishment of Carbapenemase-Producing Enterobacterales from Sink Outlets Using a Steam Cleaner

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Abstract: In 2016, Tosei General Hospital, a tertiary emergency medical facility with 633 beds in Japan, experienced a large nosocomial outbreak of carbapenemase-producing Enterobacterales (CPE) that had spread to numerous sink outlets. Based on our experience with using steam cleaners to suppress CPE on environmental surfaces, we report the efficacy of steam cleaners in the disinfection of sink outlets. Steam cleaners were used to disinfect 22 target areas. CPE disappeared in 90.9% of the sink outlets within the first two months after disinfection, and, after 12 months, 54.5% of the sink outlets remained negative throughout the remainder of the study period. This study demonstrates the effectiveness of using steam cleaners to disinfect sink outlets contaminated with CPE.

Keywords: carbapenemase-producing Enterobacterales; steam cleaner; sink outlets

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1. Introduction

Sodium hypochlorite is commonly used to remove pathogens that are resistant to alcohol or iodine disinfectants from environmental surfaces; however, it is toxic to humans and requires a long period of surface contact (up to 15 min) to kill microorganisms [1]. Some reports have suggested that steam cleaners are a practical and effective method of disinfection for areas contaminated with nosocomial pathogens. The in vitro disinfection efficacy of steam vapor systems has been demonstrated by Tanner on porous clay test surfaces for *Clostridium difficile*, *Escherichia coli*, methicillin-resistant *Staphylococcus aureus*, vancomycin-resistant *Enterococcus faecalis*, and *Pseudomonas aeruginosa* [2] and by Bagattini et al. on glass surfaces for carbapenemase-producing *Klebsiella pneumoniae*, extensively drug-resistant *Acinetobacter baumanii*, etc. [3]. Thus, steam cleaning is an efficient method for removing bacterial contamination. Recently, many medical institutions have reported nosocomial outbreaks of carbapenem-resistant pathogens [4,5] and carbapenemase-producing Enterobacterales (CPE) [6–8]. Lorenzi et al. used a steam cleaner to disinfect a hospital ward's room surfaces, such as tables, chairs, and dressers, and obtained good decontamination results [9]. Although the effectiveness of steam cleaning has been demonstrated on many environmental surfaces, the efficacy of steam cleaners on CPE-contaminated sink outlets remains uncertain. In 2016, Tosei General Hospital, a tertiary emergency medical facility with 633 beds in Japan, experienced a large nosocomial CPE outbreak that spread to numerous sink outlets. Based on our experience with using steam cleaners to suppress CPE on environmental surfaces, we report here the efficacy of using steam cleaners for disinfecting sink outlets.

2. Materials and Methods

Steam cleaner disinfection was performed on the sink outlets and plumbing of Tosei General Hospital, Aichi, Japan, between June 2016 and April 2018 during a nosocomial

CPE outbreak. The bacterial samples were collected from the sink outlets of all hospital wards by wiping the surface around the sink outlets with soaked sterile swabs. CPE was detected in 61 (22.2%) out of 275 sink outlets. Of these, 27 drainpipes were replaced, and the remaining sink outlets were treated with sodium hypochlorite by filling the drains with 0.1% sodium hypochlorite for 30 min per week. We used a steam cleaner to disinfect 22 (27.8%) sink outlets in which CPE persisted even after changing the drainpipe and treating with the disinfectant at screening two months later. Steam cleaning was performed only once and was not repeated until the pathogens re-emerged.

After the application of the steam cleaner, we continued to use the sodium hypochlorite disinfectant weekly and tested all the drainpipes for the presence of CPE every 2 months for up to 22 months. We evaluated the reduction in the number of drainpipes contaminated with CPE and the long-term effectiveness of using steam cleaning as a disinfection method during the follow-up period.

The samples were seeded on CHROMagar mSuperCARBA Plates (Kanto Chemical Co., Inc., Tokyo, Japan) and incubated at 37 °C for 24 h [10]. For grown strains from the media, the Microscan Walkaway system (Beckman Coulter, Brea, CA, USA) was used to identify enterobacterales at the species level and to determine antimicrobial susceptibility. The antibiotic susceptibility testing complied with the standards of the Clinical and Laboratory Standards Institute [11]. The presence of carbapenemase-encoding genes in the isolates was screened using polymerase chain reaction, following the methods of a previous study [12]. Direct sequencing was performed using the ABI BigDye Terminator v3.1 Cycle Sequencing Kits (Applied Biosystems, Waltham, MA, USA) and an ABI 3730xl sequencer (Applied Biosystems) [13].

A canister-type steam cleaner (STM-415; Iris Ohyama, Sendai, Japan) was used to disinfect the target sinks (stainless steel, approximately 60 × 17 × 42 cm) and their drains. The steam cleaner was fitted with a hose connected to a circular cleaning head with a radius of 1.5 cm. It was filled with ordinary tap water, activated, and allowed to reach an operating pressure of approximately 58.8 psi at 100 °C; a contact time of approximately 20 min was used (Figure 1). Each sink took approximately 80 min (30 min for preparation, 20 min for steaming, and 30 min for cooling the equipment to room temperature). Individuals who performed the steam cleaning wore gowns, goggles, a surgical mask, and heat-resistant gloves. The Kaplan–Meier method was used to evaluate the efficacy of steam cleaning based on the number of sinks that remained negative during the remainder of the study period. This was calculated using IBM SPSS Statistics 23.0 (IBM®).

(**A**) (**B**) (**C**)

Figure 1. Disinfection of sinks contaminated with carbapenemase-producing Enterobacterales using a steam cleaner. (**A**) Body (of a machine); (**B**) Nozzle tip; (**C**) View of steam.

3. Results

We disinfected the 22 sink outlets that tested positive for CPE using a steam cleaner. All detected species possessed the bla_{IMP} type gene, and 21 of the 22 CPE possessed bla_{IMP-1} (Table 1).

Table 1. Carbapenemase-producing Enterobacterales detected in the hospital sink outlets.

Enterobacterales	Carbapenemase	No. of Sink Outlets
Enterobacter cloacae	IMP-1	10
Klebsiella oxytoca	IMP-1	3
Citrobacter amalonaticus	IMP-1	3
Enterobacter cloacae	IMP-6	2
Enterobacter gergoviae	IMP-1	1
Enterobacter cloacae and *Citrobacter freundii*	IMP-1 (in both)	1
Enterobacter cloacae and *Serratia liquefaciens*	IMP-1 (in both)	1
Serratia liquefaciens and *Citrobacter freundii*	IMP-1 (in both)	1

During the 22-month study period, all the sinks initially tested negative for CPE after the first steam cleaning disinfection; 20 of the 22 sinks (90.9%) remained negative till the first 2-month screening; and 12 of the 22 sinks (54.5%) remained negative throughout the study period (Figure 2). The median duration for negative CPE results in the sink outlets was 12.3 months (range of 0.77–22.0 months). Table 2 shows the duration required by the bacterial species to recontaminate the hospital sink outlets. Sixty percent of the sinks where *Enterobacter* spp. were detected remained negative for over one year. In contrast, 60% of the sinks where *Klebsiella oxytoca* were detected showed a re-positive result within two months.

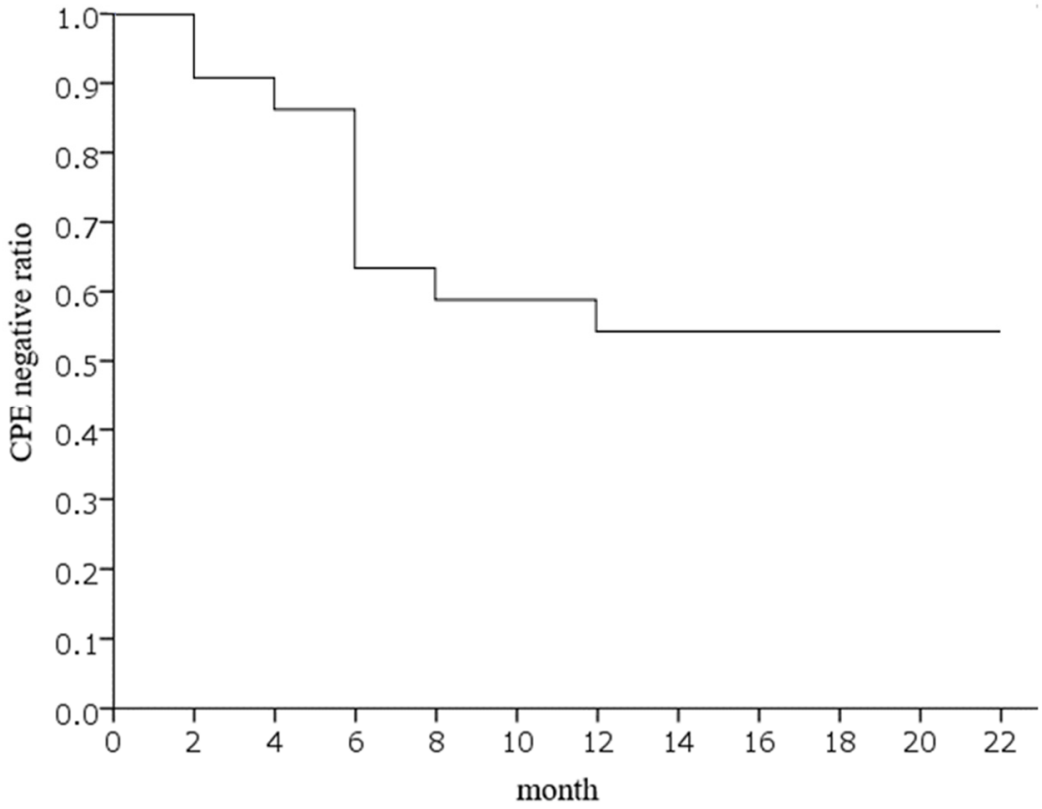

Figure 2. Kaplan–Meier curves for carbapenemase-producing Enterobacterales (CPE) negativity in 22 sink outlets after steam disinfection.

Table 2. Duration required by the bacterial species to recontaminate the hospital sink outlets.

Enterobacterales	Re-Positive		Remained Negative over 1 Year
	Within 2 Months	Within 12 Months	
Enterobacter spp.	3 (20.0%)	3 (20.0%)	9 (60.0%)
Klebsiella oxytoca	2 (66.6%)	0 (0%)	1 (33.3%)
Citrobacter spp.	1 (20.0%)	3 (60.0%)	1 (20.0%)
Serratia liquefaciens	0 (0%)	1 (50.0%)	1 (50.0%)

4. Discussion

To the best of our knowledge, this is the first study to evaluate the efficacy of using a steam cleaner to disinfect surfaces contaminated with CPE. After steam cleaning, 90.9% of the drainpipes tested negative for CPE at the 2-month screening, and 54.5% of the drainpipes remained negative throughout the 22-month follow-up period. Steam cleaners are convenient to use, and regular disinfection using steam cleaners could be an effective method for preventing nosocomial CPE outbreaks.

Nosocomial pathogen outbreaks can lead to patient deaths. To prevent the spread of CPE through sink drains, we disinfected the sinks using a steam cleaner in this study and assessed the efficacy of this disinfection method. As all 22 sink outlets tested negative for CPE after disinfection and many remained negative at follow-up, our results suggest that steam cleaning has the potential for disinfecting environmental surfaces. Bagattini et al. reported the use of a steam vapor system for the disinfection of surfaces contaminated with multidrug-resistant bacteria, such as carbapenemase-producing *Klebsiella pneumoniae* and extreme drug-resistant *A. baumanii*. Sexton et al. disinfected eight sinks using steam vapor and observed reductions in heterotrophic plate count bacteria after disinfection [14]. A strong point of our study is that we examined 22 sink outlets and continuously screened the sinks for CPE for 22 months. Very few studies have included such long follow-up periods. Kotay et al. reported sink-to-sink transmission of bacteria, observing the rapid growth of organisms through plumbing at a rate of an inch per day [15]. In the present study, 9.1% of the sink outlets tested positive for CPE within two months after steam cleaning disinfection. Because steam cleaners can only disinfect areas that are exposed to steam, removal of bacterial colonies that are present deeper inside the drainpipes is difficult. More frequent steam disinfection or another disinfection approach may be necessary to disinfect highly contaminated sink outlets. Furthermore, *Klebsiella oxytoca* had a shorter time to show a re-positive result. *Klebsiella* spp. often produce biofilms, which may have an impact. However, biofilm production capacity was not examined in this study. In addition, the conditions of use of the steam cleaner followed the method described in the instruction manual. Conditions of use vary from report to report, and whether the conditions used in this study are the optimal conditions of use are unknown. In addition, this study only considered the effect of sinks and not that of steam cleaners in nosocomial transmission.

We experienced a nosocomial CPE outbreak that spread through the sink outlets and plumbing in our institution. Disinfection using a convenient steam cleaner may be an effective means of preventing the spread of nosocomial CPE. The present study showed that 90.9% of sink outlets remained negative for CPE for two months, and 54.5% remained negative for 22 months after steam disinfection. Further studies are needed to identify the potential of steam cleaning as a CPE disinfection method for sink outlets.

5. Conclusions

Based on our experience with using steam cleaners to suppress CPE on environmental surfaces, we report the efficacy of steam cleaners in the disinfection of sink outlets. Our results indicate that steam cleaners may be an effective tool for disinfecting sink outlets contaminated with CPE.

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