**Bordetella holmesii—Like Organisms Associated with Septicemia, Endocarditis, and Respiratory Failure**

Yi-Wei Tang, Marlene K. Hopkins, Christopher P. Kolbert, Paul A. Hartley, Perry J. Severance, and David H. Persing

We recovered an unusual bacterial strain from blood or sputum of three patients with septicemia, endocarditis, and/or respiratory failure. The three isolates were thin, curved, gram-negative, light brown, pigment-producing bacilli with variable catalase activity. They were asaccharolytic, oxidase-negative, nonmotile, and fastidious. Identification was not possible on the basis of these characteristics alone or in combination with cellular fatty acid profiles. Nucleic acid amplification and sequence analysis of the 16S rRNA gene revealed that all three isolates were identical and most closely related to the emerging pathogen *Bordetella holmesii*, diverging from the published sequence at three nucleotide positions (99.8% similarity). Isolation of a *B. holmesii*—like pathogen from sputum suggests that, in addition to producing septicemia, the organism may inhabit the respiratory tract like other *Bordetella* species.

**Case Reports**

**Patient 1**

A 15-year-old boy from Austin, Minnesota, presented with fever, headache, and cough. His cough had begun 2 weeks earlier and was productive of green sputum. The cough persisted, and on the morning of admission, the patient awoke with a temperature of 104°F, headache, malaise, anorexia, and neck tenderness. While waiting in the emergency department, he vomited. The patient had had a splenectomy at age 4 years because of hereditary spherocytosis. He had remained healthy until the previous year, during which he had several episodes of fever and cough, often associated with nausea and vomiting. He had a regular history of immunization, including diphtheria-pertussis-tetanus vaccination 10 years earlier. The patient had not traveled outside the United States during the previous 3 months.

On physical examination, the patient was flushed, pleasant, and in no apparent distress. His temperature was 38.4°C (oral); pulse, 95/minute; respirations, 24/minute; and blood pressure, 112/66 mm Hg. His head, eyes, ears, nose, and throat appeared normal on examination, and the lungs were clear. The blood hemoglobin level was 15.2 g/dL, the platelet count was 407,000/mm³, and the leukocyte count was 37,500/mm³, with 87% neutrophils and 7% monocytes. Urinalysis was normal. Nasopharyngeal swab specimens obtained for tests for group A streptococcus and pertussis antigens and for culture were negative. Urine and throat swab cultures for bacteria were unrevealing. Small, curved gram-negative bacilli with similar colony and microscopic morphology grew in aerobic bottles used for both blood samples collected on admission day. One isolate (X69095) was chosen for further identification.

The patient was given a dose of ampicillin/sulbactam, was hospitalized, and began receiving intravenous fluid support and cefazidime. Subsequent cultures of blood and urine were negative. Cefazidime was changed to cefazolin 5 days later on the basis of susceptibility findings. Stabilized and defeversed, the patient was discharged 7 days later with a normal leukocyte count and differential. Oralexicillin V (250 mg b.i.d. indefinitely) was prescribed for prophylaxis.

**Patient 2**

A 25-year-old man from Little Falls, Minnesota, with a 3-week history of fever was admitted. Five years earlier, in 1992, he had received radiation therapy for stage IIA Hodgkin’s disease, and there had been no evidence of recurrence. Over the previous 3 days, he had had a constant fever refractory to acetaminophen. The patient was thirsty and fatigued and had intermittent pain in the thorax and shoulder blade. He had a bicuspid aortic valve that was diagnosed in 1988, and echocardiography in June 1996 showed thickened leaflet edges and mild regurgitation. The patient was allergic to penicillin.

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During the physical examination the young man was pleasant and in no apparent distress. His temperature was 39.3°C (oral); pulse, 110/minute; and blood pressure, 120/70 mm Hg. Head, eye, ear, nose, and throat findings were unremarkable. The lungs were clear. The patient was tachycardic with normal S1 and S2 sounds and no murmur. The blood hemoglobin level was 14.2 g/dL, the platelet count was 210,000/mm³, and the leukocyte count was 17,400/mm³, with 71% segmented and 18% banded neutrophils. A bone marrow biopsy was negative for recurrent lymphoma. Urine and throat swab cultures for bacteria were negative. Blood cultures were performed 1 and 2 days after admission, with one aerobic bottle from each set yielding gram-negative rods (I90788).

Transesophageal echocardiography revealed a posterior leaflet vegetation, substantiating the diagnosis of aortic valve endocarditis. Ceftriaxone (2 g iv q.d. for 28 days) was administered, resulting in complete recovery.

**Patient 3**

A 41-year-old woman from Uniontown, Pennsylvania, was admitted because of respiratory failure due to acute pulmonary edema and concomitant bronchitis. The patient had had a cough productive of purulent sputum for ~4 days before admission. At 5:00 A.M. on the morning of admission, she was awakened by severe dyspnea. Cyanotic and confused, she was transported to the emergency department in a 100% non-rebreather mask and intubated upon arrival. The patient had systolic congestive heart failure with ejection fraction of ~20% following myocardial infarctions 10 and 15 years before admission. She had had a seizure disorder since 1987. Her medical history included chronic obstructive pulmonary disease and tobacco abuse (at least 40 packs/year).

Initial blood gas analysis showed the following values: pH, 7.09; Paco₂, 86; and PaO₂, 154. The chest roentgenogram revealed cardiomegaly with diffuse interstitial and alveolar infiltrates consistent with pulmonary edema. The blood hemoglobin level was 13 g/dL, the platelet count was 223,000/mm³, and the leukocyte count was 15,700/mm³, with 75% segmented and 4% banded neutrophils. Cardiac enzyme levels were normal. Sputum gram staining showed >25 WBCs per low-power field.

Alcaligenes xylosoxidans [10] and Kinetoplastibacterium crithidia [11] clustered distinctly from each other and from the three Bordetella holmesii, originally called “CDC nonoxidizer group 2,” was named in 1995 in honor of Barry Holmes for his substantial contributions to characterization, classification, results of the 16S rRNA gene sequence analyses, these new isolates were identified as *B. holmesii*—like gram-negative bacilli. The patient underwent mechanical ventilation for 48 hours. She received renal-dose dopamine, nitroglycerin, furosemide, beclomethasone, and cefuroxime. After defervescence, the chest radiographic findings normalized, and she was discharged after 5 hospital days, at which time she was receiving cefpodoxime.

**Results**

All three isolates grew on blood and chocolate agar plates after 2 days; however, they did not grow on eosin methylene blue medium. Microscopic morphology included thin, curved gram-negative bacilli. Light brown pigment generated after 3 days of growth. Biochemical reactions were negative except for variable catalase activity (table 1).

The antibiotic susceptibility profile was determined by an agar dilution method previously described [2]. All three isolates were susceptible to the following antibiotics: amikacin, ampicillin, cefazolin, cefotaxime, ceftazidine, chloramphenicol, gentamicin, mezlocillin, trimethoprimsulfamethoxazole, imipenem, ciprofloxacin, and pipercillin/tazobactam.

Bacterial cells after 48 hours of growth were saponified, and the liberated fatty acids were methylated and analyzed by capillary gas-liquid chromatography [3] (MIDI, Newark, DE). The system read out “*Bordetella avium*” for isolate O56172 and “no match” for isolates X69095 and I90788. All three isolates yielded large amounts of hexadecanoate and cyloheptadecanoate and relatively small amounts of tetradecanoate and cis-9-hexadecanoate. Only trace or small amounts of other fatty acids were detected (table 1).

**Discussion**

We identified a *B. holmesii*—like bacillus in three patients, including an asplenic adolescent, a patient with previous Hodgkin’s lymphoma, and a patient with chronic obstructive pulmonary disease. *B. holmesii*, originally called “CDC nonoxidizer group 2,” was named in 1995 in honor of Barry Holmes for his substantial contributions to characterization, classification,
Table 1. Biochemical reactions and cellular fatty acid profiles of the three isolates of a *Bordetella holmesii*—like gram-negative bacillus.

<table>
<thead>
<tr>
<th>Test parameter</th>
<th>X69095 (Blood)</th>
<th>O65172 (Sputum)</th>
<th>I90788 (Blood)</th>
<th><em>B. holmesii</em> (Blood)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biochemical reaction¹</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitrate/nitrite reduction</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td>Motility</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td>Catalase</td>
<td>−</td>
<td>+</td>
<td>−</td>
<td>+</td>
</tr>
<tr>
<td>Oxidase</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td>Urease</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td>H₂S production (tri-sugar ion tube)</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td>Decarboxylase production</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td>Lysine</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td>Arginine</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td>Ornithine</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td>Acid from (oxidative fermenter):</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
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<tr>
<td>Dextrose</td>
<td>−</td>
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<tr>
<td>Maltose</td>
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<td>−</td>
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<td>−</td>
</tr>
<tr>
<td>Xylose</td>
<td>−</td>
<td>−</td>
<td>−</td>
<td>−</td>
</tr>
<tr>
<td>Cellular fatty acid profile (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hexadecanoate (C₁₆:₀)</td>
<td>56.1</td>
<td>37.4</td>
<td>47.6</td>
<td>41³</td>
</tr>
<tr>
<td>Cyloheptadecanoate (C₁₇:₀cyc)</td>
<td>33.4</td>
<td>35.2</td>
<td>27.6</td>
<td>30³</td>
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<tr>
<td>Tetradecanoate (C₁₄:₀) and cis-9-hexadecanoate (C₁₆:₁w7c)</td>
<td>10.5</td>
<td>4.4</td>
<td>1.1</td>
<td>7³</td>
</tr>
<tr>
<td>Straight-chain hydroxy acids</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2-OH-C₁₂:₀</td>
<td>Trace</td>
<td>3.2</td>
<td>3.1</td>
<td>4³</td>
</tr>
<tr>
<td>2-OH-C₁₄:₀</td>
<td>Trace</td>
<td>2.6</td>
<td>3.3</td>
<td>4³</td>
</tr>
</tbody>
</table>

¹ Data adapted from [1].
² + = positive; w = weak positive; − = negative.
³ Pooled results from eight strains.

and identification of unusual pathogenic and opportunistic bacteria [1]. Since 1989, >15 isolates have been recovered in blood cultures, mostly of specimens from young adults [1, 12]. Isolation of *B. holmesii*—like pathogens from different clinical specimens from immunocompromised patients with septicemia, endocarditis, and respiratory failure has confirmed their pathogenicity in humans. However, we believe ours is the first description of a pathogenic *B. holmesii* isolated from sputum.

*Bordetella* species are small, obligately aerobic, gram-negative coccobacilli or short rods, traditionally regarded as respiratory tract parasites. Previously, the genus *Bordetella* consisted of only four species: *B. pertussis*, *B. parapertussis*, *B. bronchiseptica*, and *B. avium*. They are closely related, showing a DNA homology of 72%–94% [13] and very limited diversity by multilocus enzyme analysis [14]. *Bordetella* species do not survive outside the body for appreciable periods of time. All four original species uniquely localize on cilia of the mammalian respiratory epithelium.

*B. pertussis*, the causative agent of whooping cough, and *B. parapertussis* are the most important human pathogens among the genus. *B. bronchiseptica* and *B. avium* are respiratory pathogens in various animal hosts; the former occasionally

**Figure 1.** Neighbor-joining analysis of DNA sequences from several of the species found to have homology with the three clinical isolates, X69095, O65172, and I90788. Phylogenetic analysis was based on 16S rRNA gene sequences. The “bootstrap” replicate percentages appear above each branch. The scale is provided as a measurement of the relative phylogenetic distance.
infects humans as well. Recent genotypic and phenotypic analyses have categorized \textit{Bordetella hinzii} [15, 16], \textit{Bordetella trematum} [17], and the recently reported emerging pathogen \textit{B. holmesii} [1]. \textit{B. hinzii} is a nonpathogenic inhabitant of the respiratory tracts of fowl that occasionally infects humans [18]. Our isolation of \textit{B. holmesii} from sputum indicates that this organism may inhabit the human respiratory tract like other \textit{Bordetella} species.

Biochemical reactions are helpful to differentiate \textit{B. holmesii} from other \textit{Bordetella} species; however, the lack of oxidase activity and of carbohydrate utilization makes it difficult to differentiate this organism from other phenotypically similar bacteria, including asaccharolytic \textit{Acinetobacter} species [19] and CDC nonoxidizer group I [20]. Herein, we distinguished \textit{B. holmesii} by sequencing the 16S rRNA gene, in which it is possible to find species-specific regions of 20–30 bases [21]. Identification of fastidious pathogens can be accomplished by sequencing of the 16S rRNA gene [6, 7], which can be amplified directly from bacterial colonies without prior extraction [22]. Our confirmation of \textit{B. holmesii} on the basis of 99.8\% sequence homology illustrates the utility of this technique.

The \textit{B. holmesii}–like organisms reported herein are susceptible to most antibiotics intended for treatment of gram-negative bacillus infection. Our laboratory investigations and those of others [12] suggest that use of an intravenous third-generation \textit{B. holmesii} sequencing of the 16S rRNA gene [6, 7], which can be amplified by polymerase chain reaction—amplified 16S rRNA-specific DNA. Int J Syst Bacteriol 1991;41:324–5.


References
