[Environmental Health and Preventive Medicine 11, 31–37, January 2006]

*Original Article*

# Risk of Transmission of Imipenem-Resistant *Pseudomonas aeruginosa* through Use of Mobile Bathing Service

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## Abstract

**Objectives: The demand for mobile bathing service (MBS) is increasing in the Japanese society. Therefore, we assessed the risk of MBS-associated infection in MBS clients and their caregivers by examining the bacterial colonization of MBS equipment and utensils.**

**Methods: Bacterial isolates collected by the stamp agar culture method were examined by disk diffusion assay for their susceptibility to the following drugs: imipenem, ciprofloxacin, amikacin, azutreonam, ceftazidim, meropenem, piperacillin, tobramycin, ofloxacin and cefoperazone. Furthermore, these isolates were subtyped by *Spe*I-pulsed field gel electrophoresis (*Spe*I-PFGE).**

**Results: Fifty-four *P. aeruginosa* isolates were recovered from different sampling sites, and of these, 26 (47.3%) were isolated from pillows. Eighteen isolates (33.3%) were imipenem (IPM) resistant. The minimum inhibitory concentrations (MICs) of 17 isolates were between 16 and 32 μg/ml, and the MIC of one isolate was greater than 32 μg/ml. The *Spe*I-PFGE typing of IPM-resistant isolates revealed that 13 of the 18 isolates were closely related ($F$=1.0–0.87).**

**Conclusion: Our findings suggest that MBS equipment and utensils, particularly pillows, are the primary sources of bacterial contamination and transmission and that there is a risk of MBS-mediated infection among MBS clients and their caregivers.**

**Key words:** imipenem-resistant *Pseudomonas aeruginosa*, mobile bathing service (MBS), MBS-mediated infections, MBS utensils, long-term care insurance

## Introduction

The proportion of elderly individuals (age: 65 years or more) in the Japanese population is the highest in the world. It is 18.0% of the population of 127 million individuals, and it is expected to reach 27.4% in 2025. A long-term care insurance plan for the elderly was introduced in April 2000 to help the elderly who require support in leading an independent life with dignity and to support their families that provide such care. In 2003, 96% of the 3.8 million individuals who benefited from in-home care services or services at facilities were elderly individuals aged 65 years or more (1). The elderly needing a long-term care are categorized into six levels, including support-required level and care levels 1 to 5, according to their mental and physical conditions. They can choose their long-term care insurance benefits, such as home-visit/day services, home-visit rehabilitation, short-stay services and long-term care facilities for the elderly, according to their care level.

The mobile bathing service (MBS) is home-visit bathing, an important in-home care service provided as one of the long-term care insurance benefits. This service enables physically-disabled individuals to maintain their skin integrity and good hygiene, to relax and be comfortable, and to participate in the maintenance of their sanitary conditions (2). As a result of their sociocultural background, most Japanese individuals want to enjoy a hot bath even if they are bedridden. However, bathing these individuals at home is a significant burden for their caregivers; therefore, the MBS has become popular among aging individuals in Japan. In 2003, there were approximately 2,000 MBS providers and approximately 70,000 individuals who benefited from the MBS. In addition, 76.6% of the MBS users belonged to care levels 4 to 5, which includes individuals

Received May 24, 2005/Accepted Oct. 18, 2005
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who are almost bedridden or completely bedridden (this includes those suffering from dementia).

These people of care levels 4 and 5 are prone to lung and urinary tract infections and bed sores. *Staphylococcus aureus* and *Pseudomonas aeruginosa* infections are one of the major causes of death in these individuals (3, 4). *P. aeruginosa* infections generally occur in the presence of a serious underlying disease. The management of such infections is often difficult due to the multiresistance conferred by the production of metallo-β-lactamase (5). Outbreaks of *P. aeruginosa* dermatitis were reported in whirlpool spas and hydrotherapy pools in long-term care facilities (LTCFs) (6–8). Similar to the case of whirlpool spas in LTCFs (6), MBS clients also share the same bathing equipment; therefore, there is a possibility of contracting infections following the use of MBS (9).

The risk of MBS-associated infections has not been assessed despite the increasing demand for MBS in the Japanese society. Therefore, as a preliminary step towards the prevention and control of MBS-mediated transmission of pathogenic organisms and with the cooperation of a MBS team, we initially examined the bacterial colonization of MBS equipment and subsequently characterized *P. aeruginosa* isolates, which were predominantly recovered from utensils used in the MBS.

## Materials and Methods

*MBS*

The MBS team consisted of a nurse, a helper, a boiler man and a specially designed vehicle. The MBS vehicle is equipped with a boiler for supplying hot water, a knockdown bathtub and a set of bath utensils, which includes a pillow, towels as the bath seat, nets as the bath lift (Fig. 1), and a set of cleansing equipment including a cleansing sponge, washing detergents and disinfectants.

On arrival at the client's home, the client's physical condition was examined by the nurse to evaluate his/her suitability for taking a bath. Subsequently, the knockdown bathtub was set up in the client's bedroom (Fig. 1) and the client was bathed for approximately 15 min in warm water (37–40°C). After the bath, the bathtub, net, and pillow, which is made of urethane foam laminated with polyvinyl chloride (PVC), were washed and disinfected by soaking them in an amphoteric surface active agent, Sanipasuta S (L) (Saraya Co., Ltd., Osaka, Japan) or 0.2% Tego 51 (Nihon Shougi Co., Ltd., Osaka, Japan), which are believed to have an antimicrobial effects on *P. aeruginosa* and *S. aureus*. The net was further cleansed in a washing machine using detergent. Most clients used the MBS once a week. The same MBS team visited approximately six to seven clients in a typical day.

*Clients*

A list of clients using the MBS was provided by an MBS provider in Ibaraki prefecture, Japan (Table 1). Bathing is humiliating for clients because they are dependent on others for this activity; therefore, it was difficult to find clients who would agree to participate in our investigation. Only eight clients

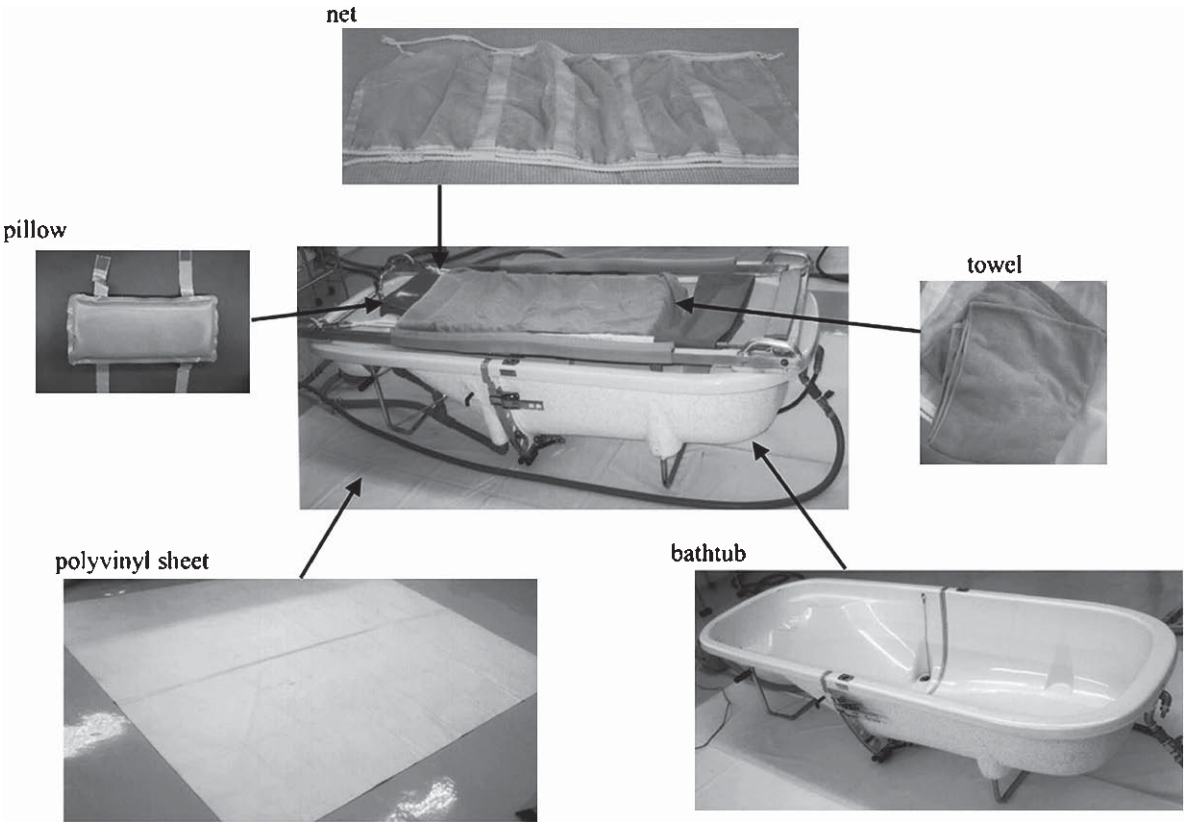


**Fig. 1 Equipment and bathing utensils used in MBS.** The client is laid down on the net covered with a towel and lowered into the bathtub. For details, refer to Materials and Methods.

**Table 1 Information of clients**

| Date | Client No. | Age/sex | Symptom | Frequency of service |
|---|---|---|---|---|
| 2002/09/03 | a | 82/F | osteoarthritis | 1/2 weeks |
| | b | 80/M | cerebral infarction, bedsore | 2/week |
| 2002/09/06 | c | 64/M | myelopathy | 1/week |
| | d | 72/F | poor vision | 3/month |
| 2003/02/20 | e | 84/F | intracerebral hemorrhage | 1/week |
| | f | 77/M | pareplegia | 1/week |
| 2003/02/21 | g | 98/F | cerebral infarction | 2/week |
| | h | 72/F | cerebral infarction, myocardial infarction | 1/week |

agreed to cooperate with the MBS team. The dates of investigation were the 3rd and 6th September 2002 (days 1 and 2, respectively) and the 20th and 21st February 2003 (days 3 and 4, respectively). The MBS team used the same MBS vehicle in this investigation; therefore, the knockdown bathtub and the pillow were common to all the clients. Other MBS utensils such as the nets and towels were personalised. The clients that participated in this study did not have any local or systemic infections according to their clinical records. This investigation was approved by the Ethics Committee of the Ibaraki Prefectural University of Health Sciences.

*Bacterial sampling*

Before and after the service, we collected bacterial isolates from the MBS equipment and bathing utensils by the stamp agar culture method (10), using Petan check medium (standard agar; Eikenkizai Co., Ltd., Tokyo, Japan) and clean stamp medium (SCDLP agar; Nissui Pharmaceutical Co., Ltd., Tokyo, Japan). Petan check medium (standard agar) was used for collecting samples before the MBS, whereas clean stamp medium (SCDLP agar) was used for collecting samples after the MBS. A 20-$cm^2$ stamp was taken randomly from three different sites on the surfaces of the bathtub, pillow, net, towel before and after bath and after the wash/disinfection. One millilitre of boiler water was collected in an Eiken Spits tube before filling the bathtub (Eikenkizai Co., Ltd.). The water sample was mixed with standard agar (Nissui Pharmaceutical Co., Ltd.) and incubated at 37°C for 48 h, in accordance with the quality control guidelines for safe water supply in Japan (11).

*Detection of P. aeruginosa*

At least five colonies suspected to be *P. aeruginosa* were randomly selected from primary culture plates and subcultured on nalidixic acid-cetrimide (NAC) agar (Nissui Pharmaceutical Co., Ltd.). They were biochemically examined to detect the presence of catalase and oxidase, and to determine Voges-Proskauer reaction and glucose fermentation ability. The results were finally confirmed using an API-20NE kit (bioMerieux, France).

*Antibiotic susceptibility test*

All the *P. aeruginosa* isolates were tested for their susceptibilities to imipenem (IPM), ciprofloxacin (CPFX), amikacin (AMK), aztreonam (AZT), ceftazidime (CAZ), meropenem (MEPM), piperacillin (PIPC), tobramycin (TOB), ofloxacin (OFLX) and cefoperazone (CPZ). The test was performed by the disk diffusion assay according to the NCCLS protocols (12). The MIC of IPM (0.002 to 32 μg/ml) was determined using an E-test strip (AB Biodisk, Sweden).

*SpeI-plused field gel electrophoresis typing*

*P. aeruginosa* isolates were subtyped by *Spe*I-pulsed field gel electrophoresis (*Spe*I-PFGE) as described previously (13, 14) under the following conditions: ramp A consisted of an initial switch time of 0.5 s, a final switch time of 25 s and a run time of 20 h; ramp B consisted of an initial switch time of 30 s, a final switch time of 60 s and a run time of 4 h.

*Interpretation of fingerprints*

The similarity between fragments from two isolates was scored using Dice coefficients as described previously (15). An *F* value of 1.0 indicates that the two isolates have identical fingerprint patterns.

## Results

*P. aeruginosa isolates from MBS equipment*

Our initial examination revealed that colonies that predominantly grew on primary culture plates were morphologically consistent with *P. aeruginosa*. Therefore, at least five randomly selected colonies from each primary culture plate were further tested to identify *P. aeruginosa*. Fifty-four *P. aeruginosa* isolates were recovered (Table 2) from the eight clients examined, and of these, 26 (48.1%) were obtained from the pillow. Only two isolates were recovered on day 3 (20th February 2003) and no *P. aeruginosa* was detected on day 4 (21st February 2003).

*Susceptibilities of P. aeruginosa isolates to antimicrobial agents*

The susceptibility of *P. aeruginosa* isolates to IPM, CPFX, AMK, AZT, CAZ, MEMP, PIPC, TOB, OFLX and CPZ were examined. Of the 54 isolates, 18 (33.3%) were IPM-resistant, which included five isolates from the bathtub after the service, eight isolates from the pillow (two before the service, three after the service and three after disinfection), three isolates from the bath water after the service, one isolate from the net after disinfection and one isolate from a towel after the service (Table 2). The MICs of these isolates were between 16 and 32 μg/ml, with the exception of isolate No. 21, the MIC of which was greater than 32 μg/ml (Table 3). IPM resistance was not detected in isolates from clients e, f, g and h. None of the isolates tested

**Table 2 *P. aeruginosa* and IPM-resistant *P. aeruginosa* isolated from equipment and utensils used in mobile bathing service**

| Isolates from | Sampling time | Number of *P. aeruginosa* (IPM-resistant *P. aeruginosa*) isolates | | | | | | | | n | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Day 1 | | Day 2 | | Day 3 | | Day 4 | | | |
| | | client a | client b | client c | client d | client e | client f | client g | client h | | |
| boiler water | BS | — | — | — | — | — | — | — | — | — | — |
| bath water | BS | — | — | — | — | — | — | — | — | — | 13 (3) |
| | AS | 2 (—) | — | 9 (2) | 2 (1) | — | — | — | — | 13 (3) | |
| bathtub | BS | — | 2 (—) | — | — | 1 (—) | 1 (—) | — | — | 4 (—) | 10 (5) |
| | AS | 4 (4) | — | 2 (1) | — | — | — | — | — | 6 (5) | |
| | AD | — | — | — | — | — | — | — | — | — | |
| pillow | BS | — | 5 (2) | — | 1 (—) | — | — | — | — | 6 (2) | 26 (8) |
| | AS | 3 (1) | 2 (—) | 3 (1) | 3 (1) | — | — | — | — | 11 (3) | |
| | AD | 3 (1) | 3 (2) | 2 (—) | 1 (—) | — | — | — | — | 9 (3) | |
| net | BS | — | — | — | — | — | — | — | — | — | 3 (1) |
| | AS | — | 2 (—) | — | — | — | — | — | — | 2 (—) | |
| | AD | 1 (1) | — | — | — | — | — | — | — | 1 (1) | |
| towel | BS | — | — | — | — | — | — | — | — | — | 2 (1) |
| | AS | — | 2 (1) | — | — | — | — | — | — | 2 (1) | |
| Total | | 13 (7) | 16 (5) | 16 (4) | 7 (2) | 1 (—) | 1 (—) | — | — | 54 (18) | |

BS, before MBS; AS, after MBS; AD, after disinfection of MBS equipment; —, not detected; bathtub, pillow, net and towel refer also to Fig. 1.

**Table 3 PFGE data of IPM-resistant *P. aeruginosa* strains**

| Client No. | | Strain No. | Isolated from | Sampling time | MIC of IPM (μg/ml) | PFGE typing (*F*) |
|---|---|---|---|---|---|---|
| Day 1 | client a | 14 | bathtub | AS | 16 | 0.90 |
| | | 15 | bathtub | AS | 16 | 0.92 |
| | | 16 | bathtub | AS | 16 | 0.87 |
| | | 17 | bathtub | AS | 32 | 0.92 |
| | | 20 | pillow | AS | 16 | 1.0 |
| | | 21 | pillow | AD | >32 | 0.33 |
| | | 18 | net | AD | 16 | 0.92 |
| | client b | 28 | pillow | BS | 16 | 0.90 |
| | | 29 | pillow | BS | 16 | 0.40 |
| | | 34 | pillow | AD | 16 | 0.29 |
| | | 35 | pillow | AD | 32 | 0.32 |
| | | 37 | towel | AS | 16 | 0.51 |
| Day 2 | client c | 47 | bath water | AS | 16 | 1.0 |
| | | 48 | bath water | AS | 16 | 1.0 |
| | | 39 | bathtub | AS | 32 | 1.0 |
| | | 41 | pillow | AS | 16 | 1.0 |
| | client d | 56 | bath water | AS | 32 | 1.0 |
| | | 52 | pillow | AS | 16 | 0.92 |

*F*, similarity index (refer to Materials and Methods); AS, after MBS; AD, after disinfection of MBS equipment; BS, before MBS; Day 1, 3rd September 2002; Day 2, 6th September 2002.

were resistant to other antibiotics (data not shown).

*PFGE types of IPM-resistant isolates*

To examine the clonal relationship among the isolates, all IPM-resistant isolates (n=18), that is from clients a to d, were typed by *Spe*I-PFGE. Representative PFGE profiles with their fingerprints are shown in Fig. 2. The fingerprints generated by PFGE consisted of 16 to 20 fragments that were distributed between 40 and 390 kb. Six isolates (20, 39, 41, 47, 48 and 56) exhibited an identical fingerprint pattern (*F*=1.0) and seven isolates (14, 15, 16, 17, 18, 28 and 52) shared a very similar fingerprint pattern (*F*=0.87–0.92) (Table 3 and Fig. 2). Identical strains were detected in the MBS equipment from samples isolated on 2 separate days (strain 20 on day 1 (3rd September 2002) and strains 39, 41, 47, 48 and 56 on day 2 (6th September 2002), Table 2). Strains 21 and 34 also shared a very similar fingerprint pattern (*F*=0.97).

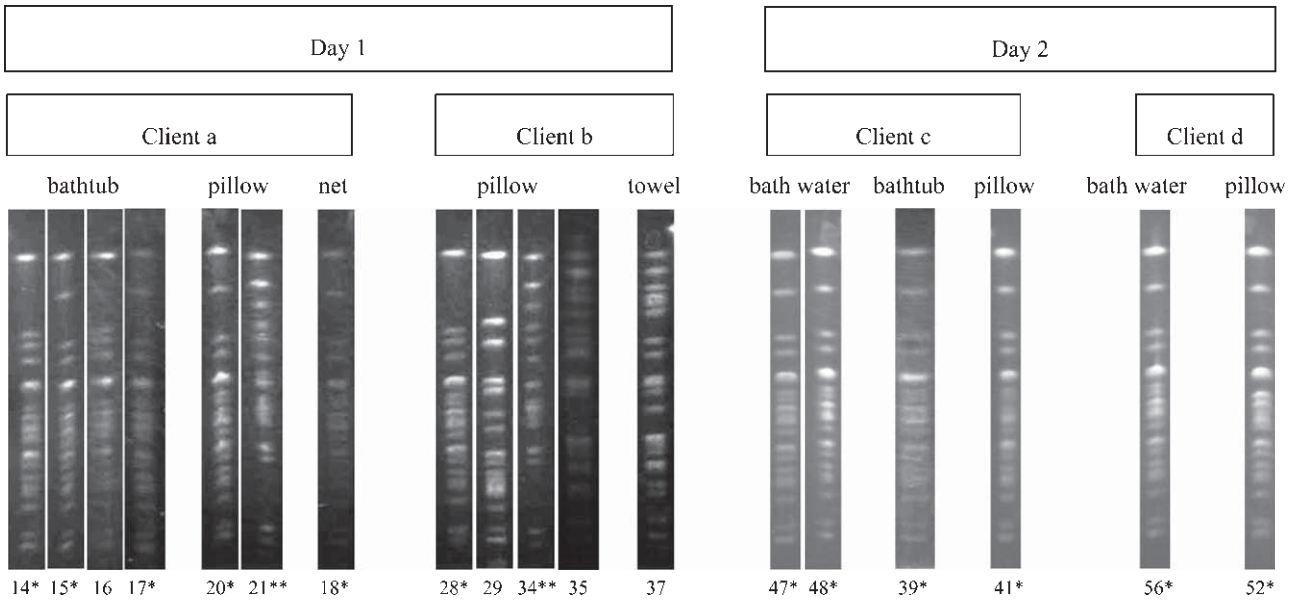


**Fig. 2 *Spe*I-PFGE patterns of representative IPM-resistant *P. aeruginosa* isolates.** Day 1, 3rd September 2002; Day 2, 6th September 2002; *, an identical ($F$=1.0) or a very similar ($F$=0.87–0.92) fingerprint pattern; **, a very similar ($F$=0.97) fingerprint pattern.

## Discussion

Among 54 *P. aeruginosa* isolates, 52 *P. aeruginosa* isolates were recovered on days 1 and 2; (3rd and 6th September 2002); however, on days 3 and 4 (20th and 21st February 2003), only two isolates were detected. The MBS equipment and utensils, except for the towels and nets, were always present in the MBS vehicle that was parked outside. The towels and nets were always stored in a non-air conditioned storehouse. These results suggest that because the weather was hot and humid on days 1 (31.8°C) and 2 (22.6°C), a larger number of *P. aeruginosa* isolates were drecovered. However, the weather was cold and dry on days 3 (6.4°C) and 4 (9.5°C); therefore, fewer isolates were recovered (9).

Eighteen of the 54 *P. aeruginosa* isolates were IPM-resistant. The MICs of these strains ranged from 16 to 32 μg/ml, with the exception of one isolate, which had an MIC greater than 32 μg/ml. In Japan, 8.3% to 21.5% of IPM-resistant *P. aeruginosa* isolates were recovered from hospitals (17–20). These IPM-resistant *P. aeruginosa* isolates were recovered from the urinary tract, skin and the respiratory tract (18–20). The isolation frequency (33.3%) of IPM-resistant *P. aeruginosa* from the MBS equipment and utensils was very high. Although these isolates were not recovered from infection sites, the rates at which they were recovered from the MBS equipment and utensils were from 1.5 to 3 times higher than those from hospitals. It is very dangerous for clients, particularly immunocompromised and bedridden individuals, to use these equipment and utensils that are contaminated with IPM-resistant *P. aeruginosa*. The isolates from MBS equipment and utensils were not highly resistant to IPM; this phenotype was not related to the emergence of metallo-β-lactamase (5, 21).

The PFGE typing results demonstrated that identical *P. aeruginosa* isolates from the pillow and bath water, and those from the bathtub and the net were also genetically closely related ($F$=0.87–0.92) (22). The recovery of identical isolates from the MBS equipment on two separate days strongly suggests the presence of a bacterial reservoir. In the MBS equipment and utensils, boiler, bathtub and pillow were used in common. During our investigation period, no *P. aeruginosa* isolates were recovered from boiler water (data not shown). In addition, there was no structure in the knockdown bathtub that can be a bacterial reservoir. However the pillow was made of the urethane foam covered with vinyl sheet, and was generally used until it was broken (i.e., for more than 2 years). Pinholes could easily form on the vinyl sheet covering urethane foam, through which bath water could easily enter and wet the foam. Although the bathing equipment used in the MBS was washed and disinfected between uses and the level of *P. aeruginosa* contamination in the bathing equipment was significantly decreased after cleaning and disinfecting according to the MBS provider's manual (9), the urethane foam could not be effectively disinfected, which was comfirmed by the recovery of nine *P. aeruginosa* isolates after the disinfection (9). Based on these results, the most probable candidate for the bacterial reservoir is the pillow. It is suspected that bacterial colonies in the pillow subsequently contaminated the bath water and other bathing utensils.

Controlling *P. aeruginosa* infection in geriatric hospitals and nursing homes is very important because the elderly population is considered to be a high risk group for opportunistic infections (3, 23). In long-term care facilities and nursing homes, hydrotherapy pools or whirlpool baths are associated with nosocomial outbreaks (8, 24, 25) particularly *P. aeruginosa* infection (6).

Although no MBS clients contracted infection during this study period, the observations presented in this paper indicate that there is an apparent risk of pathogen transmission among the clients through the use of MBS. If any client contracts an infectious disease, it would be unclear where and when they

contract pathogens because most clients use several other long-term care insurance benefits. Because most clients are bedridden, a lack of obvious symptoms of infection could delay the diagnosis and initiation of treatment (26). Major symptoms of pseudomonas dermatitis are rash, nodule and inflammation (6, 8, 24, 25, 27, 28). It is very difficult for the MBS staff to discriminate between incipient bed sores and pseudomonas dermatitis. Moreover, since most clients are bedridden, frequent and direct contacts between the clients and their caregivers are required, which extends the risk to the caregivers as well.

In summary, we infer from our findings that the pillow was the primary source of bacterial transmission and that there is a risk of MBS-mediated infections among clients and their caregivers. With the increasing popularity of MBS among physically-handicapped elderly Japanese individuals, a periodic monitoring of the MBS equipment for pathogen contamination, the use of a disposable pillow or personal pillow, and the modification of methods of decontamination or disinfection of MBS equipment and bathing utensils should be encouraged to prevent the transmission of infectious diseases through the use of MBS.

## Acknowledgements

We thank the clients and their families for cooperating with our investigation and DEVELO Co., Ltd., (Ibaraki, Japan) for facilitating arrangements for this investigation. Furthermore, we are extremely grateful to Dr. William Ba-Thein (Department of Microbiology/Immunology, Faculty of Allied Health Sciences, Thammasat University) for useful discussion and correction of this manuscript and Dr. Keiko Futagawa-Saito (Associate Professor, Department of Animal Health 2, School of Veterinary Medicine, Azabu University) for useful discussion. This work was partially supported by a grant from the Yuumi Memorial Foundation for Home Health Care, Tokyo, Japan.

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