**BRIEF REPORT**

*Mycobacterium neoaurum* Bloodstream Infection: Report of 4 Cases and Review of the Literature

Laraine L. Washer,1 James Riddell IV,1 Jennifer Rider,2 and Carol E. Chenoweth1

1Department of Infectious Diseases, Division of Infectious Diseases, Department of Internal Medicine, and 2Department of Infection Control and Epidemiology, University of Michigan Health System, Ann Arbor

We describe a cluster of 4 bloodstream infections with *Mycobacterium neoaurum* and 5 additional cases from the literature. Infections occurred mainly in immunocompromised hosts who had central venous catheters. Fever was universal at presentation, but local signs of inflammation were rare. Combination antimicrobial therapy and catheter removal resulted in clinical cure.

Infections due to rapidly growing *Mycobacterium* species are increasingly encountered, particularly among immunocompromised populations [1, 2]. *Mycobacterium fortuitum*, *Mycobacterium chelonae*, and *Mycobacterium abscessus* cause skin and soft-tissue infections, lymphadenitis, endocarditis, pneumonia, and keratitis [3]. In addition, *M. fortuitum* [4] and *M. chelonae* [5] are associated with catheter-related bacteremia and exit site infection in patients with cancer.

In contrast, *M. neoaurum*, a rapidly growing, pigmented member of the *Mycobacterium parafortuitum* complex [6], has rarely been reported as a cause of infection among immunocompromised hosts with indwelling devices. We report 4 cases of *M. neoaurum* bloodstream infection and review an additional 5 cases from the literature to define underlying conditions and outcomes associated with *M. neoaurum* bloodstream infection.

**Methods.** We conducted a retrospective review of mycobacteriology records at the University of Michigan Health System (Ann Arbor) from 2000 through 2006. We identified 3 children and 1 adult patient with blood cultures positive for *M. neoaurum*. All isolates were initially recovered from routine aerobic blood cultures (BacT/Alert; bioMérieux) and were determined to be acid-fast using Kinyoun stain. Smooth, shiny, yellow colonies grew on subculture within 7 days. Identification to the species level was performed using conventional methods and high-pressure liquid chromatography [7–9]. Biochemical characteristics were consistent with *M. neoaurum* infection, including positive results for 68°C catalase activity, nitrate reduction, Tween hydrolysis, potassium tellurite reduction, susceptibility to polymixin B, and iron uptake, with negative results for semiquantitative catalase activity and 3-day arylsulfatase. Carbohydrate utilization tests were positive for mannotol and inositol but negative for citrate and sorbitol testing [7]. High-pressure liquid chromatography patterns were consistent with *M. neoaurum* and were distinctly different from other pigmented mycobacteria (*Mycobacterium flavescens*, *Mycobacterium phlei*, and *Mycobacterium vaccae*) and nonpigmented, rapidly growing mycobacteria species. Final identification as *M. neoaurum* was performed by the Michigan Department of Community Health (Lansing).

In addition, using the Medline Database (National Library of Medicine), we searched the literature published from 1966 to 2006 using the following search terms: “*Mycobacterium neoaurum*,” “*Mycobacterium neoaurum* bloodstream infection,” “*Mycobacterium neoaurum* bacteremia,” “rapidly growing mycobacterium bloodstream infection,” and “rapidly growing mycobacterium bacteremia.” We identified additional references within bibliographies provided by Medline-cited studies. Manuscripts were reviewed to identify underlying patient demographic characteristics and risk factors, underlying comorbidities, presence of and indication for indwelling devices, treatment, and outcome. Information regarding antibiotic susceptibility was recorded when available.

**Patients and results.** Patient 1 was a 32-month-old girl with neuroblastoma who underwent stem-cell transplantation and developed neutropenic fever. After 4 days, 2 blood cultures grew *M. neoaurum*. Her Hickman catheter site was not erythematous or tender. She was treated with meropenem, amikacin, and clarithromycin, but she remained febrile until catheter removal. Antimicrobials were changed to ciprofloxacin and linezolid after 7 days to complete 3 weeks of total antimicrobial therapy. Bacteremia resolved, but she died of neuroblastoma 3 months later.

Patient 2 was a 15-month-old girl who had received a liver transplant and who presented with fever, vomiting, and diarrhea. She did not have a central venous catheter. After 6 days,
1 blood culture grew *M. neoaurum* and *Rhodococcus gordonii*. She did not receive antimicrobials and experienced a spontaneous clearance of her bacteremia.

Patient 3 was a 3-year-old boy with rhabdomyosarcoma who presented with neutropenic fever and hypotension. There was no inflammation at his Broviac catheter site. After 1 day, 6 blood cultures grew *M. neoaurum*. He was treated with amikacin for 12 days, as well as clarithromycin and levofloxacin for 6 weeks. His catheter was removed. The bacteremia cleared, but he died 14 months later of rhabdomyosarcoma.

Patient 4 was a 59-year-old woman who was receiving intravenous hydration through a peripherally inserted central catheter for short-gut syndrome resulting from colectomy for colon cancer. The patient presented with fever and hypotension. After 2 days, 5 blood cultures grew *M. neoaurum*, and her catheter was immediately removed. She received cefoxitin for 2 weeks and levofloxacin, clarithromycin, and ethambutol for 4 weeks, with resolution of bacteremia.

**Results.** A total of 9 patients were identified with bloodstream infection due to *M. neoaurum*—4 cases from the University of Michigan Health System and 5 cases from the literature [10–14]. Among the 9 patients with *M. neoaurum* bloodstream infection, 7 (77.8%) had central venous catheters, and 1 (11.1%) had an arteriovenous graft. Only 3 patients (33.3%) had localized evidence of catheter site infection with erythema or tenderness. All 9 patients presented with fever, and 2 patients (22.2%) were hypotensive. Indication for catheter or graft included chemotherapy (in 4 patients), parenteral nutrition (in 1 patient), prostacyclin (in 1 patient), dialysis (in 1 patient), and hydration (in 1 patient). Comorbidities included malignancy (in 6 patients), neutropenia (in 4 patients), renal failure (in 1 patient), stem cell transplantation (in 2 patients), solid-organ transplantation (in 1 patient), and pulmonary hypertension (in 1 patient). Individuals had a total of 1–8 positive blood culture results. When reported, the duration of bacteremia was 1–14 days (table 1).

Treatment of *M. neoaurum* bacteremia varied. Among the 7 cases of catheter-associated bloodstream infection, 5 cases were treated with catheter removal and antibiotic therapy (patients 1, 3, and 4) [13, 14], 1 case was treated with catheter removal alone [12], and 1 case was treated with antibiotics alone [11]. Among the patients without catheters, 1 patient underwent removal of an arteriovenous graft and received antimicrobial therapy [10], and 1 patient did not receive antimicrobial therapy (patient 2). Seven patients had persistent bacteremia or fever that did not resolve until catheter or arteriovenous graft removal (patients 1, 3, and 4) [10, 12–14].

Antimicrobial management of bacteremia also varied widely. Antimicrobials included aminoglycosides (in 5 patients), clarithromycin (in 3 patients), a fluoroquinolone (in 4 patients), doxycycline (in 1 patient), cefoxitin (in 2 patients), cefazidime (in 1 patient), ticarcillin-clavulanate (in 1 patient), meropenem (in 1 patient), linezolid (in 1 patient), and ethambutol (in 1 patient). Among those treated with antimicrobial therapy, 2–4 antimicrobials were used, with duration of treatment of 3–7 weeks. All patients experienced clearance of bacteremia (patients 1–4) [10–14].

Susceptibility testing by broth microdilution [15] or disk diffusion was performed on 6 of 9 patient isolates. Zones of inhibition ≥30 mm were considered to indicate susceptibility. Isolates that were tested were susceptible to ciprofloxacin (6 of 6 isolates), amikacin (6 of 6 isolates), imipenem (5 of 6 isolates), and doxycycline-tetracycline (6 of 6 isolates). Most isolates that were tested were susceptible to trimethoprim-sulfamethoxazole (3 of 4 isolates) and cefoxitin (2 of 3 isolates). Most isolates tested were resistant to rifampin (2 of 3 isolates) and clarithromycin (3 of 4 isolates; patients 1 and 3) [10, 11, 13, 14].

**Discussion.** *M. neoaurum* can be detected on routine aerobic blood culturing systems and typically grows within 5 days on Lowenstein-Jensen agar at 25°C–35°C. *M. neoaurum* can initially be distinguished from other, more-common rapidly growing mycobacterial causes of bloodstream infection, because *M. neoaurum* colonies are smooth, round, yellow-orange, and scotochromogenic, in contrast to the nonchromogenic rough or smooth colonies of *M. fortuitum* and *M. cheloneae*. Further identification of *M. neoaurum* can be performed via classic biochemical techniques or using advanced methods, including high-pressure liquid chromatography and sequencing of a unique 16S rRNA [16].

Isolation of rapidly growing mycobacteria, such as *M. neoaurum*, from clinical specimens may represent either contamination or infection [3, 12, 17]. Three infections with *M. neoaurum* occurred in pediatric patients in the University of Michigan Health System from March 2004 to June 2004, and a fourth infection occurred in an adult patient in November 2005. We found no epidemiological links to suggest an environmental source, although all patients were chronically ill and had experienced prior hospital care. Many rapidly growing mycobacteria have been described as contaminating water systems in hospitals [18]; however, *M. neoaurum* has not. When isolated from a clinical specimen in the context of fever without an alternative etiology, *M. neoaurum* should be considered to be a pathogen if multiple cultures yield the organism.

Similar to other rapidly growing mycobacterial species, including *M. fortuitum*, *M. cheloneae*, *M. abscessus*, *Mycobacterium smegmatis*, and *Mycobacterium mucogenicum* [3], patients with *M. neoaurum* bloodstream infection are typically immunocompromised, have central venous catheters, and present with undifferentiated fever. In contrast to *M. cheloneae* and *M. fortuitum* infections, for which catheter exit-site infections that require debridement are prominent, localized
Table 1. Features of 9 patients with *Mycobacterium neoaurum* bloodstream infection.

<table>
<thead>
<tr>
<th>Study</th>
<th>Location</th>
<th>Age (sex)</th>
<th>Comorbidity</th>
<th>Neutropenia</th>
<th>Catheter</th>
<th>Indication for venous access</th>
<th>Duration of catheter use, months</th>
<th>Fever</th>
<th>Infection at catheter site</th>
<th>No. of positive culture results</th>
<th>Duration of bacteremia, days</th>
<th>Catheter removal</th>
<th>Antimicrobial therapy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present study</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Meropenem, amikacin, and clarithromycin for 7 days; ciprofloxacin, linezolid for 2 weeks</td>
</tr>
<tr>
<td>Patient 1</td>
<td>United States</td>
<td>32 months (F)</td>
<td>Neuroblastoma, PBSCT</td>
<td>Yes</td>
<td>Hickman</td>
<td>Chemotherapy</td>
<td>5</td>
<td>Yes</td>
<td>No</td>
<td>2</td>
<td>2</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Patient 2</td>
<td>United States</td>
<td>15 months (F)</td>
<td>Liver transplantation</td>
<td>No</td>
<td>None</td>
<td>NA</td>
<td>NA</td>
<td>Yes</td>
<td>NA</td>
<td>1</td>
<td>1</td>
<td>NA</td>
<td>None</td>
</tr>
<tr>
<td>Patient 3</td>
<td>United States</td>
<td>3 years (M)</td>
<td>Rhabdomyosarcoma</td>
<td>Yes</td>
<td>Broviac</td>
<td>Chemotherapy</td>
<td>7</td>
<td>Yes</td>
<td>No</td>
<td>6</td>
<td>3</td>
<td>Yes</td>
<td>Amikacin for 12 days, levofloxacin and clarithromycin for 6 weeks</td>
</tr>
<tr>
<td>Patient 4</td>
<td>United States</td>
<td>59 years (F)</td>
<td>Colon cancer (distant), short gut syndrome</td>
<td>No</td>
<td>PICC</td>
<td>Hydration</td>
<td>1</td>
<td>Yes</td>
<td>No</td>
<td>5</td>
<td>2</td>
<td>Yes</td>
<td>Cefoxitin for 2 weeks, levofloxacin, clarithromycin, and ethambutol for 4 weeks</td>
</tr>
<tr>
<td>Woo et al. [14]</td>
<td>Hong Kong</td>
<td>9 years (F)</td>
<td>ALL</td>
<td>Yes</td>
<td>Hickman</td>
<td>Chemotherapy</td>
<td>NR</td>
<td>Yes</td>
<td>No</td>
<td>4</td>
<td>13</td>
<td>Yes</td>
<td>Cefazidime, amikacin for 3 weeks</td>
</tr>
<tr>
<td>Holland et al. [13]</td>
<td>Australia</td>
<td>17 years (M)</td>
<td>ALL, PBSCT</td>
<td>Yes</td>
<td>Hickman</td>
<td>Chemotherapy</td>
<td>3</td>
<td>Yes</td>
<td>Yes</td>
<td>4</td>
<td>7</td>
<td>Yes</td>
<td>Ticarcillin-clavulanate and tobramycin for 3 weeks</td>
</tr>
<tr>
<td>Davison et al. [11]</td>
<td>Australia</td>
<td>63 years (F)</td>
<td>Ovarian cancer (distant), bowel obstruction</td>
<td>No</td>
<td>Hickman</td>
<td>TPN</td>
<td>NR</td>
<td>Yes</td>
<td>NR</td>
<td>8</td>
<td>3</td>
<td>No</td>
<td>Cefoxitin and gentamicin for 7 weeks</td>
</tr>
<tr>
<td>George et al. [12]</td>
<td>United States</td>
<td>46 years (M)</td>
<td>Pulmonary hypertension</td>
<td>No</td>
<td>Hickman</td>
<td>Prostacyclin</td>
<td>10</td>
<td>Yes</td>
<td>Yes</td>
<td>2</td>
<td>NR</td>
<td>Yes</td>
<td>None</td>
</tr>
<tr>
<td>Becker et al. [10]</td>
<td>Canada</td>
<td>40 years (F)</td>
<td>Renal failure</td>
<td>No</td>
<td>AV graft</td>
<td>Hemodialysis</td>
<td>9</td>
<td>Yes</td>
<td>Yes</td>
<td>2</td>
<td>14</td>
<td>NA</td>
<td>Ciprofloxacin and doxycycline for 3 weeks</td>
</tr>
</tbody>
</table>

**NOTE.** ALL, acute lymphocytic leukemia; NA, not applicable; NR, not reported; PBSCT, peripheral blood stem-cell transplantation; PICC, peripherally inserted central catheter; TPN, total parenteral nutrition.
catheter site infection rarely occurs with M. neoaurum bloodstream infection [4, 5, 19].

Successful treatment of M. neoaurum bloodstream infection has most commonly included several weeks of combination antimicrobial therapy, including macrolides, fluoroquinolones, or aminoglycosides, and removal of devices. Among patients with M. neoaurum catheter-associated bloodstream infection, only 1 patient was successfully treated without catheter removal. Outcomes are similar to those observed with M. fortuitum catheter-related infections, for which all patients who underwent catheter removal recovered, whereas those who did not undergo catheter removal experienced persistent or recurrent bacteremia [4].

Although susceptibility testing of rapidly growing mycobacteria is not standardized and results are often delayed well into a course of empirical therapy, susceptibility testing is clinically useful. The susceptibility profile for M. neoaurum appears to be more favorable, compared with those for M. abscessus and M. chelonae. Among the cases reviewed herein, M. neoaurum was most commonly susceptible to imipenem, ciprofloxacin, and amikacin, although interlaboratory imipenem susceptibility results may not be reliable [3]. American Thoracic Society guidelines [17] suggest that susceptibility testing for rapidly growing mycobacteria should include amikacin, tobramycin, cefoxitin, ciprofloxacin, clarithromycin, doxycycline or minocycline, linezolid, and sulfonamides.

In conclusion, M. neoaurum bloodstream infection is rare and occurs most often in immunocompromised hosts who present with undifferentiated fever and have an indwelling venous catheter. Local signs of catheter inflammation are uncommon. Combination antimicrobial therapy for several weeks is most commonly employed, and when combined with catheter removal, excellent clinical results are generally observed.

Acknowledgments

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References