Fatal Meningitis in Patient with X-Linked Chronic Granulomatous Disease Caused by Virulent *Granulibacter bethesdensis*

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*Granulibacter bethesdensis* is a pathogen reported to cause recurrent lymphadenitis exclusively in persons with chronic granulomatous disease. We report a case of fatal meningitis caused by a highly virulent *G. bethesdensis* strain in an adolescent in Europe who had chronic granulomatous disease.

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*Chronic granulomatous disease (CGD)* is a primary immunodeficiency characterized by a deficient nicotinamide adenine dinucleotide phosphate oxidative burst that impairs phagocyte superoxide formation and killing of certain pathogens. Mutations can occur in any of the 5 subunits of nicotinamide adenine dinucleotide phosphate oxidase. Most cases are inherited as X-linked defects (gp91phox), but they also can occur in an autosomal recessive manner (1). Increased susceptibility develops to recurrent infections of the skin, lymph nodes, lungs, and other organs (2), mostly caused by bacteria and fungi, including *Staphylococcus aureus*, *Serratia marcescens*, *Burkholderia cepacia*, *Salmonella* spp., *Nocardia* spp., and *Aspergillus* spp. (2). Emerging organisms, such as *Granulibacter bethesdensis* and other methylo trophs, occur almost exclusively in CGD patients (3,4).

*G. bethesdensis* was first described in 2006, when it was isolated in a CGD patient with lymphadenitis (4). It is a gram-negative, aerobic, oxidase-negative, catalase-positive, nonmotile coccobacillus to rod-shaped bacterium belonging to the *Acetobacteraceae* family (5,6). *G. bethesdensis* was the first of these *Acetobacteraceae* family bacteria with proven pathogenicity in humans, causing invasive disease in CGD patients and mice (4). It has been mostly linked to indolent nonfatal lymphadenitis and deep neck infections in patients in North America. The infection can recur over several years by reactivation of the same strain or reinfection with different strains (3,7–9). The first fatal infection was reported in a 10-year-old boy from Spain, who died of fulminant sepsis (10). In vitro, *G. bethesdensis* shows extensive resistance to various antimicrobial drugs, although its slow growth makes susceptibility testing difficult. Ceftriaxone, aminoglycosides, doxycycline, and trimethoprim/sulfamethoxazole showed activity in vitro (7).

We report a case of *G. bethesdensis* meningitis in a patient with X-linked CGD. We also report animal data comparing this *G. bethesdensis* strain with the strain recovered from recurrent lymphadenitis in a US CGD patient.

**The Study**

The patient was a 16-year-old boy whose X-linked CGD (CYBB exon 13 deletion) was diagnosed when he was 2 years old. His disease had been well-controlled with cotrimoxazole, itraconazole, and interferon-γ. In September 2014, he was hospitalized with a deep cervical abscess (Figure 1, panel A) and received a 5-week course of intravenous ciprofloxacin, doxycycline, and ceftriaxone that resulted in complete clinical and radiologic resolution, followed by 6 weeks of oral amoxicillin/clavulanic acid, doxycycline, and ciprofloxacin along with his usual prophylaxis. No pathogen was identified despite blood cultures, bronchoalveolar lavage, and lymph node biopsy cultures and broad-range bacterial PCR.

After this regimen was completed, the boy was readmitted for 8 weeks with pneumonia with pleural effusion (Figure 1, panel B). Full 16S rRNA gene sequencing (≈1,500 bp) identified *Cupriavidus* spp. in pleural fluid. He received meropenem, amikacin, ciprofloxacin, teicoplanin, doxycycline, and voriconazole, and his condition improved. However, 2 weeks later, fever returned, along with splenomegaly, hemodynamic instability, pancytopenia,
hypofibrinogenemia, hyperferritinemia, and elevated soluble CD25. He received intravenous immunoglobulin and dexamethasone for this inflammatory condition and fully recovered. Neck and lung computed tomography images and positron emission tomography performed 1 month later showed no signs of active infection. Nevertheless, a few days later, the patient sought care for altered mental status, hallucinations, aggressiveness, and respiratory instability requiring admission to the pediatric intensive care unit. He had extensive bilateral pneumonia and multiple intraparenchymal brain abscesses (Figure 1, panel C). Meropenem, ciprofloxacin, amikacin, doxycycline, ...
teicoplanin, and voriconazole were started; results of cerebrospinal fluid (CSF) and lung biopsy samples were unremarkable. Teicoplanin was switched to linezolid and voriconazole to caspofungin and liposomal amphotericin B because of toxicity concerns. Four weeks later, he was discharged from the intensive care unit. One month later, fever, vomiting, and focal neurologic deficits developed. CSF showed pleocytosis and hypoglycorrhachia with elevated protein levels. Cerebral imaging confirmed leptomenigitis. Isoniazid, clarithromycin, and rifampin were initiated infection in CGD.

**Table.** Bacterial culture from blood and brain samples of gp91 KO mouse infected with *Granulibacter bethesdensis* after 4 weeks*

<table>
<thead>
<tr>
<th>Mouse</th>
<th>Strain</th>
<th>Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>gp91 phox−/−, n = 10</td>
<td>Type, USA</td>
<td>Blood</td>
</tr>
<tr>
<td>gp91 phox−/−, n = 10</td>
<td>CSF, Portugal</td>
<td>5</td>
</tr>
<tr>
<td>p47 phox−/−, n = 5</td>
<td>Type</td>
<td>0</td>
</tr>
<tr>
<td>p47 phox−/−, n = 5</td>
<td>CSF</td>
<td>0</td>
</tr>
<tr>
<td>WT, n = 9</td>
<td>CSF, Portugal</td>
<td>0</td>
</tr>
</tbody>
</table>

*Bold indicates the results of the inoculation of CSF strain in the gp91 KO mouse. CSF, cerebrospinal fluid; ND, not done; WT, wild type.

Conclusions

*G. bethesdensis* is an emerging pathogen shown to cause infection exclusively in CGD patients and has a spectrum of disease severity ranging from chronic and recurrent infections to fulminant sepsis, central nervous system infection, and death (3,7,10). Until recently, all reported North America cases were nonfatal chronic infections; 1 case from Europe (Spain) was fatal. Recently, Mayer et al. reported an X-linked CGD patient in the United States who died of fulminant infection with an organism with 100% identity to 500 bp of *G. bethesdensis* 16S (11). Unfortunately, that *G. bethesdensis* isolate was not available for analysis and comparison with other *G. bethesdensis* strains. The previous strain from Europe was highly resistant to antimicrobial agents, including colistin, most β-lactams, and quinolones (10).

We found that a CSF *G. bethesdensis* strain, showing an identical 16S sequence to a previously described fulminant strain from Europe, was more virulent and lethal in a mouse model than the *G. bethesdensis* US type strain and more virulent in gp91 phox−/− than in p47 phox−/− mice. A fatal case of *G. bethesdensis* infection in the United States suggests that heterogeneity might exist among North America *G. bethesdensis* strains. Bacterial genome sequencing may identify discrete virulence factors. *G. bethesdensis* must be included as a cause of fatal disseminated infection in CGD.

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About the Author

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References


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