Survey on bacterial contamination of bidet toilets and relation to the interval of scrubbing these units

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ABSTRACT

We conducted a survey to investigate the distribution of bacteria recovered from the bidet toilets at a district hospital. The nozzle surface and spray water of 192 bidet toilets were sampled for contamination. Of the 192 toilets sampled, the nozzle surface of 167 (87%) and the spray water of 181 (94%) were found to be contaminated by one or more of the following organisms: Enterobacteriaceae, *Enterococcus* spp., *Staphylococcus* spp., non-glucose-fermenting rods, other Gram-negative bacteria, other Gram-positive bacteria, and *Candida* spp. An extended spectrum of β-lactamase producing *Escherichia coli* was found in one nozzle surface and one spray water. The frequency of colonization with 10^4 or more recovered from the nozzle surface was significantly greater in the toilets scrubbed every week than that in the units scrubbed every day, but that from the spray water was not significantly different between the groups. The nozzle surface and the spray water in the bidet toilets were contaminated with a wide range of bacteria. Because the interval of scrubbing the toilets did not have an influence on the contamination of the spray water, self-cleaning mechanisms of spray water should be developed to prevent patients' possible infections.

Key words | bacterial contamination, bidet toilet, scrubbing the toilets

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INTRODUCTION

Electric bidet toilets are automatic devices that deliver a jet of water to clean the anus after defecation. Since the first Japanese-made electric bidet toilets were introduced in the Japanese market in 1967, they have been steadily gaining popularity and have been developed to incorporate different functions to improve user comfort. Today, the user can select the water pressure and temperature they prefer, as well as water angle, from narrow to wide. In Japan, 79% of households have bidet toilets (Cabinet Office Government of Japan 2017). We conducted a survey to investigate the use of bidet toilets among community-dwelling Japanese people and found that 55% of 4,963 responders used bidet toilets either before or after defecation (Tsunoda *et al.* 2016).

Bidet toilets have been increasingly installed in schools, airports, hotels, and other public facilities. These units are also found in many hospital lavatory facilities. However, the patient's possible infectious risk has not been assessed sufficiently. As the distribution of antimicrobial-resistant bacteria in hospitals is higher compared with the community (Roca *et al.* 2015), concerns have been reported regarding the potential risk that patients may be exposed to antimicrobial-resistant bacteria in the warm-water sprayed from bidet toilets' nozzles (Iyo *et al.* 2016; Kanayama Katsuse *et al.* 2017). Iyo *et al.* (2016) surveyed a sample of 127 bidet toilets at a university hospital and detected bacterial contamination of spray water, and found *Escherichia coli* and

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Pseudomonas aeruginosa in 5% and 2% of the spray water, respectively. Kanayama Katsuse *et al.* (2017) surveyed a sample of 292 bidet toilets at a university hospital and explored bacterial contamination of both the nozzle surface and toilet seats, and found that an extended spectrum of β-lactamase (ESBL) producing *E. coli* and methicillin-resistant *Staphylococcus aureus* was recovered from the nozzle surface.

Although the bacterial survey of spray water alone or both the toilet seats and the nozzle surface was valuable, the correlation between the contamination of the nozzle surface and the spray water may be more important to know the equipped cleaning function of the nozzle before and after use. In addition, whether the severity of bacterial contamination of bidet toilets may be affected by the interval of scrubbing the dirt from these units by a cleaning staff remains unknown. Therefore, we surveyed bacterial contamination of the nozzle surface and the spray water of bidet toilets at the Kameda Medical Center and explored its relation to the interval of scrubbing these units.

METHODS

Bidet toilets

To evaluate the hygiene status of bidet toilets, a survey of their microbial communities was conducted at a district hospital between February and March 2018. A total of 192 tank-type bidet toilets were surveyed, of those 103 were in an inpatient ward (48 individual, 55 shared), 34 were in an outpatient clinic, and 55 were in a research building for an employee. Fifty-three toilets were for men only, 67 for women only, and 72 were not fixed or shared. Bidet toilets for patients ($n = 137$) were scrubbed every day and those for employees ($n = 55$) every week by cleaning staff. The nozzle was scrubbed with a brush using Toilet Heiter™ (Kao Co., Ltd, Tokyo, Japan) which contains hypochlorous acid. Between 5 and 13 years had passed since these bidet toilets had been installed, and all were functioning properly.

Sampling protocol

Nozzle surface

The nozzle surface was sampled firstly using swabs before spray water. Samples were placed in 1 ml of sterile physiological saline, centrifuged with 3,000 *G* for 20 min, and its sediment was used for samples.

Spray water

Spray water was collected directly as it came out of the nozzle. About 50 ml of the spray water from the nozzle was collected in sterilized bottles, centrifuged with 3,000 *G* for 20 min, and its sediment was used for samples.

Tap water

Tap water for control specimens was collected from faucets in the restrooms which were surveyed. Of the 123 samples of tap water analyzed, 82 were in an inpatient ward, 17 were in an outpatient clinic, and 24 were in a research building. To eliminate as much contamination as possible on the faucet, the tap water was allowed to run for about 30 s before samples were collected for testing for microorganisms. About 50 ml of the tap water was collected in sterilized bottles, centrifuged with 3,000 *G* for 20 min, and its sediment was used for samples.

Bacterial analysis

Samples were inoculated on Trypticase Soy Agar II with 5% Sheep Blood/Drigalski Lactose Agar (Nippon Becton Dickinson Co., Ltd, Tokyo, Japan). Also, these were inoculated on CHROMager Orientation (CHO)/ESBL medium (Kanto Chemical Co. Inc., Tokyo, Japan), which differentiates Gram-negative bacteria based on the pigmentation and detection of ESBL or metallo-β-lactamase (MBL) producing organisms following incubation. To detect vancomycin-resistant *Enterococci* (VRE), the broth microdilution MIC test (National Committee for Clinical Laboratory Standards 1993) was used.

Following incubation at 37 °C under aerobic conditions for 48 h, the color and intensity of the colonies on the media were recorded according to the coloration types provided by the manufacturers' instructions. Each type of colony was counted for the colony-forming units (CFU) by the microbiological technologists, where the greater number of colonies was roughly judged as 10^4, 10^5, and 10^6 CFU or more, respectively. Thin colonies under 100 CFU were counted

as an actual number. All colonies were identified using the matrix-assisted laser desorption ionization-time of flight (MALDI-TOF) system (Bruker Daltonics GmbH, Germany) (Veloo *et al.* 2011).

Statistical analysis

Chi-squared test or Fisher's exact test was used for the comparison of the pattern of bacterial colonization of toilets between the groups, or the frequency of bacterial colonization with 10^4 CFU or more, recovered from the toilets sampled between the groups.

RESULTS

Table 1 shows the pattern of bacterial colonization of the 192 bidet toilets sampled, where the nozzle surface of 167 (87%) and the spray water of 181 (94%) were found to be contaminated. Figure 1 showed the detection frequency of colonies by CFU recovered from the toilets. Twenty-nine colonies with 10^4 CFU, 5 colonies with 10^5 CFU, and 7 colonies with 10^6 CFU or more were recovered from the nozzle surface (Figure 1(a)). Similarly, 13 colonies with 10^4 CFU and 2 colonies with 10^5 CFU and 10^6 CFU or more, respectively, were isolated from the spray water (Figure 1(b)). The mean standard deviation number of thin colonies recovered from the nozzle surface was 14.4 (16.2) CFU, and that done from the spray water was 16.3 (17.1) CFU. Of 123 samples of tap water, bacteria colonization was recovered from one toilet in an inpatient ward, which was identified as *Sphingomonas paucimobilis*.

Table 2 shows the organisms recovered from the nozzle surface and the spray water. Enterobacteriaceae were isolated from 11 (5.7%) bidet toilets. *E. coli* was recovered from five nozzle surfaces and four spray water; of these, ESBL-producing *E. coli* was found in one nozzle surface and one spray water in a different inpatient ward. *Klebsiella* spp. were found from one nozzle surface and two spray water, although *Klebsiella oxytoca* or *Klebsiella pneumonia* was not recovered. *Enterococcus* spp. were isolated from seven nozzle surfaces, although no VRE were detected. *Staphylococcus* spp. were recovered from two nozzle surfaces and three spray water; of these, *S. epidermidis* was found from two nozzle surfaces and one spray water. *S. aureus* was not isolated. Among non-glucose-fermenting rods (NFR), *Acinetobacter johnsonii* were isolated from 17 nozzle surfaces and 10 spray water and *Stenotrophomonas maltophilia* were isolated from three nozzle surfaces and six spray water, although no isolates were shown to be multi-drug resistant or MBL producer. *Sphingomonas* spp. were recovered from 32 nozzle surfaces (one *S. paucimobilis* was included) and 56 spray water. Of other Gram-negative bacteria, *Pseudomonas* spp. were isolated from 11 nozzle surfaces and 17 spray water, but *P. aeruginosa* was not included. *Bacillus* spp. were the most frequently isolated (43 toilets) Gram-positive bacteria, although possible pathogenic *Bacillus* spp., such as *B. anthracis* and *B. cereus*, were not detected. Among *Candida* spp., *C. albicance* was not isolated.

The pattern of bacterial colonization was not significantly different between the toilets scrubbed every day and every week (Table 3). When the incidence of bacterial colonization with 10^4 or more recovered from the toilets sampled was compared, the incidence recovered from the nozzle surface was significantly greater in the toilets scrubbed every week than in those done every day. However, the incidence recovered from the spray water was not significantly different between the groups. Fecal indicator bacteria showing the colonization with 10^4 or more were recovered from the nozzle surface in the toilets scrubbed every day (*E. coli* and *K. oxytoca*), and those scrubbed every week (*E. coli* and *Enterococcus faecalis*). Although fecal indicator bacteria with thin colonies were isolated from the spray water in the toilets scrubbed either every day or every week, those having the colonization with 10^4 or more were not isolated (Table 4).

The pattern of bacterial colonization was not significantly different between the toilets for men only and those for women only. Also, the incidence of bacterial colonization

Table 1 | Pattern of bacterial colonization of 192 bidet toilets in a hospital

Nozzle surface contamination	Spray water contamination	No. (%) of toilets
+	+	161 (83.9)
+	–	6 (3.1)
–	+	20 (10.4)
–	–	5 (2.6)

+, positive for bacteria; –, negative for bacteria.

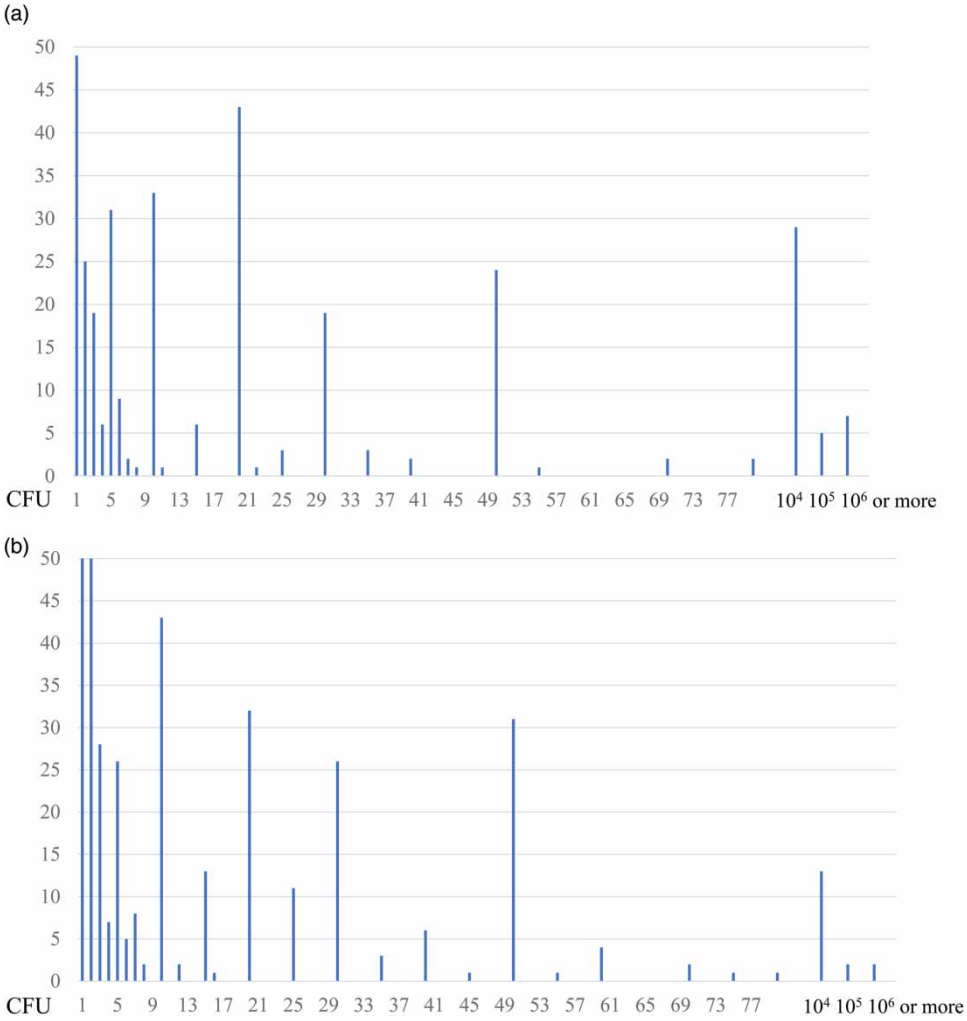

Figure 1 | (a) Detection frequency of colonies by CFU recovered from the nozzle surface. CFU, colony-forming units. (b) Detection frequency of colonies by CFU recovered from the spray water. CFU, colony-forming units.

with 10^4 or more recovered from the nozzle surface and the spray water sampled was not significantly different between the toilets for men only and those for women only (data not shown).

DISCUSSION

In this study, we surveyed the 119 bidet toilets installed at a hospital and found that the nozzle surface of 87% and the spray water of 94% were contaminated. In addition, we found that the incidence of greater contamination of the spray water was not significantly different between the toilets scrubbed every day and every week.

Fecal indicator bacteria such as Enterobacteriaceae, including *E. coli*, *Klebsiella* spp., and *Enterococcus* spp., were isolated in this study. The nozzle surface can become contaminated with feces, because users wash the anus after defecation. When feces contaminate the nozzle surface or the region around the hole from which the spray water exists, fecal indicator bacteria can be detected in the spray water. Antimicrobial-resistant bacteria were observed in two of the 192 bidet toilets (1.0%), one recovered from the nozzle surface and the other from the spray water, and both were the ESBL-producing *E. coli*. The World Health Organization has recognized the importance of studying the emergence and determinants of acquired antimicrobial resistance and the need to devise appropriate strategies for

Table 2 | Number of toilets (%) sampled that were positive for bacteria

Isolates	No. of samples (%) ($N = 192$)	Isolated from		No. of samples
		Nozzle surface	Spray water	
E. coli	8 (4.2)	+	+	1
		+	–	4 (1: ESBL producer)
		–	+	3 (1: ESBL producer)
Klebsiella spp.[a]	3 (1.6)	+	–	1
		–	+	2
Enterococcus spp.[b]	7 (3.6)	+	–	7
Staphylococcus spp.[c]	5 (2.6)	+	–	2
		–	+	3
Acinetobacter spp.	24 (12.5)	+	+	3
		+	–	14
		–	+	7
Stenotrophomonas maltophylia	8 (4.2)	+	+	1
		+	–	2
		–	+	5
Other NFR	174 (90.6)	+	+	127
		+	–	13
		–	+	34
Sphingomonas spp.[d]	71 (37.0)	+	+	17
		+	–	15
		–	+	39
Other GNR	115 (59.9)	+	+	27
		+	–	34
		–	+	54
Other GPR	83 (43.2)	+	+	7
		+	–	55
		–	+	21
Candida spp.	13 (6.8)	+	+	1
		+	–	11
		–	+	1

NFR, non-glucose-fermenting rods; GNR, Gram-negative rods; GPR, Gram-positive rods.
ESBL, extended-spectrum β-lactamase.
[a]Three *E. faecalis* (nozzle) were included.
[b]One *K. pneumoniae* (nozzle) and two *K. oxytoca* (spray water) were included.
[c]Three *S. epidermidis* (two from nozzle and one from spray water) were included.
[d]One *S. paucimobilis* (nozzle) was included.

Table 3 | Pattern of bacterial colonization of toilets which were scrubbed every day or every week

Water-jet nozzle contamination	Spray water contamination	No (%) of toilets scrubbed		*P*-value
		every day ($n = 137$)	every week ($n = 55$)	
+	+	117 (85.4)	44 (80.0)	0.97
+	−	4 (2.9)	2 (3.6)	
−	+	13 (9.5)	7 (12.7)	
−	−	3 (2.2)	2 (3.6)	

+, positive for bacteria; −, negative for bacteria.

Table 4 | Frequency of bacterial colonization with 10^4 or more recovered from the toilets sampled

	Total ($n = 192$)	Toilets scrubbed		*P*-value
		every day ($n = 137$)	every week ($n = 55$)	
Nozzle surface	39 (20.3)	21 (15.3)[a]	18 (32.7)[b]	0.00067
Spray water	15 (7.8)	14 (10.2)	1 (1.8)	0.096

Parentheses, percentage.
[a]*E. coli* and *K. oxytoca*, and [b]*E. coli* and *E. faecalis* were found as fecal indicator bacteria.

their control (World Health Organization 2018). In particular, the ESBL-producing *E. coli* are emerging worldwide (Lu *et al.* 2012) and may significantly affect the course and outcomes of infection, both in the community and in the hospital. The increased incidence of urinary tract infection due to ESBL-producing *E. coli* has been reported previously (Lu *et al.* 2012; Picozzi *et al.* 2013). An earlier report from Japan described an outbreak of an MBL-producing *P. aeruginosa* in a hospital hematology ward that was traced to the contamination of the nozzle of six bidet toilets. The study concluded that the exposure of immune-compromised patients to the contaminated nozzle led to clonal spread within the ward. The risk associated with the use of bidet toilets in immune-compromised patients should be understood (Hayashi *et al.* 2015).

NFR can be a major problem in the clinical environment, being a common cause of nosocomial infections. *A. johnsonii* and *S. maltophilia* were most frequently recovered bacteria in this study. NFR can form a viable biofilm matrix over an extended period (Capelletti & Moraes 2016). NFR in the spray water showed a marked increasing trend, rising to levels more than 100 times higher than those in the tap water. This suggests that NFR stay and biofilms form at higher rates in the water tanks and internal tubing of bidet toilets than in the tap water pipes. Iyo *et al.* (2016) reported that this was caused by the decreased level of residual chlorine in the water tank due to heating and remaining stagnant for a long period. As *A. johnsonii* and *S. maltophilia* may cause opportunistic infection in immunocompromised patients (Seifert *et al.* 1993; Muder *et al.* 1996; Calza *et al.* 2003; Rodrígues *et al.* 2014), the use of bidet toilets in this patient population must be a part of hospital risk management. *Sphingomonas* spp. are Gram-negative bacilli and found in multiple environments. Most of *Sphingomonas* spp. do not play a role in human disease, but some of those, especially *S. paucimobilis*, may cause nosocomial infection (Ryan & Adley 2010). In this study, *S. paucimobilis* were recovered from not only the nozzle surface of one bidet toilet but also the tap water of the other toilets in an inpatient ward. Of other Gram-negative bacteria, *Pseudomonas* spp. were isolated from bidet toilets, but *P. aeruginosa* were not recovered.

Staphylococcus spp., including *S. epidermidis,* were also isolated from bidet toilets in this study. When water was sprayed on the perineal skin, the nozzle surface or the region around the hole can be contaminated by the exfoliated epithelium with *S. epidermidis*.

In this study, the incidence of either nozzle surface or spray water contamination was not significantly different between toilets scrubbed every day and every week. However, when the frequency of bacterial colonization with 10^4 CFU or more recovered from the toilets sampled was compared, the frequency recovered from the nozzle surface was significantly greater in the toilets scrubbed every week than those done every day. It may be natural that considerable numbers of bacteria come from either feces or spray water existed on the nozzle surface which had not been scrubbed for the previous six days. On the other hand, the frequency recovered from the spray water was not significantly different between the toilets scrubbed every day and every week. Bidet toilets are equipped with a mechanism that cleans the nozzle and internal tubing of bidet toilet seats before and after use. Considering the low frequency of fecal indicator bacteria recovered from bidet toilets or the low frequency of greater bacterial contamination of the spray water, it appears that the equipped cleaning function of the nozzle was generally working properly.

It is interesting to observe the pattern of bacterial colonization of bidet toilets closely, because spray water was contaminated, while the nozzle surface was not contaminated in 20 of 192 toilets. The mechanism is uncertain, but this pattern may be possible if bidet toilets had not been used since the nozzle surface was scrubbed previously. The nozzle surface was sampled prior to spray water actually and was not contaminated by spray water.

This study had several limitations. First, this was a cross-sectional study and was not able to confirm the continued bacterial contamination of bidet toilets. Second, samples were taken from lavatory facilities in a rural district hospital, and this limits its generalizability to the findings in other hospitals. Third, the number of people who had used each unit since the bidet toilets were scrubbed previously is uncertain.

CONCLUSIONS

The nozzle surface and the spray water in the bidet toilets were contaminated with a wide range of bacteria, which

may be a potential vehicle for infection. Because the interval of scrubbing the toilets, including the nozzle surface, did not have an influence on the contamination of spray water, and possible infectious NFR bacteria were isolated from the spray water, self-cleaning mechanisms of spray water or structural changes should be developed to prevent patients' healthcare-associated infections.

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DISCLOSURE

The authors declare no conflicts of interest.

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