Cluster and Sporadic Cases of *Herbaspirillum* Species Infections in Patients With Cancer

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Background. *Herbaspirillum* species are gram-negative Betaproteobacteria that inhabit the rhizosphere. We investigated a potential cluster of hospital-based *Herbaspirillum* species infections.

Methods. Cases were defined as *Herbaspirillum* species isolated from a patient in our comprehensive cancer center between 1 January 2006 and 15 October 2013. Case finding was performed by reviewing isolates initially identified as *Burkholderia cepacia* susceptible to all antibiotics tested, and 16S ribosomal DNA sequencing of available isolates to confirm their identity. Pulsed-field gel electrophoresis (PFGE) was performed to test genetic relatedness. Facility observations, infection prevention assessments, and environmental sampling were performed to investigate potential sources of *Herbaspirillum* species.

Results. Eight cases of *Herbaspirillum* species were identified. Isolates from the first 5 clustered cases were initially misidentified as *B. cepacia*, and available isolates from 4 of these cases were indistinguishable. The 3 subsequent cases were identified by prospective surveillance and had different PFGE patterns. All but 1 case-patient had bloodstream infections, and 6 presented with sepsis. Underlying diagnoses included solid tumors (3), leukemia (3), lymphoma (1), and aplastic anemia (1). *Herbaspirillum* species infections were hospital-onset in 5 patients and community-onset in 3. All symptomatic patients were treated with intravenous antibiotics, and their infections resolved. No environmental source or common mechanism of acquisition was identified.

Conclusions. This is the first report of a hospital-based cluster of *Herbaspirillum* species infections. *Herbaspirillum* species are capable of causing bacteremia and sepsis in immunocompromised patients. *Herbaspirillum* species can be misidentified as *Burkholderia cepacia* by commercially available microbial identification systems.

Keywords. *Herbaspirillum*; cancer; outbreak; immunocompromised; misdiagnosis.

Herbaspirillum species are gram-negative, flagellate members of the Betaproteobacteria class of bacteria, which includes *Burkholderia*, *Ralstonia*, and other

plant-associated bacteria. Most species of *Herbaspirillum* are nitrogen-fixing bacteria that are commonly found in the rhizosphere and colonize plants endophytically. They are found in the roots and stems of maize, rice, beans, bananas, sugar cane, pineapple, and other plants [1, 2] and they have been recovered from groundwater [3] and drinking water distribution systems [4] as well. In the published literature, *Herbaspirillum* species have been recovered from respiratory secretions of patients with cystic fibrosis (CF) [5, 6] and described in case reports of 4 patients with bacteremia, 2 of whom had an underlying malignancy [6–9]. Its close phylogenetic and phenotypic resemblance to *Burkholderia cepacia*

complex led to initial misidentification in 2 of the 4 reported cases [6, 9]. To our knowledge, no outbreaks or clusters of cases have been previously reported in the literature.

Between June and August 2011, we identified an initial cluster of 5 patients with bloodstream infection caused by a gram-negative bacillus, initially identified as *B. cepacia* complex. The isolates were susceptible to all antibiotics tested, whereas over the years, previous *B. cepacia* isolates recovered in our institution were resistant to at least 1 and up to 4 of the antibiotics tested. These isolates were submitted to the Cystic Fibrosis Foundation *Burkholderia cepacia* Research Laboratory and Repository at the University of Michigan and were subsequently reidentified as *Herbaspirillum* species.

We conducted a joint investigation with the Texas Department of State Health Services (TDSHS) and the Centers for Disease Control and Prevention (CDC) to determine the nature and extent of the cluster of *Herbaspirillum* species infections. This report describes the clinical and epidemiologic findings from our investigation and provides a review of the literature.

MATERIALS AND METHODS

Setting

The University of Texas MD Anderson Cancer Center is a National Cancer Institute–designated comprehensive cancer center in Houston, Texas, with approximately 620 beds, 25 000 admissions in 2011, and >1 million patient visits per year.

Case Definition

We defined a case as a *Herbaspirillum* species clinical isolate confirmed by genetic sequencing in a patient who received care at MD Anderson between 1 January 2006 and 15 October 2013. The University of Texas MD Anderson Cancer Center Institutional Review Board approved this study and a waiver for informed consent was granted.

Case Finding

We performed a retrospective laboratory review of *B. cepacia* clinical isolates recovered at our institution from 1 January 2006 to 24 October 2011, to identify *Herbaspirillum* species cases that may have been misidentified previously, and we reviewed microbiology records prospectively until 15 October 2013 to identify additional cases. Antibiotic susceptibility was determined using Etest and interpreted according to Clinical and Laboratory Standards Institute (CLSI) 2011 standards. All pan-sensitive *B. cepacia* clinical isolates were submitted to the Cystic Fibrosis Foundation *Burkholderia cepacia* Research Laboratory and Repository at the University of Michigan for 16S ribosomal DNA (16s rDNA) sequencing as described previously [6, 10]. Any isolate identified as *Herbaspirillum* species was

sent to TDSHS, where pulsed-field gel electrophoresis (PFGE) was performed according to methods previously described [11].

Case Description

We reviewed the medical records of all *Herbaspirillum* species cases and reviewed their demographic and clinical characteristics. We also assessed for any common exposures among identified cases.

Definitions

Herbaspirillum species case-patients were considered to have sepsis if they had any 2 of the following: heart rate >90 beats per minute; respiratory rate >20 breaths per minute; temperature >38°C or <36°C; or white blood cell count >12 000 cells/μL or <4000 cells/μL or >10% bands. For this investigation, catheter-related bloodstream infection (CRBSI) was defined as per the guidelines of the Infectious Diseases Society of America [12]. *Herbaspirillum* species infections were considered community-onset when cultures were drawn as an outpatient or prior to hospital day 3, or hospital-onset when the infection was diagnosed after 3 days of hospitalization and within 3 days of discharge.

Facility Observations and Infection Prevention Assessments

We conducted an in-depth site inspection between October and November 2011, which included an inspection and review of the schematics of the hospital water system to determine the water supply for rooms occupied by case-patients. We also observed the handling, transport, and processing of blood cultures to exclude laboratory contamination.

We observed and interviewed healthcare personnel within selected areas of the hospital where case-patients had received care. The following infection prevention practices were assessed: hand hygiene and personal protective equipment use, preparation of injectable medications (in patient care areas and the central pharmacy), infusion technique and maintenance of central lines, environmental cleaning and disinfection, and the reprocessing of bronchoscopes (1 of the case-patients had a preceding bronchoscopy).

Environmental and Product Sampling

To investigate potential sources of *Herbaspirillum* species, we tested various sources of water and surface samples in case-patient-specific and common areas of the hospital. Prefilled saline syringes commonly used to flush intravenous medications were also tested.

For each small surface sample (eg, faucet aerator or shower-head hose in rooms of case-patients), we removed the aerator or showerhead and swabbed the inside surface with a sterile swab. The swab was then sealed, refrigerated, and transported to the CDC, where the swab was processed by adding 3 mL of phosphate-buffered saline and vortexed. Various concentrations of the resulting extract were placed on MacConkey II (MAC)

and tryptic soy agar (TSA) plates (Becton Dickinson Diagnostics, Sparks, Maryland).

For each large surface sample (eg, ice machine, water fountain in the hospital lobby, pharmacy hood, and pneumatic tube canister), we wiped a surface up to 2 square feet with a sterile 3M Sponge-Stick (3M, St Paul, Minnesota). Sponges were then placed in sterile bags, sealed, refrigerated, and transported to the CDC. The sponges were then processed by adding 100 mL of phosphate-buffered saline with 0.2% tween 80, and homogenized in a stomacher at 200 rpm for 1 minute. The resulting eluent was centrifuged, and the pellet was resuspended and plated on TSA and MAC plates.

For each water sample (from sinks, showerhead, water fountain, and facility water tanks), we collected 1 L of water in a sterile container with sodium thiosulfate tablets. Upon receipt by the CDC laboratory, 10 mL of each water sample was filtered through a sterile 0.45-μm membrane filter; the filters were then placed on a TSA plate, and 0.1 mL of each water sample was also spread on a control TSA plate. The remaining volume was filtered and placed on a MAC plate. All plates were incubated for 48 hours at 30°C. All environmental sampling and processing was performed according to standardized protocols developed by the Clinical and Environmental Microbiology Branch of the Division of Healthcare Quality Promotion at the CDC.

For each saline syringe sample, the exterior of each syringe was sanitized with 70% ethanol and the saline was pooled based on matching manufacturer and lot number. Membrane filtration was then performed as described in US Pharmacopeia Convention Chapter <71>, Sterility Tests [13].

RESULTS

Case Finding

Retrospective Review of B. cepacia Isolates

There were 46 clinical isolates of *B. cepacia* identified between 1 January 2006 and 24 October 2011. Nine were from blood cultures, 24 were from sputum, and 13 were from other sources. All *B. cepacia* isolates were resistant to at least 1 antibiotic tested, most frequently ticarcillin-clavulanate (Figure 1).

Herbaspirillum Species Cases

Eight patients (A–H), including the original 5 (A–E) and 3 additional cases identified prospectively (F–H), had 21 positive *Herbaspirillum* species cultures between 5 July 2011 (first isolate) and 3 August 2012 (last isolate) (Table 1). Eighteen cultures were obtained from blood, and 1 each was obtained from sputum, central venous catheter (CVC) tip, and an extracted infusaport. Isolates from 4 patients (A, C, D, and E) were indistinguishable by PFGE analysis, whereas 3 patients (F–H) had different PFGE patterns (Figure 2). The isolate from 1 patient (patient B) was not available for typing. Interestingly, the 4 cases with indistinguishable PFGE pattern isolates
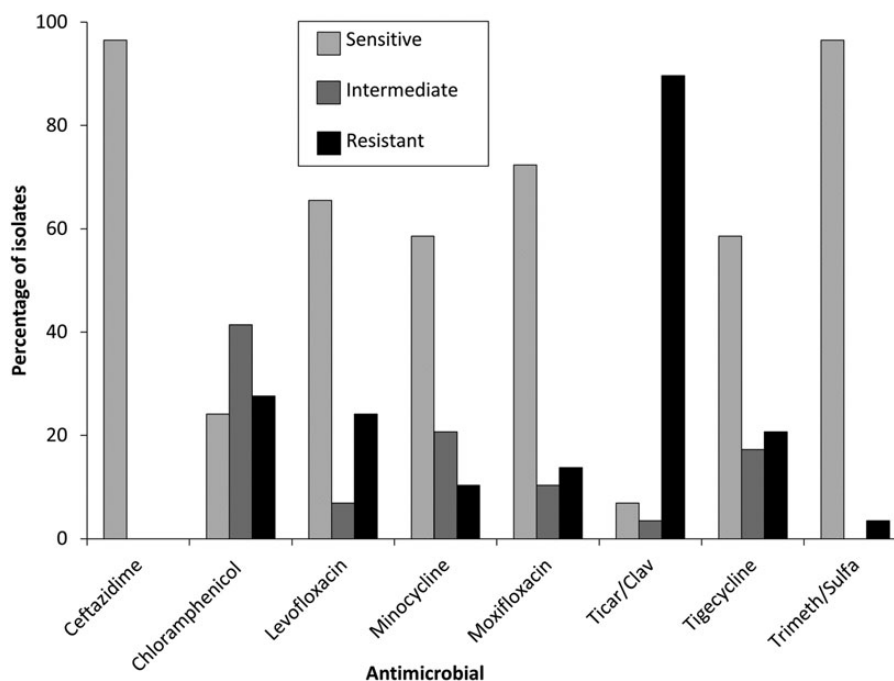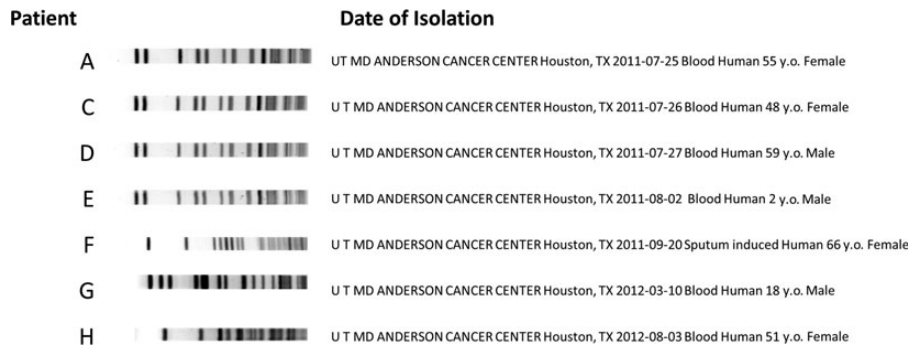

Figure 1. Antimicrobial susceptibility of the isolate of *Burkholderia cepacia* cases, 2006–2011. Abbreviations: Ticar/Clav, ticarcillin–clavulanate; Trimeth/Sulfa, trimethoprim–sulfamethoxazole.

Table 1. Cases of *Herbaspirillum* Infection

Patient	Age/Sex	Cancer/HSCT	Immunosuppression	Reason for Admission	Clinical Presentation	Type of CVC	CVC Removed	Days From Admission to Positive Culture	Date of First Positive Culture	Days From Index Case	Source (No. Positive)
A	48/F	Ovarian adenocarcinoma	Chemotherapy (−30 d)	*Pseudomonas fluorescens* BSI	Sepsis—CRBSI	Infusaport	Yes	7	5 July 2011	0[a]	Blood (3), Line tip (1)
B	67/F	Leukemia	Chemotherapy (−4 d)	Chemo, MRSA pneumonia	Sepsis—BSI	PICC in right arm	No	11	19 July 2011	14	Blood (1)
C	58/M	Leukemia/HSCT	High-dose steroids (30 d)	GI GVHD—GI bleed	BSI	PICC in right subclavian; apheresis CVC in left subclavian	Yes	36	26 July 2011	21	Blood (4)
D	55/F	Leukemia/HSCT	High-dose steroids (8 d)	GI GVHD	BSI	PICC in right arm	Yes	15	25 July 2011	20	Blood (1)
E	2/M	Ependymoma	High-dose steroids (14 d)	*Herbaspirillum*	Sepsis—BSI	PICC (basilic)	Yes	−2	2 Aug 2011	28	Blood (6)
F	66/F	Lung	Radiation therapy	*Herbaspirillum*	Sepsis—pneumonia	None	NA	0	20 Sept 2011	77	Sputum (1)
G	18/M	Lymphoma	Chemotherapy (−4 d)	Chemotherapy	Sepsis—BSI	PICC (basilic)	Yes	5	10 Mar 2012	249	Blood (2)
H	51/F	Aplastic anemia/HSCT	Tacrolimus	*Herbaspirillum*	Sepsis—CRBSI	PICC (basilic)	Yes	−1	3 Aug 2012	395	Blood (1), Line tip (1)

Abbreviations: BSI, bloodstream infections; Chemo, chemotherapy; CRBSI, catheter-related bloodstream infection; CVC, central venous catheter; GI, gastrointestinal; GVHD, graft-vs-host disease; HSCT, hematopoietic stem cell transplant; MRSA, methicillin-resistant *Staphylococcus aureus*; NA, not applicable; PICC, peripherally inserted central catheter.

[a] Index case.

Patient	Date of Isolation
A	UT MD ANDERSON CANCER CENTER Houston, TX 2011-07-25 Blood Human 55 y.o. Female
C	U T MD ANDERSON CANCER CENTER Houston, TX 2011-07-26 Blood Human 48 y.o. Female
D	U T MD ANDERSON CANCER CENTER Houston, TX 2011-07-27 Blood Human 59 y.o. Male
E	U T MD ANDERSON CANCER CENTER Houston, TX 2011-08-02 Blood Human 2 y.o. Male
F	U T MD ANDERSON CANCER CENTER Houston, TX 2011-09-20 Sputum induced Human 66 y.o. Female
G	U T MD ANDERSON CANCER CENTER Houston, TX 2012-03-10 Blood Human 18 y.o. Male
H	U T MD ANDERSON CANCER CENTER Houston, TX 2012-08-03 Blood Human 51 y.o. Female

Figure 2. Pulsed-field gel electrophoresis patterns of *Herbaspirillum* species isolates obtained from 7 of 8 patients reported.

(A, C, D, and E) were clustered temporally within a period of 10 days.

All *Herbaspirillum* species isolates were susceptible to ceftazidime, levofloxacin, minocycline, moxifloxacin, ticarcillin/clavulanate, tigecycline, and trimethoprim/sulfamethoxazole. All were susceptible to chloramphenicol except 2 patients' isolates, which were intermediate (patients F and G; Table 1).

Case Description

The clinical presentation was bacteremia in 7 patients and polymicrobial pneumonia in 1 patient. Sepsis was present in 6 of 8 patients, including 2 with CRBSI (1 peripherally inserted central catheter and 1 infusaport), 3 with bacteremia, and 1 with pneumonia. Five of 8 patients were female (Table 1), and the median age was 53 years (range, 2–67 years). Three patients were hospitalized for community-onset *Herbaspirillum* species infections (E, F, and H), and the remaining 5 patients with hospital-onset infections (A–D, G) were originally hospitalized for either chemotherapy administration (2 patients), complications of graft-vs-host disease (GVHD) of the gastrointestinal tract (2 patients), or *Pseudomonas fluorescens* bacteremia (1 patient). Possible risk factors for poor outcomes from infection in 6 patients included cytotoxic chemotherapy 4–6 days before the first positive cultures (3 patients); high doses of corticosteroids (>1 mg/kg/day of prednisone or equivalent) 8–30 days prior to their first positive culture (3 patients); receipt of tacrolimus for GVHD prophylaxis (1 patient); and a history of emphysema, lung irradiation, and recurrent pneumonia in the only patient who had pneumonia secondary to *Herbaspirillum* species. All patients had CVCs at the time of the infection except patient F, who had pneumonia without bacteremia. Interestingly, no patients were neutropenic immediately before or during infection onset, with absolute neutrophil counts between 2110 and 23 160 cells/μL.

All patients were treated with intravenous antibiotics, either cefepime (5 patients), ceftazidime (1 patient), moxifloxacin (1 patient), or meropenem (1 patient) initially, followed by ceftriaxone or a fluoroquinolone. The CVCs were removed from all patients except patient B, who improved promptly with intravenous antibiotics and had negative repeat blood cultures. All patients responded to therapy, and only 1 patient (patient A) had a recurrence, which resolved once the implanted port was removed.

No common exposures were identified among the initial 5 cases (A–E). Cases A–E (including community-onset case E) were all hospitalized from 19 to 28 July 2011, but they were located on different wards on different floors and did not share common healthcare providers. Cases A–E also had different types of central lines (Table 1). Only 1 of the initial cases had used the outpatient infusion services, and another had been directly transferred to our hospital from an out-of-state hospital. The only common intravenous medications among all 5 cases were individually packaged sterile saline flushes and single-use vials of morphine. There was no evidence to suggest reuse or sharing of these sterile medications. There were no common procedures, and the only common diagnostic test was a nonportable chest radiograph. Patients F–H were identified by prospective surveillance and had positive cultures several months apart (identified on 20 September 2011, 10 March 2012, and 3 August 2012, respectively), and their *Herbaspirillum* species isolates had different patterns by PFGE (Figure 2).

Facility Observations and Infection Prevention Assessment

Our inspection of the schematics of the hospital water system revealed that case-patients received care in rooms supplied by many subsegments of the water supply system; therefore, only the main water supply system was common to all case-patients. We did not observe opportunities for contamination during the storage, transport, and handling of microbiology specimens.

Over the course of 11 days of observation, all available opportunities for observing hand hygiene, personal protective equipment use, medication preparation, central line care, and infusions resulted in no clear systematic breaches in infection control practices.

Environmental and Product Sampling

We collected 40 environmental samples, including 19 water samples, 12 large surface samples, and 9 small surface samples. No *Herbaspirillum* species or *B. cepacia* were recovered. Non-lactose-fermenting gram-negative rods were isolated from 13 samples: ice machine water (2), ice machine surface (3), patient sink water (1), patient shower water (2), patient shower surface (1), water from the main water tank (2), outdoor waterfall water (1), and lobby fountain water (1). Specific organisms that were identified in 7 of these samples included *P. fluorescens*, *Pseudomonas putida*, *Pseudomonas aeruginosa*, *Cupriavidus pauculus*, and *Aeromonas salmonicida*. Finally, we tested 6 different lots of saline flushes and all were sterile.

DISCUSSION

We report a hospital-based cluster of *Herbaspirillum* species infections in patients with cancer as well as subsequent sporadic cases of hospital- and community-onset infections. The first 5 cases at our institution were initially misidentified as a cluster of *B. cepacia* infections, and 4 of them, when tested by PFGE, were indistinguishable from each other, strongly suggesting a common source from their common hospitalization period that was not identified. Continued epidemiologic surveillance revealed 3 additional cases of *Herbaspirillum* species that presented 1, 7, and 11 months, respectively, after the initial cluster. These 3 isolates were unrelated to the initial cluster by PFGE, which is more consistent with sporadic infections. Two of these latter cases had community-onset infections, as did 3 of 4 cases reported in the literature [7–9]. Because *Herbaspirillum* species are water- and soil-based organisms, we suspected an environmental source, as in 3 previous case reports [7–9]. However, our joint public health investigation and environmental sampling did not reveal a source of *Herbaspirillum* species. Although other opportunistic soil and waterborne bacteria were recovered, these organisms were not found in greater than expected counts for treated municipal water. This may suggest that unique and transient circumstances introduced *Herbaspirillum* species into either the water supply, or another reservoir such as a contaminated medical product or a contaminated food product. We did not identify any pervasive infection control lapses that could explain acquisition of this organism. Thus, the source and mechanism of transmission of this cluster remain unknown.

No clusters of *Herbaspirillum* species infections have been reported in the literature, and limited case descriptions suggest different mechanisms of acquisition. Whereas all but 1 case in this study presented as bacteremia or CRBSI, only 4 separate cases of *Herbaspirillum* species bacteremia have been reported in the literature [6–9]; only 2 of these cases had central lines [6, 9], and no infusion-related acquisition was identified. Although the frequency of bacteremia in our study makes infusion-related acquisition plausible, no likely source was identified during our investigation. *Herbaspirillum* species may also be acquired via the respiratory tract in patients with preexisting lung pathology, as reported in CF patients [6], potentially explaining acquisition in our case-patient with pneumonia who had previously undergone lung radiation therapy and had a history of recurrent pneumonia. *Herbaspirillum* species may also enter through skin lacerations, as described in a cirrhotic patient who developed cellulitis and bacteremia from injuries sustained while jumping into a canal in Florida [8]. A leukemia patient in China developed *Herbaspirillum* species bacteremia after ingesting juice from sugar cane [7], one of several plants known to be colonized by this organism [4], suggesting that the ingestion of uncooked, *Herbaspirillum* species–contaminated food by vulnerable cancer patients could potentially explain the sporadic appearance of new cases, and the acquisition of infection inside and outside the hospital environment. Neutropenic patients in our institution may not have been affected because of heightened dietary precautions that include the avoidance of uncooked vegetables and/or the use of antimicrobial prophylaxis.

Herbaspirillum species can be incorrectly identified as *B. cepacia* by commercially available rapid microbial identification systems [5, 6]. Respiratory isolates from patients with CF [6] and 2 of the reported bacteremia cases [5, 9], as well as our clinical isolates, were initially misidentified as *B. cepacia*. We did not find additional *Herbaspirillum* species cases in our retrospective review of *B. cepacia* isolates based on susceptibility patterns. Antimicrobial susceptibility patterns can potentially serve as a surrogate marker for suspecting *Herbaspirillum* species instead of *B. cepacia* and suggest the need for further examination of the isolate(s). 16S rDNA sequencing can reliably confirm either isolates. Previous outbreaks and sporadic infections may have been incorrectly attributed to *B. cepacia* in other institutions. Furthermore, all cases but one were documented in the United States and most of these isolates were identified at the same referral laboratory at the University of Michigan. These findings suggest that there might be an underestimation of the prevalence of this pathogen due to the inability to identify it correctly at local laboratories. Increased awareness and improved diagnostic methods are therefore needed to accurately identify cases at other institutions. Interestingly, without any specific interventions, our prospective surveillance failed to identify further cases after August 2012.

This investigation has several limitations. First, more than a month had elapsed from isolation of *Herbaspirillum* species from case E to the start of the investigation. If there had been a common exposure that could have transmitted *Herbaspirillum* species, it may no longer have been present. Second, very little is known about the pathogenesis of *Herbaspirillum* species

infections or the reservoirs and modes of exposure that lead to human infection. Therefore, generating and testing plausible hypotheses for *Herbaspirillum* species acquisition was challenging, especially in light of the small number of confirmed cases. Finally, because *B. cepacia* isolates were not saved before this cluster was identified, we were unable to reexamine the likelihood of these isolates being *Herbaspirillum* species.

In summary, *Herbaspirillum* species are opportunistic pathogens capable of colonizing the airways of patients with CF and causing bacteremia and sepsis in CF and immunocompromised patients, particularly those who have cancer or have undergone hematopoietic stem cell transplant. Even though most patients in this study were septic at presentation, their infections resolved with appropriate antibiotic therapy in all cases and removal of their CVCs in all but 1 case. *Herbaspirillum* species infections may be hospital-onset, either in a cluster or sporadic, as well as community-onset. Although a source and mechanism of acquisition was not identified in this study, the organism may enter the body via intravenous infusions, the respiratory tract [5, 6], environmental contamination of lacerated skin [8], or ingestion of uncooked vegetable products [7]. In addition, research is needed to determine whether infections caused by *Herbaspirillum* species and other genera of plant-associated bacteria, such as *Burkholderia*, *Enterobacter*, *Ochrobactrum*, *Pseudomonas*, *Ralstonia*, and *Stenotrophomonas*, could be acquired by immunocompromised hosts via consumption or exposure to plants in their environment [14]. *Herbaspirillum* species may be widely misidentified as *B. cepacia* by current testing methods; therefore, improved identification methods and increased awareness are necessary to document the true prevalence of this pathogen in human hosts and identify preventive measures.

Notes

References

1. Baldani JI, Pot B, Kirchhof G, et al. Emended description of *Herbaspirillum*; inclusion of [*Pseudomonas*] *rubrisubalbicans*, a milk plant pathogen, as *Herbaspirillum rubrisubalbicans* comb. nov.; and classification of a group of clinical isolates (EF group 1) as *Herbaspirillum* species 3. Int J Syst Bacteriol **1996**; 46:802–10.
2. Schmid M, Baldani J, Hartmann A. The genus *Herbaspirillum*. In: Dworkin M, Falkow S, Rosenberg E, Schleifer K-H, Stackebrandt E, eds. The prokaryotes. New York: Springer, **2006**:141–50.
3. Ghosh S, Sar P. Identification and characterization of metabolic properties of bacterial populations recovered from arsenic contaminated ground water of north east India (Assam). Water Res **2013**; 47: 6992–7005.
4. Chen L, Jia RB, Li L. Bacterial community of iron tubercles from a drinking water distribution system and its occurrence in stagnant tap water. Environ Sci Process Impacts **2013**; 15:1332–40.
5. Coenye T, Goris J, Spilker T, Vandamme P, LiPuma JJ. Characterization of unusual bacteria isolated from respiratory secretions of cystic fibrosis patients and description of *Inquilinus limosus* gen. nov., sp. nov. J Clin Microbiol **2002**; 40:2062–9.
6. Spilker T, Uluer AZ, Marty FM, et al. Recovery of *Herbaspirillum species* from persons with cystic fibrosis. J Clin Microbiol **2008**; 46:2774–7.
7. Chen J, Su Z, Liu Y, et al. *Herbaspirillum species*: a potential pathogenic bacteria isolated from acute lymphoblastic leukemia patient. Curr Microbiol **2011**; 62:331–3.
8. Tan M, Oehler R. Lower extremity cellulitis and bacteremia with *Herbaspirillum seropedicae* associated with aquatic exposure in a patient with cirrhosis. Infect Dis Clin Pract **2005**; 13:277–9.
9. Ziga ED, Druley T, Burnham CA. *Herbaspirillum species* bacteremia in a pediatric oncology patient. J Clin Microbiol **2010**; 48:4320–1.
10. LiPuma JJ, Dulaney BJ, McMenamin JD, et al. Development of rRNA-based PCR assays for identification of *Burkholderia cepacia* complex isolates recovered from cystic fibrosis patients. J Clin Microbiol **1999**; 37:3167–70.
11. Kutty PK, Moody B, Gullion JS, et al. Multistate outbreak of *Burkholderia cenocepacia* colonization and infection associated with the use of intrinsically contaminated alcohol-free mouthwash. Chest **2007**; 132:1825–31.
12. Mermel LA, Allon M, Bouza E, et al. Clinical practice guidelines for the diagnosis and management of intravascular catheter-related infection: 2009 update by the Infectious Diseases Society of America. Clin Infect Dis **2009**; 49:1–45.
13. US Pharmacopeial Convention, Inc. Chapter <71> sterility tests. US Pharmacopeia 36—National Formulary 31. Rockville, MD: US Pharmacopeial Convention, Inc, **2012**; 71–970.
14. Berg G, Eberl L, Hartmann A. The rhizosphere as a reservoir for opportunistic human pathogenic bacteria. Environ Microbiol **2005**; 7: 1673–85.