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Epidemiologic Investigation of a Cluster of Neuroinvasive *Bacillus cereus* Infections in 5 Patients With Acute Myelogenous Leukemia

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**Background.** Five neuroinvasive *Bacillus cereus* infections (4 fatal) occurred in hospitalized patients with acute myelogenous leukemia (AML) during a 9-month period, prompting an investigation by infection control and public health officials.

**Methods.** Medical records of case-patients were reviewed and a matched case-control study was performed. Infection control practices were observed. Multiple environmental, food, and medication samples common to AML patients were cultured. Multilocus sequence typing was performed for case and environmental *B cereus* isolates.

**Results.** All 5 case-patients received chemotherapy and had early-onset neutropenic fevers that resolved with empiric antibiotics. Fever recurred at a median of 17 days (range, 9–20) with headaches and abrupt neurological deterioration. Case-patients had *B cereus* identified in central nervous system (CNS) samples by (1) polymerase chain reaction or culture or (2) bacilli seen on CNS pathology stains with high-grade *B cereus* bacteremia. Two case-patients also had colonic ulcers with abundant bacilli on autopsy. No infection control breaches were observed. On case-control analysis, bananas were the only significant exposure shared by all 5 case-patients (odds ratio, 9.3; \( P = .04 \)). Five environmental or food isolates tested positive for *B cereus*, including a homogenized banana peel isolate and the shelf of a kitchen cart where bananas were stored. Multilocus sequence typing confirmed that all case and environmental strains were genetically distinct. Multilocus sequence typing-based phylogenetic analysis revealed that the organisms clustered in 2 separate clades.

**Conclusions.** The investigation of this neuroinvasive *B cereus* cluster did not identify a single point source but was suggestive of a possible dietary exposure. Our experience underscores the potential virulence of *B cereus* in immunocompromised hosts.

**Keywords.** acute myelogenous leukemia; *Bacillus cereus*; central nervous system infection; infection control investigation.

*Bacillus cereus* is an unusual cause of nosocomial outbreaks and central nervous system (CNS) infections in immunocompromised patients [1, 2]. Five patients receiving chemotherapy for acute myelogenous leukemia...
(AML) developed neuroinvasive \textit{B. cereus} infection between May 2013 and February 2014 at Brigham and Women’s Hospi-
tal (BWH) in Boston, Massachusetts. Four of the infections were
fatal. We summarize the cases and investigation by the BWH
infection control department, Boston Public Health Commis-
sion, Massachusetts Department of Public Health (MDPH),
and the Centers for Disease Control and Prevention (CDC).

\section*{METHODS}

Brigham and Women’s Hospital is a 779-bed academic hospital
with general medical and surgical services and a large oncology
patient population. Cases were defined as \textit{B. cereus} blood or CNS
isolates obtained from an AML patient with fever, neurological
symptoms, and radiological evidence of acute CNS disease oc-
curring >48 hours after admission. After the initial 5 cases were
identified, we reviewed medical records of patients with \textit{B. cereus}
isolated from any source from January 2011 through February
2014 and AML patients with unexpected deaths in 2013 to assess
for other potential cases. We reviewed records of case-patients to
collect information relevant to possible risk factors including
room locations, medical staff contacts, procedures, medications,
blood products, and dietary exposures. Multiple medication sam-
ple, environmental swabs, and air samples from areas shared by
AML patients were sent for microbiologic culture. Pharmacy, in-
terventional radiology, blood bank, nursing, and kitchen practic-
es were observed.

A matched case-control study was performed to assess risk
factors, including medications, procedures, and dietary expo-
sures. Controls were randomly selected among patients hospital-
ized for AML treatment within the same month for an
equal or longer duration than the time to onset of illness for
each case (defined as the start of recurrent fever before \textit{B. cereus}
bacteremia and/or neurological deterioration). The number of
controls per case depended upon the availability of medication
(4 controls), procedures (4 controls), and dietary (1–4 controls)
exposure data. Odds ratios and \(P\) values were calculated using
Fisher’s exact test. Due to the small number of cases, the analy-
sis focused only on exposures that were common to 4 or more
case-patients. Some 2-by-2 tables contained cells with a value of
zero; for these exposures, odds ratios and \(P\) values were calcu-
lated by adding \(0.5\) to each cell. There were too few case-patients
to construct a multivariable regression model.

\section*{Microbiologic, Pathologic, and Genomic Analysis}

Standard histologic methods were used for perioperative or post
mortem tissue samples, and standard microbiological methods
were used in our laboratory to identify \textit{Bacillus} species in blood
and tissue cultures. Confirmatory support was performed by in-
vestigators at the CDC using pan-eubacterial 16S ribosomal
DNA polymerase chain reaction (PCR) and a \textit{Bacillus}-specific antibody for immunohistochemistry staining.

Genomic DNA was extracted from patient-derived (blood or
CNS cultures) and environmental \textit{B. cereus} isolates using the
QIAamp DNA mini kit (as per manufacturer’s instructions)
preceeded by lysis with lysozyme. Multilocus sequence typing
(MLST) was performed as previously described [3]. Bar-
coded sequencing libraries were prepared using the Nextera
XT kit per manufacturer’s instructions (Illumina, San Diego,
CA), and paired-end whole genome sequencing (WGS) was
performed (minimum sequencing coverage was 195 million
bases per organism). Sequencing reads were computationally
assembled using SPAdes, a graph theory-based assembly tool
(http://bioinf.spbau.ru/spades) using paired-end default param-
eters. Multilocus sequence typing sequences were identified
from these assembled sequences, by homology, using the
BLASTn aligner. Multilocus sequence typing sequences were
extracted and concatenated. The concatenated MLST sequenc-
es were aligned using MUSCLE (http://www.ebi.ac.uk/Tools/
msa/muscle/), and a phylogenetic tree was generated using
FastTree (http://www.microbesonline.org/fasttree/). This tree
was generated using the neighbor joining method with 1000
resamplings.

Per discussion with the Partners Human Research Commit-
tee, Institutional Review Board approval was not sought because
this study was done as part of a public health and infection con-
tral investigation.

\section*{RESULTS}

\subsection*{Case-Patient Description and Clinical Investigation}

No additional case-patients were found after reviewing records
of patients with \textit{B. cereus} isolates and AML patients with unex-
pected deaths. The clinical characteristics, hospital courses, and
relevant neuroimaging and pathology findings for the 5 case-
patients are summarized in Table 1. All 5 case-patients were
hospitalized to receive induction or salvage chemotherapy for
AML and developed severe neutropenia with an absolute neu-
 trophil count \(<100/\text{mm}^3\). The median age was 49 years (range,
32–58), and 4 of the case-patients were female. All developed
neutropenic fevers early on that rapidly resolved with empiric
antibiotics (typically cefepime). All had either abdominal pain
or significant nausea with vomiting. Fevers recurred in all patients
more than 1 week later (median time of onset, 17 days; range,
9–20) with concurrent headaches and neurological changes.
Abnormalities on neuroimaging included abscesses, infarctions,
intraparenchymal and subarachnoid hemorrhages, leptomenin-
geal enhancement, cerebral edema, and brainstem herniation.
Vancomycin was initiated around the time of neurologic
decompensation in all cases.

Case-patient 1, the sole survivor, underwent neurosurgical
drainage of her brain abscess on hospital day 28, 8 days after
developing fever, headache, and blurry vision; intraoperative
cultures were negative, but samples sent to the CDC were
Table 1. Clinical Characteristics of Five Neuroinvasive *Bacillus cereus* Case-Patients

<table>
<thead>
<tr>
<th>Case no., Age/Sex, Admit Date</th>
<th>Chemo Regimen</th>
<th>Preceding GI Symptoms</th>
<th>Timing of Illness</th>
<th>Symptoms at Time of Illness</th>
<th>Abxs Prior to Illness</th>
<th>Positive <em>B. cereus</em> Blood Cultures?</th>
<th>Neuroimaging</th>
<th>Outcome</th>
<th>Pathology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 1, 32F, May 2013</td>
<td>Induction (7 + 3)</td>
<td>(+) Abd pain, n/v, diarrhea</td>
<td>HD20</td>
<td>HA, blurry vision</td>
<td>VM, CP, CZ, CT</td>
<td>No</td>
<td>Occipital lobe abscess</td>
<td>Survived</td>
<td>Surgical pathology: Brain abscess with <em>B. cereus</em> detected by PCR and IHC.</td>
</tr>
<tr>
<td>Case 2, 58F, May 2013</td>
<td>Induction (7 + 3)</td>
<td>(+) n/v; no Abd pain or diarrhea</td>
<td>HD17</td>
<td>HA, AMS, seizures</td>
<td>CP, CZ, AM</td>
<td>No</td>
<td>Multifocal infarction</td>
<td>Expired</td>
<td>Autopsy: Brain abscess with <em>B. cereus</em> isolated from cultures and consistent histopathology. Ascending colon ulceration with <em>Bacillus</em> species identified by IHC.</td>
</tr>
<tr>
<td>Case 3, 54F, Sept 2013</td>
<td>Salvage (Ara-C + CAFdA)</td>
<td>(+) Abd pain; no n/v or diarrhea</td>
<td>HD13</td>
<td>HA, AMS, seizures</td>
<td>CP, CZ</td>
<td>Yes</td>
<td>Leptomeningeal enhancement, multifocal infarcts, right basal ganglia enhancing lesion</td>
<td>Expired</td>
<td>Autopsy: Multifocal infarcts and abscess in putamen with negative cultures. Rare bacilli seen on GMS stain of abscess (CDC). No lesions in GI tract.</td>
</tr>
<tr>
<td>Case 4, 50F, Sept 2013</td>
<td>Induction (7 + 3)</td>
<td>(+) Abd pain; no n/v or diarrhea</td>
<td>HD20</td>
<td>HA, AMS, septic shock</td>
<td>CP, CZ</td>
<td>Yes</td>
<td>Diffuse SAH, cerebral edema, herniation</td>
<td>Expired</td>
<td>Autopsy: Edema and tonsillar herniation, patchy areas of SAH. Rare bacilli in subarachnoid space. Cultures, stains, IHC negative. GI tract unremarkable except a single flat lesion in colon with mixed bacteria.</td>
</tr>
<tr>
<td>Case 5, 52M, Feb 2014</td>
<td>Induction (AraC + Ida)</td>
<td>(+) Abd pain and diarrhea</td>
<td>HD9</td>
<td>Abd pain, AMS, septic shock</td>
<td>PT, CP, VM, CT</td>
<td>Yes</td>
<td>Extensive petechial hemorrhages, large basal ganglia ICH, uncal herniation</td>
<td>Expired</td>
<td>Autopsy: Brain with cerebral edema, hemorrhage, herniation, and multiple bacilli; cultures (+) for <em>B. cereus</em>. GI tract with multiple colonic ulcerative lesions with surrounding erythema and abundant bacilli (identified as <em>B. cereus</em> by PCR). Liver with subcapsular necrosis with sinusoids filled with bacilli.</td>
</tr>
</tbody>
</table>

Abbreviations: 7 + 3, cytarabine + daunorubicin; Abxs, antibiotics; Abd, abdominal; AM, amoxicillin; AMS, altered mental status; Ara-C, cytarabine; CAFdA, clofarabine; CDC, Centers for Disease Control and Prevention; Chemo, chemotherapy; CP, cefepime; CT, cefazidime; CZ, cefazolin; GI, gastrointestinal; GMS, Gomori methenamine silver; HA, headache; HD, hospital day; ICH, intracerebral hemorrhage; Ida, idarubicin; IHC, immunohistochemistry; MZ, metronidazole; n/v, nausea/vomiting; PCR, polymerase chain reaction; PT, piperacillin/tazobactam; SAH, subarachnoid hemorrhage; VM, vancomycin.
ultimately identified as *B. cereus* by PCR and immunohistochemistry. The patient was treated with a prolonged course of parenteral vancomycin with resolution of her brain abscess. Case-patients 2, 4, and 5 were transitioned to comfort measures and expired within 2–3 days after the onset of neurologic symptoms and had catastrophic findings on neuroimaging as described above. Case-patient 3 had progressively worsening neurological status and recurrent seizures over the ensuing 3 weeks before expiring.

Case-patients 1 and 2 had negative blood cultures, and *B. cereus* was detected later only on CNS tissue examination. Case-patients 3–5 had documented *B. cereus* bacteremia in multiple blood culture sets with the organism also identified on CNS pathological stains. Only case-patient 3 had a lumbar puncture after onset of neurologic symptoms, and cerebrospinal fluid (CSF) analysis revealed an elevated opening pressure (32 mmHg), elevated total protein (239 mg/dL), normal glucose (63 mg/dL), elevated red blood cells (620 in tube 1, 530 in tube 4), a normal number of total nucleated cells (4 in tube 1, 3 in tube 4), and no organisms on Gram stain or culture. Autopsies performed on the 4 patients who expired were notable for colonic ulcers with abundant bacilli in 2 cases (identified as *Bacillus* species by immunohistochemistry for case 2 and *B. cereus* by PCR in case 5). Susceptibility testing (E-test method) done on 4 available isolates showed a minimum inhibitory concentration of 32 µg/mL or more for cefepime, 2 µg/mL or more for vancomycin, and 0.125 µg/mL or less for ciprofloxacín for all isolates.

There was no overlap of hospital location or in the medical staff who cared for case-patients. Transfusion records were examined and no common donors were identified, and there was no overlap in the technicians who drew blood from each of the relevant donors. On case-control analysis, no medication or procedure was significantly associated with *B. cereus* infection. However, bananas were consumed by all 5 case-patients and were significantly associated with infection (odds ratio [OR], 9.3; *P* = .04) (Table 2). Cranberry juice was consumed by 4 case-patients and was the only other significant exposure (OR, 9.6; *P* = .04).

Medications and foods common among the patients (including cefepime, potassium chloride, magnesium sulfate, mouthwashes, body lotions, bananas, yogurt, eggplant, and various fruits) were sent to the MDPH laboratory for culture; *B. cereus* was isolated from 1 sample of homogenized banana peels. The significance of this isolate was unclear at this early point in the investigation; thus, the isolate was not archived. Multilocus sequence typing was not pursued before discarding the isolate. Recent renovation and construction projects at the hospital were reviewed; there were 11 hospital renovation projects during the cluster period, but no breaches were identified in construction containment practices. No breaches in practice were observed in any of the other examined departments or observed procedures, including chemotherapy preparation and administration and central line care. Of the 47 environmental, food, and medication samples sent to the CDC, only 4 tested positive for *B. cereus* at very low concentrations, including a kitchen cart

<table>
<thead>
<tr>
<th>Table 2. Summary of Case-Control Analysis to Assess for Risk Factors for Neuroinvasive <em>Bacillus cereus</em> Infection in Hospitalized AML Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Medications</strong></td>
</tr>
<tr>
<td>-----------------</td>
</tr>
<tr>
<td>Acetaminophen (PO)</td>
</tr>
<tr>
<td>Allopurinol (PO)</td>
</tr>
<tr>
<td>Cefazolin (IV)</td>
</tr>
<tr>
<td>Cefepime (IV)</td>
</tr>
<tr>
<td>Chlorhexidine mouthwash</td>
</tr>
<tr>
<td>Colace (PO)</td>
</tr>
<tr>
<td>Cytarabine (IV)</td>
</tr>
<tr>
<td>Magnesium sulfate (IV)</td>
</tr>
<tr>
<td>Normal saline (IV)</td>
</tr>
<tr>
<td>Nystatin swish and swallow</td>
</tr>
<tr>
<td>Ondansetron (IV)</td>
</tr>
<tr>
<td>Potassium chloride (IV)</td>
</tr>
<tr>
<td>Sarna (TP)</td>
</tr>
<tr>
<td><strong>Procedures</strong></td>
</tr>
<tr>
<td>Central venous catheter</td>
</tr>
<tr>
<td>Bone marrow biopsy</td>
</tr>
<tr>
<td><strong>Dietary Exposures</strong></td>
</tr>
<tr>
<td>1% Milk</td>
</tr>
<tr>
<td>Aquafina</td>
</tr>
<tr>
<td>Banana</td>
</tr>
<tr>
<td>Chicken noodle soup</td>
</tr>
<tr>
<td>Chicken pot pie</td>
</tr>
<tr>
<td>Cranberry juice</td>
</tr>
<tr>
<td>Fruit cup</td>
</tr>
<tr>
<td>Ketchup</td>
</tr>
<tr>
<td>Oatmeal</td>
</tr>
<tr>
<td>Oatmeal raisin cookie</td>
</tr>
<tr>
<td>Pepper</td>
</tr>
<tr>
<td>Salt</td>
</tr>
<tr>
<td>Spring water</td>
</tr>
<tr>
<td>Strawberry frappe</td>
</tr>
<tr>
<td>Strawberry yogurt</td>
</tr>
</tbody>
</table>

**Abbreviations:** PO, oral; IV, intravenous; TP, topical.

* Twenty controls were used for medications and procedures; only 13 controls were available for dietary exposures due to incomplete dietary records.

** Indicates statistically significant exposures.
had colonic ulcers with evidence of infection as the likely route of infection for some or all of the case-patients, because all had notable gastrointestinal symptoms and 2 had colonic ulcers with evidence of neurologic sequelae in immunocompromised patients.

Clinical and pathologic review suggests gastrointestinal translocation by the absence of other cases in the preceding 3 years at BWH. Although there were few cases, the investigation was performed with urgency because of the high associated mortality (80% in our series) and the unusual nature of this cluster, as supported by the fact that isolation from blood cultures, but patients receiving chemotherapy for hematological malignancies have been noted to be at disproportionate high risk for CNS infection, with substantial associated mortality [12–15]. The pathogenicity of Bacillus cereus

### DISCUSSION

These 5 cases of B. cereus infection highlight the risk of nosocomial infection from this organism and the potential for devastating neurologic sequelae in immunocompromised patients. Although there were few cases, the investigation was performed with urgency because of the high associated mortality (80% in our series) and the unusual nature of this cluster, as supported by the absence of other cases in the preceding 3 years at BWH. Clinical and pathologic review suggests gastrointestinal translocation as the likely route of infection for some or all of the case-patients, because all had notable gastrointestinal symptoms and 2 had colonic ulcers with evidence of Bacillus cereus infection on autopsy.

Multilocus sequence typing demonstrated that the cluster was not the result of a single B. cereus strain. Rather, the infections appear to have been attributable to multiple distinct strains within at least 2 distinct genotypic clusters. Although this is less consistent with a point-source outbreak, a common environmental or food exposure is still possible, particularly if the exposure was due to intermittent environmental contamination of a common food. All 5 case-patients had consumed bananas, 1 of only 2 dietary items significantly associated with infection in the case-control analysis. Bacillus cereus was recovered from the shelf where the bananas were stored in the kitchen, and B. cereus was also cultured from a banana peel. The timing of the cluster with multiple hospital renovation and construction projects, some of which were proximate to the kitchen storage area, raises the possibility of environmental contamination of foods stored in the kitchen or direct inoculation of patients, although no breaches were identified in construction containment practices.

Nosocomial B. cereus outbreaks at other institutions have been reported with various suspected sources, including construction work, contaminated linen and towels, intravenous catheters, infusion fluids, ventilator equipment, air ventilation systems, tea bags, gloves, and hands of staff [4–10]. However, definitively establishing the source of an outbreak is complicated by the fact that B. cereus is a ubiquitous organism (including in food), and so the significance of isolating low colony counts from environmental cultures is often unclear. When outbreaks do occur, obtaining control can be difficult because Bacillus is able to survive long periods in the environment and is resistant to many commonly used cleaning products [11].

Bacillus cereus is typically disregarded as a contaminant when isolated from blood cultures, but patients receiving chemotherapy for hematological malignancies have been noted to be at disproportionately high risk for CNS infection, with substantial associated mortality [12–15]. The pathogenicity of Bacillus cereus

### Table 3. Results of Multilocus Sequence Typing of Bacillus cereus Strains From Clinical Investigationa

<table>
<thead>
<tr>
<th>Source</th>
<th>Sample ID</th>
<th>glpF</th>
<th>gmk</th>
<th>ilvD</th>
<th>pta</th>
<th>pur</th>
<th>pycA</th>
<th>tpi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 1 Brain biopsy</td>
<td>Brain biopsy</td>
<td>33</td>
<td>12</td>
<td>87</td>
<td>28</td>
<td>7</td>
<td>17</td>
<td>7</td>
</tr>
<tr>
<td>Case 2 Blood</td>
<td>Blood</td>
<td>65</td>
<td>1</td>
<td>93</td>
<td>1</td>
<td>51</td>
<td>37</td>
<td>24</td>
</tr>
<tr>
<td>Case 3 Blood</td>
<td>Blood</td>
<td>47</td>
<td>8</td>
<td>88</td>
<td>26</td>
<td>86</td>
<td>36</td>
<td>7</td>
</tr>
<tr>
<td>Case 4 Blood</td>
<td>Blood</td>
<td>94</td>
<td>2</td>
<td>232</td>
<td>5</td>
<td>32</td>
<td>156</td>
<td>143</td>
</tr>
<tr>
<td>Case 5 Brain</td>
<td>Brain</td>
<td>47</td>
<td>8</td>
<td>14</td>
<td>12</td>
<td>2</td>
<td>36</td>
<td>142</td>
</tr>
<tr>
<td>Environmental sample</td>
<td>Blanket warmer</td>
<td>37</td>
<td>8</td>
<td>14</td>
<td>12</td>
<td>37</td>
<td>157</td>
<td>144</td>
</tr>
<tr>
<td>Environmental sample</td>
<td>Banana cart</td>
<td>12</td>
<td>8</td>
<td>9</td>
<td>192</td>
<td>11</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>Environmental sample</td>
<td>Air sample near construction site</td>
<td>81</td>
<td>53</td>
<td>117</td>
<td>193</td>
<td>113</td>
<td>93</td>
<td>145</td>
</tr>
<tr>
<td>Environmental sample</td>
<td>Beneprotein</td>
<td>6</td>
<td>4</td>
<td>42</td>
<td>4</td>
<td>16</td>
<td>6</td>
<td>3</td>
</tr>
</tbody>
</table>

Abbreviations: ID, identification; MLST, multilocus sequence typing; PCR, polymerase chain reaction.

a Bacterial isolates and, in 1 case, a pathological specimen from a brain biopsy were subjected to whole genome sequencing and targeted amplification of genes for MLST (http://www.pubmlst.org/bcereus). In cases in which PCR-based amplification of MLST locus was unsuccessful, the MLST genomic sequence was identified, by homology, from whole genome sequencing data. In all cases in which both PCR-based and whole genome sequencing-based MLST data were available, the results were concordant.
(both intestinal and extraintestinal) is associated with the production of a wide range of tissue-destructive exotoxins and enterotoxins [16–18]. Central nervous system infection in immunocompromised patients may result from bloodstream seeding from gastrointestinal infection (particularly in the setting of mucosal injury from chemotherapy), or from central venous catheters with subsequent CNS invasion, or possibly from direct introduction via intrathecal administration of chemotherapy [14, 19, 20]. It is important to note that our first 2 case-patients never had positive blood cultures, and none received lumbar punctures or intrathecal chemotherapy before onset of disease. All 5 case-patients shared risk factors for poor prognosis, including acute leukemia, an absolute neutrophil count approaching zero, neurological symptoms at the time of febrile episodes, and active receipt of induction or reinduction chemotherapy [1]. It is interesting to note that the 1 case-patient who received a lumbar puncture had a normal number of total nucleated cells on CSF analysis. *Bacillus cereus* meningitis has been reported to be associated with a relatively bland CSF profile in patients with hematological malignancies. This may be a reflection of underlying host immunosuppression and possibly an intrinsic lack of inflammatory response by the organism [7, 13, 21]. Neuropathology in our cases demonstrated areas of acute infarction, cerebritis, abscesses, hemorrhage, and meningitis, reflecting the wide range of potential CNS manifestations of this organism [12–14, 20, 22–27].

Several control measures were instituted as a result of this investigation, including enhanced environmental cleaning and exclusion of bananas and fresh fruits, vegetables, and rice from the diets of AML patients undergoing induction chemotherapy.

**Figure 1.** Phylogenetic tree of selected *Bacillus cereus* strains generated using multilocus sequence typing (MLST) results. A phylogenetic tree was constructed using MLST information from strains from cases 2–5 (because incomplete MLST information was available for case 1) in this study, as well previously published genome sequences of both environmental and pathogenic *B. cereus* strains. This tree was constructed using the neighbor joining method with 1000 resamplings, as described in the Methods section of the manuscript. Of note, analysis of the sequences from the *B. cereus* strains in cases 3 and 4, although temporally closely related, revealed that these strains were genetically very diverse from one another.
Our hospital’s empiric antibiotic recommendations were also modified to include the addition of ciprofloxacin for recurrent neutropenic fever to optimize B cereus coverage, given that susceptibility testing on the isolates revealed low minimum inhibitory concentrations for ciprofloxacin. No additional cases have been found in the year after the last case.

CONCLUSIONS

In summary, this cluster of neuroinvasive B cereus infections in 5 AML patients prompted an extensive epidemiologic and genomic investigation that ultimately did not support the hypothesis of a single point source, but it did suggest the possibility of a dietary exposure to B cereus. Our experience underscores the potential virulence of this organism in susceptible hosts. Clinicians should not automatically disregard Bacillus in blood cultures as being contaminants and B cereus should be considered in febrile immunocompromised patients with neurological symptoms, even without positive blood cultures. It is possible that the responsible organisms share a transferable virulence-conferring factor, and comparative microbial genomic and biological efforts are underway that may identify bacterial and host factors that induce heightened virulence.

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