

Original

Cleansing Effectiveness of Electrolyzed Water Depending on the Nursing Procedure and Degree of Hand Contamination

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We examined the antibacterial effectiveness of handwashing with electrolyzed water (EW) depending on the type of nursing procedure and differences in the degree of bacterial contamination on hands after the procedure. With respect to the bacteria on the hands after diapering (relatively heavy contamination), changing positions (relatively light contamination), and endotracheal aspiration (light contamination), handwashing for 10s and 30s with EW lowered the hand bacterial counts after handwashing to the same level as or lower than that before the procedures. Washing with EW was as effective as washing with medicated liquid soap and 7.5% (w/v) povidone-iodine liquid. Based on these results, we considered that handwashing for 10s with EW could be applied to any of the procedures that require direct contact with the patient's skin (diapering) or clothing (changing positions), as well as the procedures involving no direct contact with the patient (endotracheal aspiration). Furthermore, effective washing could be expected in a short period of time, with no rising of resident bacteria to the surface of the hand.

Key words : Electrolyzed water/Handwashing/Nursing procedures/Povidone-iodine/Infection control.

INTRODUCTION

Contamination via hands of hospital personnel is known as one of the causes for the transmission of nosocomial infections. Handwashing after nursing procedures is important in order to prevent transmission of bacteria that cause nosocomial infection via the hands of hospital personnel, in particular nurses. It is necessary to clarify the relationship between various nursing procedures and bacteria on the hands, as well as the types of bacteria and bacterial counts, and to examine and suggest the most suitable handwashing method.

For the purpose of suggesting the most suitable handwashing method at nursing sites, there have been reports in which the condition of bacterial con-

tamination of the hands is artificially created in a laboratory in order to examine the cleansing effectiveness of liquid soap or hand disinfectants (Alyliffe et al., 1988; Cardoso et al., 1999; Guihermetti et al., 2001; Takeshita et al., 2001a). However, there are very few reports that examine the bacteria on the hands after nursing procedures and handwashing at a nursing site to quantitatively evaluate cleansing effectiveness (Takeshita et al., 2001b).

Electrolyzed water (EW) is strongly acidic (pH 2.3–3.0) or slightly acidic (pH 5.0–7.0) electrolyzed water containing hypochlorous acid produced when electrolysis is conducted by adding an ancillary agent such as salt into tap water. It is known that EW shows strong microbicidal efficacy against various kinds of peccant bacteria and fungi (Hotta et al., 1994; Middleton et al., 2000; Shetty et al., 1999; Zinkevich et al., 2000). In addition, since it is safe to the skin, it has been increasingly expected to be used for

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handwashing purposes by hospital personnel who are having skin problems due to frequent handwashing using hand disinfectants (Iwasawa and Nakamura, 1995; Suzuki et al., 1997; Takamori et al., 1992).

In the present study, then, cleansing effectiveness of electrolyzed water, depending on the type of nursing procedure and degree of bacterial contamination on hands, against bacterial contamination on hands after nursing procedures was examined and compared with the cleansing effectiveness of 7.5% (w/v) povidone-iodine liquid, non-antiseptic, plain liquid soap, and medicated liquid soap commonly used in wards.

MATERIALS AND METHODS

Preparation of electrolyzed water

Electrolyzed water was produced by using "ACID WATER PRODUCTION APPARATUS[®]" (TOTO Ltd., TFS400A model, non-diaphragm, running-water type). Previous reports by the authors were used for electrolysis conditions (Takeshita et al., 2001b). A pH meter (Horiba, Ltd., F-14) was used for measuring pH of the produced electrolyzed water, and a residual chlorine meter (HACH Co., 46700-00) was used to measure free residual chlorine, respectively. The water quality of the electrolyzed water was pH6.0-6.5 and the free residual chlorine concentration was 18.0-20.0mg/L.

Nursing subject

A long-term hospitalized patient with no nosocomial infection who was hospitalized in the physician's ward of hospital A was chosen as the nursing procedure subject. Two nurses conducted many kinds of daily nursing procedures performed in the ward including endotracheal aspiration, changing positions, and diapering. A sterile glove was worn on the right hand for endotracheal aspiration due to requirements for an aseptic operation. In addition, diapering and changing positions were performed one after the other with handwashing conducted between the two procedures.

Method for counting the bacteria on the hands

First, a sampling of bacteria on the hands before and after performing a nursing procedure was conducted. Two ml of physiological saline was used for the sampling of bacteria, and the bacteria on the hands were collected from both the right and left palms of the nurses by using sterilized swabs. As for procedures performed with a glove, bacteria on the right hand were collected from the palm after the nurses removed the glove when the nursing

procedure was finished. Handwashing was performed by rubbing hands together well under running electrolyzed water (EW) (3.0L/min) produced by "ACID WATER PRODUCTION APPARATUS[®]" right after the sampling. A paper towel was used to dry off the hands, and the bacteria remaining on the right and left palms were collected by sterile swabs with 2 ml of physiological saline. The collected samples from both palms of the nurses before and after the nursing procedures and after handwashing were diluted appropriately, smeared into ovine blood agar (Nissui Plate Sheep Blood Agar[®]; Nissui Pharmaceutical, Co., Ltd.). After a 48-h aerobic incubation at 36°C, total bacterial counts on the hands were calculated by counting the bacterial numbers on the ovine blood agar. The handwashing time was set at 10 and 30s.

Methods of washing with electrolyzed water, liquid soap, medicated liquid soap and 7.5% (w/v) povidone-iodine liquid

The washing methods used were general handwashing methods used in wards, and the following handwashing agents and methods were used: non-antiseptic, plain liquid soap (1 ml) and tap water (3.0L/min) (hereinafter referred to as ls-washing); medicated liquid soap containing triclocarban and triclosan as sterile ingredients and tap water (3.0L/min) (mls-washing); and 7.5% (w/v) povidone-iodine liquid and tap water (3.0L/min) (PI-washing). Furthermore, after the PI-washing, 2 ml of 0.1% sodium thiosulfate solution instead of physiological saline was used for the collection. Fifteen seconds of rubbing-washing with ls-washing, mls-washing and PI-washing was conducted, followed by a 15s rinsing with tap water. Furthermore, washing for 10s with EW (sampling counts = 30), washing for 30s with EW (sampling counts = 30), 30s-ls-washing (sampling counts = 30), 30s-mls-washing (sampling counts = 22), and 30s-PI-washing (sampling counts = 30) were conducted alternately every day, and the same handwashing method was used for the same day.

RESULTS

Cleansing effectiveness against the bacteria on the hands after diapering (nursing procedure involving direct contact of the patient's skin; relatively heavy bacterial contamination)

The mean \pm S.D. of the hand bacterial counts after diapering was 3.64 ± 0.72 (log cfu/hand), and it was the highest bacterial count and indicated relatively heavy contamination in comparison to other nursing procedures in this study. Table 1 showed the mean \pm S.D. with regard to the hand bacterial counts

before and after diapering, as well as after conducting all the handwashing methods. Table 2 showed the result of Scheffe's multiple comparison test concerning the hand bacterial counts before and after diapering, and the bacterial counts after handwashing.

A significant difference depending on the day was found in the hand bacterial counts after diapering when ls-washing, mls-washing, washing for 30s with EW, washing for 10s with EW, and PI-washing were conducted. Lower hand bacterial counts were found on the day when washing for 30s with EW was conducted, compared to the day when the PI-washing ($p < 0.001$) and washing for 10s with EW ($p < 0.05$)

were conducted. The hand bacterial counts were smaller after washing for 30s with EW compared to after ls-washing, but no significant difference was found between mls-washing, PI-washing, and washing for 10s with EW.

The hand bacterial counts after washing for 10s with EW showed a tendency to be higher than the hand bacterial counts after PI-washing, but no significant difference was found.

Cleansing effectiveness against the bacteria on the hands after changing positions (procedure involving touching the patient's clothing; rela-

TABLE 1. Hand bacterial counts before and after diapering and after handwashing using each washing method.

Washing method	No. of samples	Hand bacterial counts (log cfu/hand)		
		Before diapering	After diapering	After hand washing
Ls-washing	12	2.44 ± 0.51 ^a	3.61 ± 0.32	2.50 ± 0.31
Mls-washing	8	1.34 ± 0.47	3.40 ± 0.50	1.88 ± 0.55
Washing for 30s with EW	12	1.74 ± 0.53	3.03 ± 0.40	1.74 ± 0.32
Washing for 10s with EW	12	2.00 ± 0.24	3.81 ± 0.66	2.09 ± 0.31
PI-washing	12	1.86 ± 0.83	4.28 ± 0.88	1.69 ± 0.49

^aMean ± S.D.

TABLE 2. P-value of Scheffe's multiple comparison test.

Washing method	Washing method				
	Ls-washing	Mls-washing	Washing for 30s with EW	Washing for 10s with EW	PI-washing
Ls-washing					
Mls-washing	0.0025 ^a				
	0.9561				
	0.0437 ^a				
Washing for 30s with EW	0.0598	0.6535			
	0.2314	0.7698			
	0.0020 ^a	0.9436			
Washing for 10s with EW	0.4434	0.1632	0.8497		
	0.9593	0.6831	0.0497 ^a		
	0.2284	0.8766	0.4117		
PI-washing	0.1776	0.3848	0.9893	0.9837	
	0.1268	0.0427 ^a	0.0002 ^c	0.4385	
	0.0007 ^c	0.9024	0.9980	0.2481	

Each line indicated the p-value concerning the bacterial counts from hands before and after diapering and after handwashing, respectively.

^aStatistically significant at 5%.

^bStatistically significant at 1%.

^cStatistically significant at 0.1%.

tively light bacterial contamination)

The mean \pm S.D. of hand bacterial counts after changing positions was 2.81 ± 0.51 (log cfu/hand), and indicated relatively light contamination in comparison to other nursing procedures in this study. Table 3 showed the mean \pm S.D. with regard to the hand bacterial counts before and after changing positions, as well as after conducting all the handwashing methods. No significant difference was found in the hand bacterial counts after changing positions when ls-washing, mls-washing, washing for 30s with EW, washing for 10s with EW, and PI washing were conducted. On the other hand, the hand bacterial counts were smaller after washing for 30s or 10s with EW compared to after ls-washing, but no significant difference was found between mls-washing and PI-washing. In addition, the hand bacterial counts after ls-washing were higher than any other washing methods.

Cleansing effectiveness against the bacteria on the hands after endotracheal aspiration (procedure involving no direct contact with the patient's skin; light bacterial contamination)

The mean \pm S.D. of hand bacterial counts after endotracheal aspiration was 2.37 ± 0.54 (log cfu/hand), and it was the lowest bacterial count and indicated light contamination in comparison to other nursing procedures in this study. Table 4 showed the

mean \pm S.D. with regard to the hand bacterial counts on the hands before and after endotracheal aspiration, as well as after handwashing using all the handwashing methods. No significant difference was found in the bacterial counts on the hands after endotracheal aspiration when ls-washing, mls-washing, washing for 30s with EW, washing for 10s with EW, and PI-washing were conducted. In addition, no significant difference was found in the bacterial counts on the hands after handwashing with each washing method.

DISCUSSION

We have reported that the bacterial counts on the hands after diapering were higher than endotracheal aspiration and changing positions because it is a procedure that involves direct contact with the patient's skin. We have also reported that higher hand bacterial counts were found on the days when there was some bowel movement (Takahashi Y., Takeshita A., Endo M., Sasaki M., submitted.).

In the present study, washing for 10s with EW and PI-washing were conducted when defecation occurred, and washing for 30s with EW, ls-washing, and mls-washing were conducted when no defecation occurred. Both incidences of defecation occurred early in the morning. There was a tendency in which the bacterial counts on the hands at the time of diapering

TABLE 3. Hand bacterial counts before and after changing positions and after handwashing using each washing method.

Washing method	No. of samples	Hand bacterial counts (log cfu/hand)		
		Before changing positions	After changing positions	After hand washing
Ls-washing	12	2.50 ± 0.31^a	2.60 ± 0.32	2.40 ± 0.54
Mls-washing	8	1.88 ± 0.55^b	2.74 ± 0.34	1.65 ± 0.58^c
Washing for 30s with EW	12	1.74 ± 0.32^c	2.82 ± 0.59	1.58 ± 0.48^e
Washing for 10s with EW	12	2.09 ± 0.31	2.85 ± 0.32	1.57 ± 0.57^e
PI-washing	12	1.69 ± 0.49^d	3.01 ± 0.74	1.30 ± 0.39^e

^aMean \pm S.D.

^bSignificant difference at 5% by the Scheffe's multiple comparison test was found concerning the hand bacterial counts before changing positions, compared to ls-washing.

^cSignificant difference at 1% was found concerning the hand bacterial counts before changing positions, compared to ls-washing.

^dSignificant difference at 0.1% was found concerning the hand bacterial counts before changing positions, compared to ls-washing.

^eSignificant difference at 0.1% was found concerning the hand bacterial counts after handwashing, compared to ls-washing.

TABLE 4. Hand bacterial counts before and after endotracheal aspiration and after handwashing using each washing method.

Washing method	No. of samples	Hand bacterial counts (log cfu/hand)		
		Before endotracheal aspiration	After endotracheal aspiration	After hand washing
Ls-washing	6	1.94±0.55 ^a	2.53±0.80	1.70±0.68
MIs-washing	6	1.81±0.69	1.87±0.58	1.74±0.48
Washing for 30s with EW	6	2.51±0.42	2.52±0.20	1.37±0.49
Washing for 10s with EW	6	2.47±0.14	2.53±0.41	1.63±0.46
PI-washing	6	2.11±0.78	2.38±0.33	1.15±0.16

^aMean±S.D.

immediately after the occurrence of defecation was higher than the bacterial counts on the hands at the time of the same procedure conducted later on, on the days washing for 10s with EW was conducted (Table 5). In the meantime, on the days when PI-washing was conducted not only immediately after defecation, but also after some passage of time, the hand bacterial counts showed a tendency to be high after the same procedure. Based on this, it was considered that not only immediately after defecation, but also for a period of several hours the degree of bacterial contamination stayed high in the diaper on the days when defecation occurred. It was also considered that the bacterial counts on the hands after procedures that required the nurses to touch inside the diaper were strongly affected by the degree of contamination inside the diaper. According to this, after defecation, even if there is no visible contamination, in the nursing procedures afterwards that involve direct touching of the skin, it is anticipated that hands will get heavily contaminated: thus, we thought that sufficient care was necessary in handwashing after the procedures.

Then, it was seen that on the day when defecation occurred, there was high contamination in the diaper, and that on the day when no defecation occurred there was light contamination in the diaper. In the case of heavy contamination in the diaper (washing for 10s with EW), compared to the case of light contamination in the diaper (washing for 30s with EW), the hand bacterial counts were high after the nursing procedures. However, washing for 10s with EW showed about the same level of hand bacterial counts after hand washing as washing for 30s with EW. In addition, washing for 10s with EW showed about the same level of effectiveness as other hand washing methods. Furthermore there was no rising of resident bacteria to the surface of the hand when EW was

used in the case of light or heavy contamination in the diaper. Based on these results, we considered that handwashing for 10s with EW could be applied to the procedures that require direct contact with the patient's skin (diapering).

After diapering and handwashing after that, changing positions was performed continuously. We have reported that changing positions involved negligible contact with the patient's skin, the bacterial counts after changing positions were not affected by the occurrence of defecation, meaning the conditions in the diaper, and that bacterial contamination was relatively light (Takahashi Y., Takeshita A., Endo M., Sasaki M., submitted.).

In the present examination, no significant difference depending on the day was found. Furthermore on the day when washing for 10s with EW was conducted, no significant difference was found between the hand bacterial counts after changing positions immediately after defecation and the hand bacterial counts after

TABLE 5. Hand bacterial counts after diapering categorized into whether the procedure was conducted immediately after the occurrence of defecation or conducted later on.

The day when diapering was conducted	Hand bacterial counts (log cfu/hand)	
	When the procedure was conducted immediately after the occurrence of defecation (n=4)	When the same procedure was conducted later on (n=8)
Washing for 10s with EW	4.19±0.25 ^a	3.62±0.73
PI-washing	3.75±1.09	4.55±0.68

^aMean±S.D.

TABLE 6. Hand bacterial counts after changing positions categorized into whether the procedure was conducted immediately after the occurrence of defecation or the same procedure was conducted later on.

The day when changing positions was conducted	Hand bacterial counts (log cfu/hand)	
	When the procedure was conducted immediately after the occurrence of defecation (n=4)	When the same procedure was conducted later on (n=8)
Washing for 10s with EW	2.80 ± 0.38 ^a	2.88 ± 0.32
PI-washing	3.78 ± 0.82 ^{b,c}	2.63 ± 0.25

^aMean ± S.D.

^bThe hand bacterial counts after changing positions immediately after defecation were higher compared to the bacterial counts on the hands after the same procedure was conducted later on (statistically significant at 1% by Mann-Whitney test).

^cThe hand bacterial counts after changing positions immediately after defecation when PI-washing was conducted were higher compared to those when washing for 10s was conducted (statistically significant at 1% by Mann-Whitney test).

the same procedure was conducted later on (Table 6). However, on the day when PI-washing was conducted, the hand bacterial counts after changing positions immediately after defecation were higher compared to the bacterial counts on the hands after the same procedure was conducted later on. It may be considered that the cause of such a change was that the time passed after defecation was shorter after defecation on the day when PI-washing was used, but the cause remains uncertain. However, as a result of the present study, the nursing procedures performed immediately after defecation cause heavier contamination than other ones, and it was suggested that even if they do not involve direct contact with the skin, sufficient hand washing was necessary.

In the present examination, the hand bacterial counts after changing positions were relatively small on any of the conducted days, and the hand bacterial counts after handwashing for 10s or 30s with EW were as low as those after PI-washing. Based on this, we considered that if handwashing is performed after each nursing procedure, the use of a hand disinfectant is not necessary other than after the procedures that are expected to have heavy contamination, and that it was possible to remove bacteria on the hands sufficiently with EW. Though there were cases where bacteria on the hands did not get removed completely or there was rising of resident bacteria to the surface

of the hand after Is-washing, after handwashing with EW no rising of resident bacteria to the surface of the hand was found, and it was possible to maintain the low hand bacterial counts.

Since endotracheal aspiration is a nursing procedure with little contact with the patient's skin, the bacterial counts on the hands after the procedure were not affected at all by the conditions inside the diaper, and there was light post-procedural contamination. Because of this, it was considered possible to maintain low hand bacterial counts after washing hands with EW, in a similar manner as that after changing positions.

Based on these results, we considered that handwashing for 10s with EW could be applied to the procedures that require direct contact with the patient's skin (diapering) and clothing (changing positions), as well as the procedures involving no direct contact with the patient's skin (endotracheal aspiration).

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