

ORIGINAL ARTICLE

Outbreak of *Shewanella algae* and *Shewanella putrefaciens* Infections Caused by a Shared Measuring Cup in a General Surgery Unit in Korea

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OBJECTIVE. To control an outbreak of *Shewanella algae* and *S. putrefaciens* infections by identifying the risk factors for infection and transmission.

DESIGN. Matched case-control study.

SETTING. A university-affiliated tertiary acute care hospital in Seoul, Republic of Korea, with approximately 1,600 beds.

PATIENTS. From June 20, 2003, to January 16, 2004, a total of 31 case patients with *Shewanella* colonization or infection and 62 control patients were enrolled in the study.

INTERVENTIONS. Requirement to use single-use measuring cups and standard precautions (including hand washing before and after patient care and use of gloves).

RESULTS. *S. algae* or *S. putrefaciens* was isolated from blood, for 9 (29.0%) of 31 patients who acquired one of the organisms; from bile, for 8 (25.8%), and from ascitic fluid, for 8 (25.8%). The attack rate of this outbreak was 5.8% (31 patients infected or colonized, of 534 potentially exposed on ward A) and the pathogenicity of the two species together was 77.4% (24 patients infected, of 31 who acquired the pathogens). The estimated incubation period for *Shewanella* acquisition was 3–49 days. Using logistic analysis, we identified the following risk factors: presence of external drainage catheters in the hepatobiliary system (odds ratio [OR], 20; $P < .001$), presence of hepatobiliary disease (OR, 6.4; $P < .001$), admission to the emergency department of the hospital (OR, 2.9; $P = .039$), wound classification of “contaminated” or “dirty or infected” (OR, 16.5; $P = .012$), an American Society of Anesthesiologists score of 3 or higher (OR, 8.0; $P = .006$), duration of stay in ward A (OR, 1.1; $P < .001$), and, for women, an age of 60–69 years (OR, 13.3; $P = .028$). A *Shewanella* isolate was recovered from the surface of a shared measuring cup, and 12 isolates of *S. algae* showed the same pulsed-field gel electrophoresis pattern.

CONCLUSIONS. This *Shewanella* outbreak had a single-source origin and spread by contact transmission via a contaminated measuring cup. *Shewanella* species are emerging as potentially serious human pathogens in hospitals and could be included in hospital infection surveillance systems.

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The natural habitats of *Shewanella* species are water (including fresh, brackish, and salt) and soil; they have also been isolated from marine environments, sediments, and oil fields.^{1–7} The first report of *Shewanella* acquisition by humans was in 1964,⁸ and there was no report of humans being infected with *Shewanella* until 1975.⁹ Since then, more than 40 reports or reviews concerning *Shewanella* infection in humans have been published (according to a search of Medline). *Shewanella algae* and *Shewanella putrefaciens* are associated with human infections that include bacteremia,^{6,10–22} cellulitis (skin and soft tissue infection),^{6,9,10,14–16,23–27} ear infection,^{28,29} cere-

bellar abscess,³⁰ wound infection,³¹ osteomyelitis,³² empyema,³³ endocarditis,^{34,35} and peritonitis.³⁶

The typical predisposing factors for infection with *S. algae* or *S. putrefaciens* are exposure to a marine environment with a skin lesion or skin trauma^{10,14,16,23,24,28,30,31}; other factors include the presence of a severe underlying debility, liver disease, or malignancy; prematurity; and a compromised immune system.^{6,11,12,24,26,35} Most infections with *Shewanella* have been community associated; hospital-associated infections have been very uncommon.³⁶

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No *Shewanella* infections in humans or clinical isolates of this pathogen had been reported in the Republic of Korea before June 2003. Between June 20, 2003, and January 16, 2004, a total of 31 cases of *S. algae* or *S. putrefaciens* infection or colonization were identified; they were clustered in a single general surgical ward of Seoul National University Hospital. In this study, we report the results of an investigation of this epidemic. The aims of this study were to describe the epidemiological features of *Shewanella* infection and to identify the modes of transmission and the risk factors for acquisition, so that the infections can be controlled in the hospital.

METHODS

Settings

The study hospital is a university-affiliated tertiary acute care hospital in Seoul, Republic of Korea, with approximately 1,600 beds. There are 5 general surgery wards for inpatients. The outbreak of *S. algae* and *S. putrefaciens* occurred in a single general surgery ward, ward A, which has 34 beds, 11 registered nurses, 2 nurse aides, and 3 physicians (2 resident physicians and 1 intern). Surgeons, who were professorial staff, attended to patients and performed surgery in their specialty areas in the 5 general surgery wards. The patients were randomly admitted to any of the 5 general surgery wards, regardless of diagnosis, severity of disease, or other considerations.

Case Definition and Case Ascertainment

Case patients were defined as patients on ward A who had *S. algae* or *S. putrefaciens* isolated from any clinical specimens from June 20, 2003, to January 16, 2004. Both *S. algae* and *S. putrefaciens* were included because they are biologically similar, and *S. algae* has only recently been reclassified to distinguish it from *S. putrefaciens*.¹ A total of 31 case patients were enrolled in the study. Case patients were categorized as infected or colonized with *Shewanella* according to the definitions of the Centers for Disease Control and Prevention.^{37,38} We identified case patients by microbiologic surveillance.

Epidemiologic Investigation and Statistical Analysis

A retrospective, matched case-control study was performed. A total of 62 control patients were selected from ward A to be matched at a ratio of 2:1 by month of admission, to control for exposure time during the epidemic period. These control patients were randomly selected using SPSS for Windows, version 12.0 (SPSS). Patient data were collected on age, sex, underlying disease, duration of hospital stay, history of smoking and drinking, type of hospital admission, type of surgery performed, receipt of other invasive treatments, and type of surgical drain used.

Data distributions were checked using data exploration methods and then initially analyzed using descriptive statistics (frequency distribution, the Student *t* test, and the χ^2 test). Univariate analysis was done with a general linear model and

univariate logistic methods, and multivariate logistic analysis (ie, forward stepwise conditional logistic regression analysis) was also done. Odds ratios (ORs) were used to identify the risk factors for the acquisition of *S. algae* or *S. putrefaciens*. Statistical analyses were performed using SPSS for Windows, version 12.0 (SPSS). A *P* value of less than .05 was considered statistically significant.

Procedure and Observational Reviews

We closely observed the following infection control practices of healthcare workers (HCWs): use of aseptic technique for an entire operative procedure, for angiographic procedures, and for postoperative wound and drain care; use of saline solution; disinfection and sterilization of devices; hand hygiene; and use of gloves before and after caring for a patient's wound. We reviewed any changes in patient care: use of commercial normal saline, invasive devices, and other materials; the skills and practices of HCWs; and the staff-to-patient ratio.

Microbiological Studies

We performed an extensive environmental investigation because of the wide range of natural habitats and halophilicity of *Shewanella* species.^{1,3} The water sources investigated included the normal saline solution used in intravenous infusions, wound irrigation, and drainage catheter flushing or irrigation; distilled water used in large room air humidifiers, sink water, and diluted antiseptics; water and soil in flowerpots in the nursing station; and any food preserved with salt or raw seafood supplied by the patients' families. The following patient-care devices were also included in the investigation: the surfaces of stainless steel dressing carts and the blood-pressure cuffs, stethoscopes, and thermometers that are commonly shared among patients.

Clinical specimens submitted for bacterial culture were analyzed with standard microbiologic procedures. Environmental samples were inoculated onto MacConkey agar plates, and colorless colonies were selected after overnight incubation. The isolates were identified with the Vitek 2 automated system (boiMérieux).

Pulsed-Field Gel Electrophoresis (PFGE)

PFGE was performed according to the modified procedures of PulseNet.³⁹ In brief, agarose-embedded DNA was digested with 40 U of *Sma*I (New England Biolabs) for 4 hours at 25°C. The restriction fragments were separated by electrophoresis in a 0.5 × Tris-borate-ethylenediaminetetraacetic acid buffer at 14°C for 15 hours using a CHEF Mapper electrophoresis system (Bio-Rad) with pulse times of 5.16–40.17 seconds. The gels were stained with ethidium bromide, and DNA bands were visualized with UV transillumination.

Infection Control Procedures

After this outbreak, single-use measuring cups were used, and standard precautions for HCWs included hand hygiene before

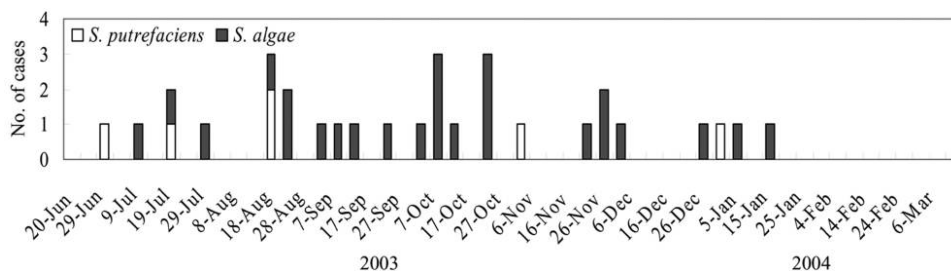


FIGURE 1. Epidemic curve for the outbreak of infection with *Shewanella algae* or *Shewanella putrefaciens* ($n = 31$), by month

and after patients care and glove use. Use of strict aseptic technique was also required.

RESULTS

Case Patients

From June 20, 2003, to January 16, 2004, a total of 31 case patients with *S. algae* or *S. putrefaciens* infection or colonization were identified (Figure 1). There were 2 possible index patients. One was a 63-year-old woman with a Klatskin tumor, who was admitted to the emergency department with ascending cholangitis on June 20, 2003. She had had recurring episodes of common bile duct stones since 1991, when she had undergone a cholecystectomy and choledochostomy for common bile duct stones. *S. putrefaciens* and *Aeromonas hydrophila* were first isolated from culture of her external percutaneous transhepatic biliary drainage catheter on June 29, 2003. The other possible index patient was a 66-year-old woman with hepatocellular carcinoma, who was admitted on June 26, 2003; *S. algae* was first isolated from culture of her Jackson-Pratt catheter on July 9, 2003.

S. algae was isolated from 25 case patients, and *S. putrefaciens* was isolated from 6 case patients; both species were not isolated from any single case patient. *S. algae* and *S. putrefaciens* were isolated from blood, for 9 patients (29.0%, 8 with *S. algae* and 1 with

S. putrefaciens); from bile, for 8 (25.8%, 7 with *S. algae* and 1 with *S. putrefaciens*); from ascitic fluid, for 8 (25.8%, 5 with *S. algae* and 3 with *S. putrefaciens*); from skin and soft tissue, for 5 (16.1%, 4 with *S. algae* and 1 with *S. putrefaciens*); and from stool, for 1 (3.2%) with *S. algae*. Healthcare-acquired *Shewanella* infections developed in 24 (77%) of the 31 case patients (20 [64%] with *S. algae* and 4 [13%] with *S. putrefaciens*). The remaining 7 (23%) case patients were colonized with either *S. algae* or *S. putrefaciens*. Of the 24 case patients infected with *Shewanella*, 5 (21%) developed a bloodstream infection (all with *S. algae*), and 19 (79%) developed a surgical site infection (15 [79%] with *S. algae* and 4 [21%] with *S. putrefaciens*). Of the 19 cases of surgical site infection, 13 (68%) were an intra-abdominal infection with hepatobiliary tract infection, 4 (21%) were superficial incisional wound infection, and 2 (11%) were deep incisional wound infection.

Of the 31 case patients, 21 (67.7%) had hepatobiliary disease. All 31 case patients had external drainage catheters, 23 (74.2%) of whom had their catheters located in or near the hepatobiliary system.

Case patients presented with the following signs and symptoms: fever (temperature, $>38^{\circ}\text{C}$) in 23 patients (74.2%), abdominal pain in 9 (29.0%), pus or purulent drainage in 9 (29.0%), and chills in 6 (19.4%). The mean interval (\pm SD)

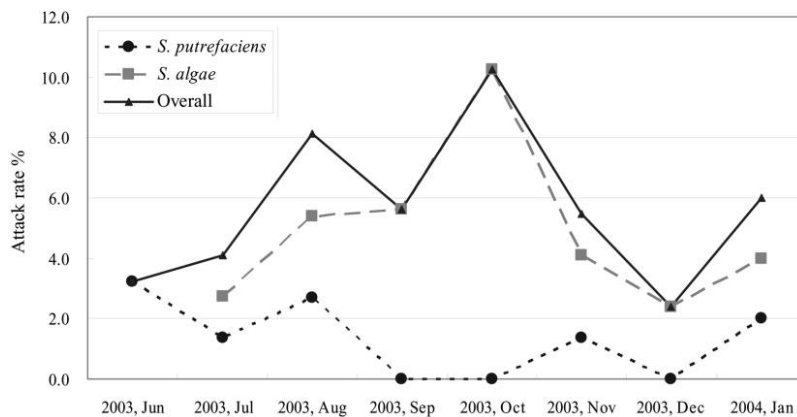


FIGURE 2. Monthly attack rate of infection or colonization with *Shewanella algae* and *Shewanella putrefaciens*. There were 534 patients potentially exposed.

TABLE 1. Univariate Logistic Analysis (Forward Stepwise Conditional) of Variables Possibly Associated With Acquisition of *Shewanella algae* and *Shewanella putrefaciens*

Variable, by class	Case patients (n = 31)	Control patients (n = 62)	OR (95% CI)	P
Demographic				
Sex				
Male	17 (54.8)	39 (63.0)		
Female	14 (45.2)	23 (37.0)		
Age				
Mean age \pm SD, years				
All patients	59.1 \pm 11.5	54.9 \pm 14.7		.166 ^b
Male patients	56.5 \pm 13.4	57.8 \pm 15.2		.759 ^b
Female patients	62.3 \pm 8.0	50.0 \pm 13.1	1.124 (1.029–1.220)	.010
Age group, female patients				
<50 years	1 (7.1)	10 (43.5)	1.0	
60–69 years	8 (57.1)	6 (26.1)	13.333 (1.321–134.615)	.028
Tobacco use	3 (11.5)	18 (29.5)		.073 ^a
Alcohol use	3 (11.5)	26 (42.6)		.003 ^a
Clinical				
Hepatobiliary disease	18 (58.1)	11 (17.7)	6.420 (2.443–16.870)	<.001
Admitted via emergency department	11 (35.5)	10 (6.1)	2.860 (1.052–7.772)	.039
Duration of stay in ward A, mean \pm SD, days	29.5 \pm 20.3	12.1 \pm 9.1	1.141 (1.073–1.214)	<.001
Angiography	19 (61.3)	5 (8.1)	0.055 (0.017–0.178)	<.001
Surgery	28 (90.3)	59 (96.7)		.371 ^a
Duration of procedure, minutes, mean \pm SD	224.5 \pm 110.8	144.7 \pm 85.2	1.008 (1.003–1.014)	<.001
Wound classification				
Clean	2 (6.5)	1 (1.6)	1.0	
Clean contaminated	20 (64.5)	46 (74.2)		
Contaminated, or dirty or infected	6 (19.4)	2 (3.2)	16.500 (1.862–48.606)	.012
ASA score				
1	6 (19.4)	24 (38.7)	1.0	
2	13 (41.9)	26 (41.7)		
3 or 4	8 (25.8)	4 (6.5)	8.000 (1.790–35.744)	.006
Drainage catheter remained in situ	31 (100.0)	36 (58.1)		<.001 ^a
Catheter located in the hepatobiliary system	20 (63.5)	3 (8.3)	20.000 (4.971–80.473)	<.001
Amount of external drainage fluid, mean \pm SD, mL per day	151.1 \pm 181.7	71.9 \pm 63.6	1.006 (1.001–1.012)	.031

NOTE. Data are no. (%) of patients or mean value SD, unless otherwise indicated. ASA, American Society of Anesthesiologists; CI, confidence interval; OR, odds ratio.

^a P value obtained by χ^2 test.

^b P value obtained by *t* test.

from admission to ward A to isolation of *Shewanella* was 15.9 \pm 10.1 days (range, 5–57 days), and the mean interval from first drain insertion to isolation of *Shewanella* was 14.0 \pm 10.0 days (range, 3–49 days).

Of the 31 case patients, 6 (19%) developed secondary sepsis: 5 (16%) with *S. algae* and 1 (3%) with *S. putrefaciens* ($P = .99$; Fisher exact test). Of the 5 case patients who were infected with *S. algae*, 3 (60%) died; the remaining 28 case patients recovered from their infection.

Epidemiologic and Statistical Analysis

The attack rate of this outbreak of *Shewanella* infection was 5.8% (31 patients infected or colonized, of 534 potentially exposed on the 5 study wards). The attack rate of for *S. algae* infection was 5.0% (25 patients infected or colonized, of 503

potentially exposed), and the attack rate for *S. putrefaciens* infection was 1.1% (6 patients infected or colonized, of 534 potentially exposed) (Figure 2). The pathogenicity of the two species together was 77.4% (24 patients developed infection, of 31 who acquired the pathogens); the pathogenicity of *S. algae* was 80% (20 of 25 patients), and that of *S. putrefaciens* was 66.7% (4 of 6 patients) (Fisher's exact test, $P = .596$).

In univariate analysis, we found that use of an external drainage catheter was a significant risk factor (OR, 20; $P < .001$) for acquisition of *Shewanella* species. The other risk factors identified were as follows: presence of hepatobiliary disease (OR, 6.4; $P < .001$), being female (OR, 13.3; $P < .01$), hospital admission via the emergency department, a surgical wound classification of "contaminated" or "dirty or infected" (OR, 16.5), an American Society of Anesthesiolo-

TABLE 2. Multivariate Logistic Analysis (Forward Stepwise Conditional) Identifying Variables Associated With Acquisition of *Shewanella algae* and *Shewanella putrefaciens*

Variable	β coefficient	SE	Wald χ^2 test statistic	OR (95% CI)	P
Duration of stay in ward A	0.118	0.031	14.598	1.125 (1.059–1.195)	<.001
Hepatobiliary disease	1.707	0.589	8.392	5.515 (1.737–17.509)	.004
Constant	-3.410	0.649	27.577	0.033	<.001

NOTE. CI, confidence interval; OR, odds ratio.

gists score of 3 or higher (OR, 8.0), and a hospital stay in ward A (Table 1).

In multivariate logistic analysis with the variables hospital stay in ward A, admission via the emergency unit, and hepatobiliary disease, we found that the probability of acquisition of *Shewanella* species was significantly influenced by the presence of hepatobiliary disease and a hospital stay in ward A (Table 2).

Procedure and Observational Review

We did not find any lapses in the use of aseptic technique, disinfection, and sterilization practices during operations or angiographic procedures, or in use of salinity fluids. We did not find any changes in use of commercial products or in the staff-to-patient ratio. However, a measuring cup that was used for catheter drainage was reused continuously for many patients. Strict “no-touch” technique was not maintained: when a HCW drained a patient’s catheter bag, the bag’s opened port easily touched the measuring cup. Hand hygiene and glove use were not routinely practiced when HCWs cared for a patient’s wound or external drainage catheter.

Microbiological Studies

There were 134 environmental specimens cultured. *S. algae* and *A. hydrophila* were both isolated only from the surface of the measuring cup that was reused continuously in ward A. All 12 *S. algae* isolates showed the same PFGE pattern (Figure 3)

DISCUSSION

To the best of our knowledge, no outbreak of *Shewanella* infection in a hospital has been reported until now. In this study, we identified some very important new findings concerning *Shewanella* as an emerging pathogen in hospitals, including its mode of transmission, its clinical manifestations, and its pathogenicity, virulence, and infectivity. These have not been described previously, to our knowledge.

This outbreak, which occurred in general surgery ward A, was exceptionally unusual and unpredictable. We isolated *Shewanella* species from patients’ clinical specimens in October 2003. When we subsequently reviewed all of the microbial reports closely and retrospectively, we found that *Shewanella* species had been isolated in June 2003. We strongly suspected all kinds of water to be the common source of this outbreak, especially saline solution, because of its natural properties.^{1,40} We closely observed any lapses in the use of aseptic technique and infection control, in the operating room and the angiog-

raphy room, where Jackson-Pratt catheters, percutaneous catheter drainage catheters, or percutaneous transhepatic bile drainage catheters were inserted, as well as in ward A. Interestingly, no angiographic procedure was definitely identified as a risk factor for *Shewanella* acquisition (Table 1). This might be because catheters inserted in the angiography room drained well.

All 31 case patients had external drainage catheters, which could constitute the exact entrance of *Shewanella*. Of these 31 case patients, 18 (58%) had a diagnosis of hepatobiliary disease (Tables 1 and 2). Hepatobiliary disease was confirmed by logistic analysis to be a risk factor for the acquisition of *Shewanella* (OR, 5.5–6.4; Tables 1 and 2). This finding is consistent with the results of previous studies^{6,11,13} and might be related to the lipophilicity of *Shewanella* species.⁴¹

A hospital stay in ward A showed a positive dose-response correlation with the probability of *Shewanella* acquisition (OR, 1.1) (Tables 1 and 2). This finding might be related to the HCW practice in ward A of draining catheters with a common cup that was continuously reused, and this could explain why this epidemic occurred only in ward A and not in the other general surgery wards. Other confirmed risk factors, such time of surgery, wound classification of “contaminated” or “dirty or infected” (OR, 16.5), American Society of Anesthesiologists score of 3 or higher (OR, 8.0), and hospital admission via the emergency department (OR, 2.9), could illustrate the severity of host-related factors (Table 1).

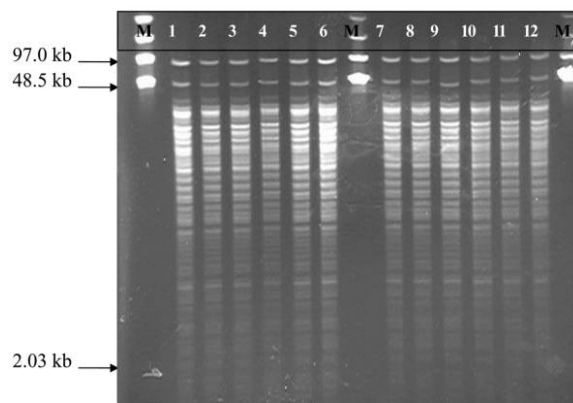


FIGURE 3. Pulsed-field gel electrophoresis banding patterns of the 12 *Shewanella algae* isolates. Lanes 1–9, 11, and 12, isolates recovered from blood specimens; lane 10, isolate recovered from a wound specimen. kb, kilobase; M, DNA marker.

Interestingly, greater age (60–69 years; OR, 13.3) was a risk factor for *Shewanella* acquisition for women but not for men (Table 3). This finding is also unique because it has not been described in previous reports.^{1,6,12,42}

We estimated that the incubation period for *Shewanella* acquisition ranged widely, from 3 to 49 days, based on the probable day of infection with *Shewanella* (ie, when the drainage catheter was inserted). We could not assess exposure times exactly because we could not accurately estimate when the measuring cup was changed between patients. Therefore, exposure time could validly be considered as equivalent to the period from drainage catheter insertion to diagnosis. Previous reports of definite exposures to seawater or freshwater have shown various ranges of incubation periods: 1–5 days,²⁸ 1 day,⁴² 3 days,^{23,26} 6 days,³¹ 4 months,¹⁰ and 10 months.³²

The medical histories of 2 possible index patients indicated no exposure of any kind to seawater or freshwater. We could not confirm how they originally acquired *Shewanella*. However, the eating of raw fish, such as sushi and other raw fish preserved in salt, is very popular among the general population of South Korea. Therefore, we cannot completely exclude the possibility that these patients, or their families or visitors, ingested raw seafood.

In this study, the pathogenicity of the *Shewanella* species was relatively high. However, we found no difference in pathogenicity or virulence between *S. algae* and *S. putrefaciens*, which is inconsistent with data from other reports.^{1–4,43} This discrepancy might be attributable to the small number of *S. putrefaciens* infections. Infectivity was higher for *S. algae* than for *S. putrefaciens*, which has not been described in previous reports (Figure 2).

Because *Shewanella* was recovered only from the surface of a measuring cup used commonly for multiple patients and PFGE patterns were identical for all isolates (Figure 3), we conclude that this outbreak had a single-source origin; namely, the shared measuring cup. Only 12 isolates of *S. algae* recovered from blood specimens were stored, so we were able to perform PFGE on only some of the *Shewanella* isolates. The DNA fragments were very small and could not be easily separated; we tried 5 times to get the typing results (Figure 3).

After it was established that the measuring cup must be changed after every use and that stricter infection control methods must be implemented (including hand washing before and after patient care and use of gloves, as well as other standard precautions), this epidemic of *Shewanella* infection was brought under control. We regret that we did not detect this unusual organism earlier.

In conclusion, we found that this outbreak had a single-source origin, which was the shared measuring cup. *Shewanella* species are more than simple environmental organisms, they can act with extraordinary effectiveness as significant opportunistic human pathogens, if they are introduced into a hospital by chance. Furthermore, it cannot be overstated that standard precautions must be strictly maintained in hospitals.

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Potential conflicts of interest. All authors report no conflicts of interest relevant to this article.

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