High-Level Pan-Azole-Resistant Aspergillosis

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High-level pan-azole-resistant Aspergillus fumigatus was recovered from four patients with chronic lung disease. In one patient, the development of progressive resistance followed long-term azole therapy and switching between antifungal azoles. The high-level pan-azole-resistant phenotypes were not associated with a specific cyp51A gene mutation. New strategies that avoid the development of progressive azole resistance are needed.

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zole resistance in Aspergillus fumigatus is an emerging problem which is associated with treatment failure in patients with aspergillosis diseases (1). Resistance is commonly due to mutations in the cyp51A gene (1) that typically lead to high-level resistance (MIC, ≥8 mg/liter) against one azole and low-level resistance (MICs close to the resistance breakpoint) against others (2, 3).

We identified four A. fumigatus isolates with MIC of ≥8 mg/liter for all mold-active azoles, measured using EUCAST methodology (4). We labeled this unique phenotype high-level pan-azole resistance. We analyzed the cyp51A gene sequence of the isolates, using previously published algorithms (5), and retrieved clinical data for these four patients (Table 1).

The first patient was a 22-year-old male with cystic fibrosis. After being diagnosed with allergic bronchopulmonary aspergillosis (ABPA), he commenced itraconazole and steroid maintenance therapy. Fungal sputum cultures after 8 months of itraconazole therapy revealed an A. fumigatus isolate with the high-level pan-azole-resistant phenotype. The patient continued itraconazole maintenance therapy, and the high-level pan-azole-resistant isolate was not recovered from repeat cultures.

The second patient was a 71-year-old male with a medical history of asthma, bronchiectasis, and intermittent culture positivity with itraconazole- and voriconazole-susceptible A. fumigatus. The patient did not meet diagnostic criteria for ABPA and was never treated with azoles. The high-level pan-azole-resistant A. fumigatus isolate was isolated once from a sputum sample; follow-up sputum cultures yielded azole-susceptible A. fumigatus.

The third patient was a 47-year-old female with severe pulmonary sarcoidosis, complicated by a pneumothorax with subsequent pleural empyema. From this empyema, an azole-susceptible A. fumigatus isolate was cultured (itraconazole and voriconazole MICs, 0.5 mg/liter; posaconazole MIC, 0.063 mg/liter). Treatment with itraconazole was started, later changed to voriconazole, and ultimately changed to posaconazole as a chronic suppressive therapy. After 18 months of azole therapy, the patient’s disease progressed, and a sputum sample was ordered for fungal culture. This sample grew the high-level pan-azole-resistant isolate and induced a switch to liposomal amphotericin B therapy. Despite treatment, the patient’s condition deteriorated, and she died of respiratory failure.

The fourth patient was a 39-year-old male diagnosed with chronic granulomatous disease and ABPA. The patient had been treated for multiple episodes of invasive pulmonary aspergillosis, and he received secondary prophylaxis with itraconazole. He then presented with arthritis of the sternoclavicular joint, and itraconazole-resistant A. fumigatus was cultured from biopsy specimens. Treatment with voriconazole was initiated, but visual disturbances forced a switch to liposomal amphotericin B and anidulafungin. The patient responded and was discharged on posaconazole maintenance therapy. After 11 months, the patient presented with increasing dyspnea, dry cough, and fever. A chest computed tomography (CT) scan revealed a cavity and bronchiolitis in the right lower lobe. Bronchoalveolar lavage cultures were positive for A. fumigatus, which exhibited the high-level pan-azole-resistant phenotype and an M220R mutation in the cyp51A gene, absent in the patient’s previous isolates. Micafungin was added to posaconazole, based on susceptibility test results (Table 1). After 1 and 7 days of treatment, follow-up cultures remained positive for the high-level pan-azole-resistant strain. After 10 days of therapy, the patient died of pulmonary hemorrhage. Microsatellite typing (4) showed that the isolates from this patient were isogenic.

The isolates cultured from these four patients reveal a new and highly worrisome phenotype characterized by high-level resistance to all mold-active azoles, including the new azole isavuconazole. Isavuconazole was shown to exhibit cross-resistance to voriconazole (6). All patients had chronic lung diseases, and a chronic aspergillus disease was diagnosed in three patients. In patients 1 and 2, there were no clinical factors that might explain the single recovery of the high-level pan-azole-resistant A. fumigatus isolates. The high-level pan-azole-resistant isolates might have been acquired as such from the environment (7).

In patient 3, a persisting aspergillus infection was treated with various antifungal azoles. Although the initial isolate was azole susceptible, the high-level pan-azole-resistant isolate with an environmental resistance mechanism (TRy121F/T289A) was cultured during therapy. The high-level pan-azole-resistant phenotype may have developed during azole therapy or may have been acquired as such from the environment. Clear evidence for the development of progressive resistance was present in patient 4. As

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### TABLE 1: Patient characteristics, azole *in vitro* activities, and *cyp51A* resistance mechanisms in four high-level azole-resistant *A. fumigatus* isolates

<table>
<thead>
<tr>
<th>Case</th>
<th>Sex</th>
<th>Age (y)</th>
<th>Underlying condition</th>
<th>Aspergillus disease</th>
<th>Prior azole exposure</th>
<th>Origin of isolate</th>
<th>MIC (mg/liter) of:</th>
<th>cyp51A mutation(s)</th>
<th>AMB</th>
<th>AFG</th>
<th>ITC</th>
<th>VRC</th>
<th>POS</th>
<th>ISA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M</td>
<td>22</td>
<td>None</td>
<td>Chronic invasive</td>
<td>ABPA</td>
<td>Sputum</td>
<td>&gt;16</td>
<td>TR34/L98H</td>
<td>1.0</td>
<td>0.063</td>
<td>0.063</td>
<td>0.063</td>
<td>0.063</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>M</td>
<td>71</td>
<td>Bronchiectasis</td>
<td>None</td>
<td>None</td>
<td>Sputum</td>
<td>&gt;16</td>
<td>H11022</td>
<td>&gt;16</td>
<td>&gt;16</td>
<td>&gt;16</td>
<td>&gt;16</td>
<td>&gt;16</td>
<td>&gt;16</td>
</tr>
<tr>
<td>3</td>
<td>F</td>
<td>47</td>
<td>Sarcoidosis</td>
<td>Empyema</td>
<td>ITC, VRC, POS</td>
<td>Sputum</td>
<td>0.5</td>
<td>None detected</td>
<td>&gt;16</td>
<td>&gt;16</td>
<td>&gt;16</td>
<td>&gt;16</td>
<td>&gt;16</td>
<td>&gt;16</td>
</tr>
<tr>
<td>4</td>
<td>M</td>
<td>39</td>
<td>Chronic granulomatous</td>
<td>Disease</td>
<td>None</td>
<td>BAL specimen</td>
<td>0.5</td>
<td>M220R</td>
<td>&gt;16</td>
<td>&gt;16</td>
<td>&gt;16</td>
<td>&gt;16</td>
<td>&gt;16</td>
<td>&gt;16</td>
</tr>
</tbody>
</table>

**MIC**: minimum inhibitory concentration. **Amb**: amphotericin B; **AFG**: anidulafungin; **ITC**: itraconazole; **VRC**: voriconazole; **POS**: posaconazole; **ISA**: isavuconazole.

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We report the emergence of high-level pan-azole-resistant *A. fumigatus* isolates. This phenotype might originate from the environment but also may develop through switching betweenazole compounds in patients with chronic aspergillosis. There is a clear need to develop strategies in patients at risk for chronic aspergillosis that avoids high-level resistance development.
REFERENCES


