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Effects of water flow volume on the isolation of bacteria from motion sensor faucets

Yasutaka Nakamura[1,2*], Masaharu Watanabe[1,3], Etuko Kubo[1,4], Akiko Suzuki[1,5], Hidetoshi Igari[1,6], Mitsukazu Kitada[2], Takeyuki Sato[1,6]

[1] Infection Control Team, Chiba University Hospital, Chiba, Japan; *Corresponding Author: 86834@kou.ja-shizuoka.or.jp
[2] Division of Pharmacy, Chiba University Hospital, Chiba, Japan;
[3] Division of Laboratory Medicine, Chiba University Hospital, Chiba, Japan;
[4] Division of Nursing, Chiba University Hospital, Chiba, Japan;
[5] Department of Pathobiology, Graduate School of Nursing, Chiba University, Chiba, Japan;
[6] Division of Control and Treatment of Infectious Diseases, Chiba University Hospital, Chiba, Japan.

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ABSTRACT

Water outlets for washing hands and medical equipment are essential for preventing hospital infection. The present study clarified the effects of water flow volume on the identification and quantitative evaluation of bacteria found around spouts in the 17 hand-washing stations. *Pseudomonas aeruginosa* was detected from 4 stations before adjustment and 2 after adjustment. Although no significant difference was identified in the detection rate of *P. aeruginosa* ($p = 0.368$), when combining *P. aeruginosa* and glucose non-fermentative Gram-negative bacilli (NFB), the number of stations with *P. aeruginosa* and/or NFB decreased significantly from 15 before adjustment to 9 after adjustment ($p = 0.023$). Before adjustment, quantity of bacteria was "2+" for 3 stations and "1+" for 7 stations, but was "1+" for 3 stations and "2+" for 0 stations after adjustment. These results show that quantity of bacteria could be reduced from spouts by adjusting flow volume. These results were also supported by experiments for cleanliness using Adenosine 5'-triphosphate bioluminescence method.

Keywords: Infection Control; Water Flow Volume; Motion Sensor Faucets

1. INTRODUCTION

Water outlets for washing hands and medical equipment are essential for preventing hospital infection. In our hospital, to prevent hospital infection via water outlets, non-contact faucets and bigger sinks have been installed to minimize splashing. However, spouts cannot be easily removed, and spouts are difficult to clean because water is turned on and off automatically using a motion sensor. Also, chlorine sterilization is insufficient with mixing faucets. These factors can contribute to hospital infection. In addition, Gram-negative bacteria have been found around water outlets, and some hospital outbreaks have been attributed to tap water contamination [1-4]. In particular, *Pseudomonas aeruginosa* is a clinically important Gram-negative bacteria that can be lethal if sepsis results [5]. In recent years, problems surrounding multidrug-resistant *P. aeruginosa* have arisen as an important social issue, and although various studies have examined environmental infection, to our knowledge, no studies appear to have investigated water flow volume. The present study clarified the effects of water flow volume on the identification and quantitative evaluation of bacteria found around spouts.

2. METHODS

2.1. Hand-Washing Stations, Equipment and Adjustment Period

Bacteria tests were conducted at 17 hand-washing stations located at nurse stations in 8 wards and used exclusively and frequently by hospital staff. All hand-washing stations had motion-sensor faucets, with a shell sink (L-50G; INAX Corporation, Aichi, Japan; pressure of water supply: 0.05~0.74 Mpa [0.5~7.5 kgf/cm^3]) used at 13 stations and an integrated sink (AWL-76AM (P); INAX Corporation; pressure of water supply: 0.08~0.74 Mpa [0.8~7.5 kgf/cm^3]) used at 4 stations. Water flow volume was adjusted at the end of November 2007, and was adjusted for all 17 stations on the same day.

2.2. Water Flow Volume Adjustment

First, without any notification, water flow volume was

measured at each hand-washing station (pre-adjustment flow volume). Next, based on sink size, flow volume was adjusted at 120-200 mL/s (post-adjustment flow volume). Flow volume per second was calculated by measuring flow volume over a 10-s period twice. Also, when adjusting flow volume, each floor was notified that water flow volume would be adjusted as part of activities of Infection Control Team (ICT) and was instructed to refrain from performing any action that could have impacted the surveillance, such as changing flow volume or contacting a cleaning service.

2.3. Sample Collection, Identification and Quantity of Bacteria

Samples were collected by wiping the entire spout using a cotton swab soaked in physiological saline before and after adjustment at intervals of 1 month. One person collected all samples from all hand-washing stations before and after volume adjustment. Each sample was inoculated using Drigalski improved medium (Eiken Chemical, Tokyo, Japan) and tryptic soy agar II supplemented with 5% sheep blood (Becton Dickinson, Tokyo, Japan) and cultured at 35˚C for 72 h. Gram-positive bacilli (GPB) were identified by Gram staining alone, and Gram-positive cocci were biochemically divided into Streptococcus, *Staphylococcus* aureus and coagulase-negative staphylococci (CNS). Gram-negative bacilli were biochemically divided into Enterobacteriaceae, *P. aeruginosa* and glucose non-fermentative Gram-negative bacilli (NFB).

Growth was semiquantitated as follows: <50 colonies, <50 colonies in the first inoculation zone; 100 colonies, 50-100 colonies in the first zone; 1+, >100 colonies in the first zone; 2+, >10 colonies in the second zone.

2.4. Adenosine 5'-Triphosphate (ATP) Bioluminescence Method

ATP was purchased from Oriental Yeast Co., LTD. Japan. The ATP solution at the concentration of 2.0×10^{-6} M with 1% of the starch was prepared for the experiments. The entire spout was cleaned by brushing with soap and water. One mL of ATP solution was poured to the faucet from the side of up-stream after removal of the faucet. After reset of forcet, water was running at various water volume for 15 and 30 seconds, respectively. Water flow Volume performed 40, 80 mL/ss. Then, samples were collected by wiping the entire surface of spout with the attached tape for the experiments. The experiments were done 10 times and the results were shown as the average (+/–SD). Samples were measured in relative light units (RLU) by using a luminometer (ATP Luminometer PD-20 Kikkoman Co., Japan)

2.5. Statistical Assessment

When statistically analyzing bacteria detection rates in relation to flow volume adjustment, a χ^2 independence test was used with the level of significance set at $p < 0.05$.

2.6. Detection Rate of *P. Aeruginosa* in Inpatients and Drug Usage for *P. Aeruginosa*

Detection rate of *P. aeruginosa* in inpatients was calculated before and after adjustment for the entire hospital and each floor at which *P. aeruginosa* was detected a 3-month period before and after adjustment.

Drug usages for *P. aeruginosa* were also studied for the entire hospital and each floor at which *P. aeruginosa* was detected a 3-month period before and after adjustment. Usage of the following antibiotics injected for treatment was determined: Ceftazidime, cefepime dihydrochloride hydrate, cefozopran hydrochloride, imipenem hydrate, meropenem hydrate, panipenem, doripenem hydrate, biapenem, pazufloxacin mesilate, and ciprofloxacin. When comparing usage among drugs, defined daily dose (DDD) as recommended by the World Health Organization (WHO) was used to correct for non-uniformity in specifications and dose (**Table 1**) (www.whocc.no/atcddd/). DDD for drugs not listed by WHO was defined by modifying with the recommendation of WHO. The study period before adjustment was from August to October 2007 and after adjustment from January to March 2008.

3. Results

3.1. Water Flow Volume Before and After Adjustment

Average flow volume before and after adjustment was 87.6 mL/s and 149.4 mL/s, respectively (**Table 2**). Before

Table 1. Drug list and defined daily dose (DDD).

Drugs	DDD (g)	
Ceftazidime	4	
Cefepime Dihydrochloride Hydrate	2	
Cefozopran Hydrochloride	2	*
Imipenem Hydrate	2	
Meropenem Hydrate	2	
Panipenem	2	*
Doripenem Hydrate	1	*
Biapenem	1.2	*
Pazufloxacin mesilate	1	
Ciprofloxacin	0.5	

*DDD for drugs not listed by WHO was defined by modifying with the definition of WHO.

Table 2. Water flow Volume before and after adjustment.

	Water flow Volume（mL/s）													mean ± S.D
	30	50	60	70	90	110	120	130	140	150	160	170	200	
Before adjustment	1	1	4	4	1	2	2		1		1			85.3 ± 35.4
After adjustment							4	3	2	1	1	4	2	149.4 ± 27.0

adjustment, minimum flow volume was 30 mL/s, and flow volume at 11 hand-washing stations was <120 mL/s. Maximum flow volume after adjustment was 200 mL/s.

3.2. Detection of *P. Aeruginosa* and NFB from Hand-Washing Stations

P. aeruginosa was detected from 4 hand-washing stations (A-D) before adjustment and 1 station (A) after adjustment. Quantity of bacteria was "1+" for Station A, "100 colonies" for Station D, and "<50 colonies" for Stations B and C before adjustment. After adjustment, *P. aeruginosa* was not detected from Stations B, C and D. *P. aeruginosa* was detected from Station A, but quantity of bacteria decreased from "1+" before adjustment to "<50 colonies" after adjustment. Also, at 1 station (E), *P. aeruginosa* was not detected before adjustment, but was detected after adjustment, although quantity of bacteria was low at "<50 colonies" (**Table 3**).

Although no significant change was identified in the detection rate of *P. aeruginosa* including newly isolated 1 station ($p = 0.368$), when combining *P. aeruginosa* and NFB, the number of stations with *P. aeruginosa* and/or NFB decreased significantly from 15 before adjustment to 9 after adjustment ($p = 0.023$) (**Table 4**). Before adjustment, quantity of bacteria was "2+" for 3 stations and "1+" for 7 stations, but was "1+" for 3 stations and "2+" for no stations after adjustment (**Figure 1**). As for the other bacterial species, GPB was detected before and after adjustment at 12 and 8 stations, respectively, and CNS was detected before and after adjustment at 1 station each. Streptococcus species, S. aureus and Enterobacteriaceae were not detected.

3.3. ATP Bioluminescence

ATP method is recommended due to ATP being widely found in microorganisms and there are good correlations between ATP bioluminescence method and microbiological swabbing method [6]. So cleanliness was examined using ATP bioluminescence method for the confirmation of microbiological swabbing method. Increase of flow volume resulted the increase of cleanliness at both 15 and 30 seconds of running water (**Table 5**).

3.4. Comparison of *P. Aeruginosa* Detection and Drug Usage among Inpatients

Detection rate of *P. aeruginosa* in all inpatients was compared before and after adjustment. Detection rate of *P. aeruginosa* for all floors before adjustment was 4.5% (patients with *P. aeruginosa*/total patient count = 159/3,500) and that 3 months after adjustment was 3.6% (128/3,523). On the floors with Stations A through D where *P. aeruginosa* was detected before adjustment, detection rate before adjustment ranged from 3.5% to 10.8% and that after adjustment ranged from 2.3% to 9.1%, revealing no significant differences (**Table 6**).

Total drug usage over the 3-month period for all floors before adjustment was 3,917 units and that after adjustment was mostly comparable at 4,083 units (102.8%).

Table 3. Water flow Volume and quantity of bacteria of hand-washing stations at which *P. aeruginosa* were detected.

Hand-washing stations	Type of sink	Before adjustment		After adjustment	
		Quantity of bacteria	Water flow Volume (mL/s)	Quantity of bacteria	Water flow Volume (mL/s)
A	Shell	1+	90	＜50 colonies	120
B	Shell	＜50 colonies	110	No Detection	140
C	Integrated	＜50 colonies	30	No Detection	200
D	Shell	100 colonies	70	No Detection	130
E	Shell	No Detection	120	＜50 colonies	170

Table 4. Umber of stations at which *P. aeruginosa* and/or glucose non-fermentative Gram-negative bacilli were detected or not before and after adjustment.

	Detection	No Detection	*P*
Before adjustment	15	2	0.023
After adjustment	9	8	

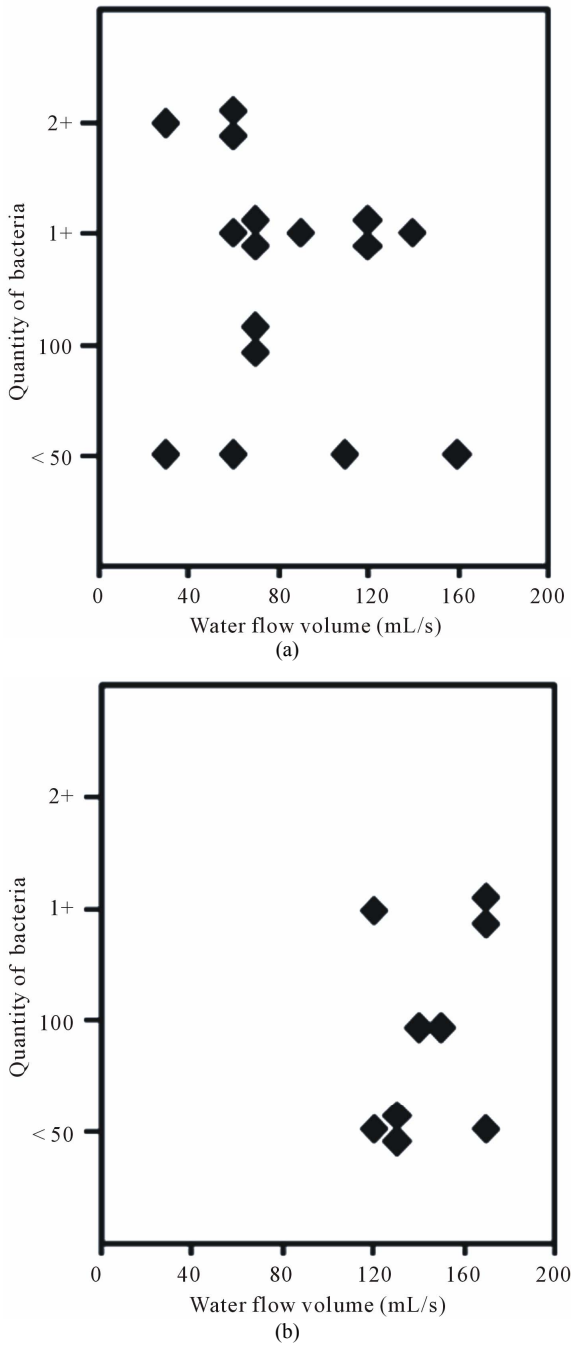

Figure 1. Water flow Volume and quantity of bacteria for hand-washing stations at which *P.* aeruginosa and/or NFB was detected before (a) and after (b) adjustment.

Table 5. The results of ATP bioluminescence.

Time of running water (sec)	Water flow Volume (mL/s)	After running water (RLU : mean ± S.D)	*P*
15	84	498.1 ± 275.16	0.0091
	40	1434.0 ± 974.21	
30	84	445.7 ± 346.15	0.0017
	40	1343.8 ± 642.81	

Experiments were done 10 times and the results were shown as the average of 10 experiments (+/–SD).

Although average of drug usage for *P. aeruginosa* slightly decreased to 83.3% at 4 stations on which *P. aeruginosa* was detected, no significant change existed Drug usage for *P. aeruginosa* decreased to 52.7% and 74.7% at Stations A and B, respectively (**Table 7**).

4. DISCUSSION

Various microorganisms exist in hospitals, and complete removal is not really plausible. Furthermore, studies have found no correlation between environmental microbes and hospital infection [5,7,8], and the guidelines published by the Centers for Disease Control and Prevention state that periodic surveillance for environmental bacteria is unnecessary [9,10]. However, Rutala *et al.* reported surfaces may potentially contribute to cross-transmission by acquisition of transient hand carriage by health care personnel due to contact with a contaminated surface [11]. In addition, Endlhart *et al*. reported a *P. aeruginosa* outbreak in a hematology-oncology unit associated with contamination of the surface cleaning equipment when non-germicidal cleaning solutions were used instead of disinfectants [12].

Microorganisms that adhere to surfaces directly touched by people can be spread not only by hospital staff, but also by patients, family members and visitors [13,14]. Issues of cross-contamination and outbreak thus need to be addressed and appropriate measures must be taken to prevent environmental infection.

Recently, the use of motion sensor faucets has gained popularity in hospitals throughout the Japan. To the best of our knowledge, no studies that investigated water flow volume, and the present study is the first to show that highly hydrophilic *P. aeruginosa* and NFB can be reduced by adjusting flow volume. This result was also supported by experiments for cleanliness using ATP bioluminescence method.

However, the present study did not find that higher water flow volume could decrease the number of *P. aeruginosa* patients or drug usage (**Table 6**). In the present study, the design of sinks precluded sufficient in-

Table 6. Detection rate of *P. aeruginosa* in inpatients on the floors of hand-washing stations at which *P. aeruginosa* was detected before adjustment.

Hand-washing stations	Before adjustment			After adjustment		
	Patients detected *P. aeruginosa*	No. of all inpatients	Detection rate of *P. aeruginosa*(%)	Patients detected *P. aeruginosa*	No. of all inpatients	Detection rate of *P. aeruginosa*(%)
A	8	130	6.2	8	122	6.6
B	12	111	10.8	12	132	9.1
C	9	255	3.5	6	262	2.3
D	11	158	7.0	14	155	9.0

Table 7. Total drug usage over a 3-month period for hand-washing stations where *P. aeruginosa* was detected before and after adjustment.

Hand-washing stations	Total drug usage over a 3-month period		Rate (%)
	Before adjustment	After adjustment	
A	193.0	100.5	52.1
B	218.8	163.5	74.7
C	128.0	124.0	96.9
D	192.5	222.0	115.3
Total	732.3	610.0	83.3

creases in flow volume due to splashing, so sink designs need to be investigated in relation to flow volume.

The present results showed that isolation and quantity of bacteria could be reduced from spouts by adjusting flow volume. Further studies might be needed.

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