


Address for correspondence: Giordano Madeddu, Dipartimento di Medicina Clinica, Sperimentale e Oncologica, Università degli Studi di Sassari, Via de Nicola 1, 07100 Sassari, Italy; email: giordano.madeddu@uniss.it

---

**Leishmania Resistance to Miltefosine Associated with Genetic Marker**

To the Editor: During 2000–2010, serial *Leishmania* isolates obtained from an HIV-infected patient who was not responding to treatment showed a gradual decrease in vitro miltefosine susceptibility. We performed *L. donovani* miltefosine transporter (*Ldmt*) gene analysis to identify an association between miltefosine resistance of reference *L. donovani* lines and variability in miltefosine response of *L. infantum* isolates. A new single-nucleotide polymorphism (SNP), L832F, was identified, which might be a marker of miltefosine resistance in leishmaniasis.

The patient, a 46-year-old woman, had lived in France since 1994 but regularly returned to Algeria, her country of birth. HIV-1 infection was diagnosed in 1991. Antiretroviral therapy was initiated in 1993, leading to undetectable viral load and a CD4+ T-cell count of 185 cells/mm³. Concurrent conditions were thoracic herpes zoster in 1996, hairy leukoplakia of the tongue, oropharyngeal candidiasis, and chronic renal failure of unknown cause since 2000.

Visceral leishmaniasis was diagnosed in 1998 by culture of a bone marrow smear, which showed intracellular amastigotes. Use of meglumine antimonate (Glucantime; Sanofi, Paris, France), a drug of choice for the treatment of leishmaniasis, was contraindicated because of pancreatitis in the patient and in vitro isolate susceptibility variation; therefore, induction therapy consisted of liposomal amphotericin B (AmpB [AmBisome; Astellas Pharma US, Deerfield, IL, USA]) at a dose of 3 mg/kg/d for 5 consecutive days, then 1× week for 5 weeks (total dose 30 mg/kg) during 1998–2000 (Table). The same medication was administered for relapses at 4 mg/kg/d for 5 days, then 4 mg/kg 1× week for 5 weeks (total dose 40 mg/kg) during 2001–2010. Given the adverse effects of AmpB and the availability of oral miltefosine (Impavido; AEterna Zentaris Inc., Quebec City, Quebec, Canada), the latter drug was used for maintenance treatment during 2001–2007 at 50 mg 2×/d. Leishmaniasis was monitored by leukocytocentrifugation and culture of blood samples on Novy-Nicolle-McNeal medium.

When signs of biological and clinical relapse appeared, bone marrow was aspirated for parasite detection. After culture of the aspirate and isoenzyme determination, the strain was identified as *L. infantum*, zymodeme MON-24. Eleven relapses were documented; all were confirmed by positive direct examination of bone marrow or blood, but cultures of only 7 samples yielded positive results (Table).

The susceptibility of 4 cryopreserved isolates (S₀, S₁, S₂, and S₅; Table) to AmpB and to miltefosine was studied in the *in vitro* promastigote and axenic amastigote form by determining the concentrations inhibiting parasite growth by 50% (IC₅₀). The 50% inhibitory concentration (IC₅₀) was determined in parallel for the following reference *L. donovani* lines: a wild-type *L. donovani* LV9 (MHOM/ET/67/HU3) line (LV9 WT), a wild-type *L. donovani* DD8 (MHOM/IN/80/DD8) line (DD8 WT), a laboratory miltefosine-resistant line obtained from LV9 WT (LV9 miltefosine-R, resistant to 90 μmol/L miltefosine), and the laboratory AmpB-resistant line obtained from DD8 WT (DD8 Amb-R, resistant to 1.4 μmol/L AmpB) on promastigote and axenic amastigote forms (3,4).

The AmpB susceptibility of the isolates did not change notably over time; IC₅₀ values ranged from 0.09...
μmol/L to 0.24 μmol/L, regardless of parasite form, similar to those of wild-type reference strains (Table). In contrast, the IC₅₀ values of miltefosine increased greatly over time, from 5.00 μmol/L to 50.10 μmol/L. During the 6 years of follow-up with miltefosine maintenance therapy, the susceptibility of the isolate (S₃) obtained 6 months after miltefosine treatment withdrawal in 2008 was 6-fold higher than that of the isolate (S₁) obtained in 2000.

The L. donovani miltefosine transporter protein (LdMT) promotes miltefosine translocation (5), and LdMT inactivation in L. donovani promastigotes leads to miltefosine resistance at the promastigote and amastigote stages (6). In 2003 and 2006 studies, several mutations were linked to the inability of parasites to take up miltefosine and to miltefosine resistance (5,7). In a 2009 study, the weak expression of LdMT and its β subunit LdROS3 in L. braziliensis isolates was linked to diminished sensitivity (8). We sequenced the entire Ldmt gene (3,294 bp) in the reference strains and the clinical isolates for SNP analysis (3,7). Only 1 new SNP, L832F, was found in the miltefosine-resistant reference strain (LV9 miltefosine-R) and in clinical isolate S₆. The L832 wild-type allele was found in isolate S₁ and in the miltefosine-sensitive reference lines (LV9, DD8, and DD8 AmpB-R), whereas both alleles were found in isolates S₃ and S₄, with a decrease in the wild-type allele (Table). The last isolate, which was obtained 3 years after miltefosine withdrawal and could not be subcultured, had reverted to the wild-type allele (L832).

These results point to a relation between the 832F allele and diminished susceptibility to miltefosine. Analysis of this case of miltefosine resistance in a patient co-infected with Leishmania sp. and HIV strongly suggests that an SNP (L832F) in the Ldmt gene could represent a molecular marker of miltefosine resistance in L. infantum and L. donovani.

<table>
<thead>
<tr>
<th>Isolate</th>
<th>Year</th>
<th>AmpB</th>
<th>Miltefosine</th>
<th>Promastigotes</th>
<th>Axenic amastigotes</th>
<th>Promastigotes</th>
<th>Axenic amastigotes</th>
<th>Ldmt SNP</th>
</tr>
</thead>
<tbody>
<tr>
<td>S₁</td>
<td>2000</td>
<td>3 mg/kg/d × 5 d; then 1 wk × 5 wk</td>
<td>–</td>
<td>0.09 ± 0.04†</td>
<td>0.10 ± 0.03</td>
<td>7.14 ± 0.56†</td>
<td>5.00 ± 0.7†</td>
<td>L832</td>
</tr>
<tr>
<td>S₂</td>
<td>2001</td>
<td>4 mg/kg/d × 5 d; then 1 wk × 5 wk</td>
<td>50 mg 2×/d</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>S₃</td>
<td>2005</td>
<td>4 mg/kg/d × 5 d; then 1 wk × 5 wk</td>
<td>–</td>
<td>0.13 ± 0.03</td>
<td>0.20 ± 0.03</td>
<td>25.93 ± 1.46†</td>
<td>21.00 ± 1.50†</td>
<td>832/F</td>
</tr>
<tr>
<td>S₄</td>
<td>2007</td>
<td>4 mg/kg/d × 5 d; then 1 wk × 5 wk</td>
<td>–</td>
<td>0.24 ± 0.01†</td>
<td>0.15 ± 0.02</td>
<td>27.89 ± 1.76†</td>
<td>31.90 ± 1.60†</td>
<td>832F</td>
</tr>
<tr>
<td>S₅</td>
<td>2008</td>
<td>4 mg/kg/d × 5 d; then 1 wk × 5 wk</td>
<td>–</td>
<td>0.16 ± 0.03</td>
<td>0.11 ± 0.03</td>
<td>44.30 ± 3.70†</td>
<td>50.10 ± 1.00†</td>
<td>L832</td>
</tr>
<tr>
<td>S₆</td>
<td>2010</td>
<td>4 mg/kg/d × 5 d; then 1 wk × 5 wk</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>

Reference strains:
- LV9 WT
- LV9 Miltefosine-R
- DD8 WT
- DD8 AmpB-R

IC₅₀, 50% inhibitory concentration; AmpB, amphotericin B; Ldmt, Leishmania donovani miltefosine transporter gene; SNP, single-nucleotide polymorphism; –, assay not performed because sample unavailable or not culturable; WT, wild type; R, resistant.
†Significance was analyzed by using the nonparametric Mann-Whitney U test to compare the IC₅₀ of the isolates with the IC₅₀ of reference strains; p<0.01 was considered significant. IC₅₀ of AmpB and miltefosine was compared with IC₅₀ of reference strains and S₁/S₃, S₁/S₄, and S₁/S₆. Miltefosine: S₁/S₃, S₁/S₄, S₁/S₆; p<0.01. AmpB: S₁/S₄ significant p<0.01; S₁/S₃, S₁/S₆ not significant.
‡For each relapse.

**Table. Comparisons of IC₅₀ for AmpB and miltefosine against promastigotes and axenic amastigotes and distribution of LdMT SNPs in Leishmania infantum isolates and reference strains**

**References**

1. Vieira NC, Herrenknecht C, Vacus J, Fournet A, Bories C, Figadère B, et al. Selection of the most promising 2-substituted quinoline as antileishmanial can-
**LETTERS**

**Prolonged KI Polyomavirus Infection in Immunodeficient Child**

To the Editor: Two novel polyomaviruses (PyVs), KIPyV and WUPyV, were identified in respiratory and fecal specimens from children with signs and symptoms of respiratory tract infection (1,2). A review of literature on emerging viruses in transplant recipients indicated that up to 80% of patients harboring these PyVs are coinfected with another respiratory virus, complicating interpretation of positive findings (3). Seroprevalence of KIPyV and WUPyV in healthy blood donors in Germany have been reported to be 67% and 89%, respectively (4).

The effect of these viruses in immunocompromised patients is unknown. Some studies report a higher frequency of KIPyV DNA detection in hematopoietic stem cell transplant (HSCT) recipients (5–7) than in immunocompetent patients. In fact, HCST recipients might be more prone to productive infection with KIPyV and WUPyV than to infection with PyVs JC and BK (BKPyV) (5).

We report prolonged detection of KIPyV DNA in the respiratory tract of an immunocompromised child. A 12-year-old girl with severe combined immunodeficiency was admitted to the Freiburg University Medical Center, Germany, in November 2009 for treatment of progressive respiratory problems and cytomegalovirus (CMV) disease. Although the molecular basis of the immune disorder was unknown, HSCT was indicated because of uncontrolled CMV infection and progressive clinical deterioration.

Allogenic HSCT was performed in February 2010. Pretransplant treatments included thymothesis (day −7; 8 mg/kg), fludarabine (days −6 to −3; 120 mg/m²), treosulfan (days −6 to −4; 42 g/m²), and antithymocyte globulin (days −4 to −2; 45 mg/kg). The patient received bone marrow cells (4.2 × 10⁶ CD34-positive cells/kg) from an 8/10 human leukocyte antigen-matched, CMV-positive, unrelated donor. Graft-versus-host disease prophylaxis consisted of cyclosporine A (from day −1) and methotrexate (days +1, +3, +6; 10 mg/m²). Leukocyte, granulocyte, and platelet engraftment occurred on days +18, +19, and +32, respectively. Full donor chimera was detected by day +62 (Figure, panel A).

Before hospitalization, the child had several pulmonary infections. At admission, chest radiograph showed middle lobe atelectasis but no visible infiltrates. On day −83, human bocavirus was detected. On day −27, the occurrence of bilateral infiltrates was assessed, and pneumonia was diagnosed. On day +55, fever and hypoxia were monitored; chest radiograph revealed regressive infiltrates in the lower lobes but central infiltrates in the upper lobes. Rhinovirus RNA was detected at this time and persisted in the respiratory tract until day +98 (Figure, panel A). Retrospectively, KIPyV DNA was detected in 6 nasopharyngeal aspirate specimens, 4 throat swab specimens, and 1 bronchoalveolar lavage specimen collected between days −103 and +98 (Figure, panel B). No KIPyV was detected in EDTA-treated blood samples at any time.

Stool samples were not available. The highest level of KIPyV DNA (10⁵ copies/mL) was detected on day +16. Starting from day +43, a steady decrease in KIPyV viral load was observed. Phenotypical analysis of blood leukocytes on day +55 showed normal CD56/+,+16/ natural killer cells and good T-cell engraftment but no B cells. On day +108, viral clearance had occurred. Sequencing of the small t antigen amplified from all available samples was performed (8) and showed 100% nucleotide identity (GenBank accession no. JN874415).