Leishmania (Viannia) lainsoni (Kinoplastida: Trypanosomatidae), a divergent Leishmania of the Vianna subgenus – A mini review

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Leishmania (Vianna) lainsoni is the Leishmania species that presents the most distinct biological (morphology, growth in axenic culture medium), biochemical (enzymatic electrophoresis profile), and molecular biology characteristics, when compared to other species of the Vianna subgenus. Development of promastigote forms of this parasite attached to the wall of the pyloric and hind gut regions of sand fly vectors is a solid characteristic that allows its positioning in the Vianna subgenus. However, taxonomic data from biochemical and molecular techniques on this Leishmania species are still not conclusive. It is evident the difficulty in taxonomically positioning this borderline Leishmania species. In this review we present the data accumulated since L. (Vianna) lainsoni has been described and we discuss its position in the Vianna subgenus.

Key words: Leishmania (Vianna) lainsoni - trypanosomatid - taxonomy - review

Human leishmaniasis is a disease with a wide spectrum of clinical manifestations, caused by different species of flagellate protozoa belonging to the Leishmania genus (Grimaldi et al. 1991, Grimaldi & Tesh 1993). These heteroxenic flagellates (Protozoa: Kinoplastida: Trypanosomatidae) are obligate intracellular parasites (under the amastigote form) of vertebrate hosts, being transmitted (as promastigote forms) by sand flies (Diptera: Psychodidae: Phlebotominae). There are two main clinical manifestations of leishmaniasis: cutaneous and visceral (WHO 2003). The cutaneous form is polymorphic, affects the skin and/or mucoes, and is characterized by the presence of either (a) single/multiple painless lesions (simple cutaneous form), (b) nodular lesions spread over the body (diffuse cutaneous form) or (c) muco-cutaneous lesions that affect the nasofaringeal region (muco-cutaneous form).

Leishmania flagellates are grouped into two sub-genera, Leishmania and Vianna, according to their development in the insect digestive tract. Members from the Leishmania subgenus grow at the pyloric and midgut regions (suprapyllarian development), while Vianna species grow at the hindgut region (peripyllarian development) (Lainson & Shaw 1979, 1987). Nevertheless, complementary tests are necessary for accurate taxonomic positioning, such as isoenzyme profile, immunoreaction with monoclonal antibodies or PCR-based techniques.

Among the several Leishmania species identified in Brazil, L. (Vianna) lainsoni (Silveira et al. 1987) presents an atypical phylogenetic profile. Its divergent position into the Vianna subgenus is a common sense (Cupolillo et al. 1995, 2001, Eresh et al. 1995, Fernandes et al. 1995, McCann et al. 1999), but the available data are still not sufficient for an unequivocal taxonomic placement of this species. Characteristic features of L. (Vianna) lainsoni are its exuberant amastigote growth in skin lesions and the easy of cultivation in simple axenic culture media, which are typical of parasites belonging to the Leishmania subgenus. In this review we present the data accumulated since L. (Vianna) lainsoni has been described and we discuss its position in the Vianna subgenus (Table).

The parasite Leishmania (Vianna) lainsoni Silveira, Shaw, Braga & Ishikawa, 1987

New Leishmania species have been continuously described in Brazil, due to its large territorial dimension and its ecological diversity in tropical and subtropical areas, mainly at the Amazon region. Among the latest descriptions, an isolate was obtained from human samples collected in different locations in the state of Pará (Brazilian Amazon region). The parasites were successful isolated from human patients, and a new Leishmania species could be identified and named as L. (Vianna) lainsoni (Silveira et al. 1987).

The isoenzymatic profile of the first isolate of L. (Vianna) lainsoni (MHOM/BR/81/M6426) was compared to that of the reference strains L. (Vianna) braziliensis (MHOM/BR/75/M2903), L. (Vianna) guyanensis (MHOM/BR/75/M4147), and L. (Leishmania) amazonensis (IFLA/BR/67/P18). The isoenzymatic banding patterns showed that L. (Vianna) lainsoni was different from these reference strains by six among ten tested enzymes. This L. (Vianna) lainsoni strain was also probed against specific monoclonal antibodies (Mabs) against L. (Vianna) braziliensis (Mab B18), L. (Vianna) guyanensis (Mab B19), and L. (Vianna) panamensis (Mab B11), as well as against three other L. (Vianna) braziliensis group-specific monoclonal antibodies (Mabs B2, B3, and B12). The results by indirect immunofluorescence showed absence of cross-reactivity with all tested antibodies (Sil-
veira et al. 1987) and confirmed the status of *L. (Viannia) lainsoni* as a distinct species. Experimental infection of *Lutzomyia longipalpis* sand flies with *L. (Viannia) lainsoni* was performed, resulting in exuberant growth of promastigotes adhered to the insect hindgut wall, thus confirming the status of this parasite as a Peripylarian member. Taken together, these data contributed for inclusion of this species in the *Viannia* subgenus (Silveira et al. 1987).

Morphological studies of infected hamsters skin showed that *L. (Viannia) lainsoni* presents elongated amastigotes, as compared to other *Leishmania* species (length: 3.49 ± 0.37 µm; width: 1.4 ± 0.18 µm), with a bulk kinetoplast (Silveira et al. 1987). Axenic culture pro-mastigotes of *L. (Viannia) lainsoni* grown from skin biopsies of infected hamsters are characterized by a long flagellum, about 25 µm in length. These axenic promastigotes present an exuberant growth and are easily maintained in different culture media (Corrêa et al. 2005). In this sense, *L. (Viannia) lainsoni* differs from the other members of the *Viannia* subgenus, which grow poorly in vitro (Silveira et al. 1987).

Detailed ultrastructural studies on *L. (Viannia) lainsoni* are still lacking. A preliminary observation by transmission electron microscopy (TEM) of lesions in ex-perimentally infected hamsters showed intracellular oval amastigotes, measuring about 2.24 µm in length and 1.72 µm in width, with no megasomes (Soares et al. 1990). These values are slightly lower than the light microscopy measurements reported in the original description of the species (Silveira et al. 1987), but they seem to be more accurate, due to the better preservation obtained during the processing for TEM. An ultrastructural image (TEM) of a tissue amastigote was shown in a recent work on the cultivation of *L. (Viannia) lainsoni* (Corrêa et al. 2005). A single round amastigote, with no megasomes, was contained within a small parasitophorous vacuole, tightly adhered to the vacuole membrane.

The disease

*L. (Viannia) lainsoni* causes single cutaneous ulcers without evidence of posterior nasofaringeal involvement (Silveira et al. 1987), similar to that caused by other *Leishmania* parasites belonging to the *Viannia* subgenus: small self-limiting nodules or small ulcers, with abundant amas-tigotes at the lesion site.

Experimental infection of *Cebus apella* (Primates: Cebidae) with *L. (Viannia) lainsoni* showed that this neotropical primate is susceptible to infection by this parasite, with lesions lasting for about four months, a suitable time period for testing leishmanicidal drugs (Silveira et al. 1989). Histopathological analyses comparing skin lesions caused by *L. (Viannia) lainsoni*, *L. (Leishmania) amazonensis*, and *L. (Viannia) braziliensis* showed the same stages of lesion development, independent of the *Leishmania* species: (1) chronic unspecific infiltrate, (2) macrophage nodules with several parasites, (3) necrosis of the parasitized cells, (4) epithelial granulome, (5) absorption of the necrosis area, (6) unspecific residual infiltrate, and (7) scar (Silveira et al. 1990). However, *L. (Viannia) lainsoni* produces skin lesions with distinct characteristics: (a) non-ulcerated and nodular as those caused by *L. (Leishmania) amazonensis*; (b) active and with parasites for a long time, as also observed with *L. (Leishmania) amazonensis* (Silveira et al. 1990).

The humoral response of *C. apella* experimentally infected with *L. (Viannia) lainsoni*, *L. (Viannia) braziliensis*, and *L. (Leishmania) amazonensis* was analyzed by a direct agglutination test (DAT). The assay was performed with homologous [L. (Leishmania) amazonensis; L. (Viannia) braziliensis] and heterologous [L. (Leishmania) donovani] antigens. However, no homologous antigen could be obtained for *L. (Viannia) lainsoni*. Animals infected with *L. (Leishmania) amazonensis* and *L. (Viannia) braziliensis* presented detectable antibody titers when tested with both homologous and heterologous antigens, but animals infected with *L. (Viannia) lainsoni* presented significant titers only for the DAT performed with the heterologous antigen (Garcez et al. 1997). The course of infection with *L. (Viannia) lainsoni* was similar to that of *L. (Leishmania) amazonensis*, and in both cases the lesions did not ulcerate and remained active for a longer period (Garcez et al. 1997).

The insect host

Studies have been made to identify the wild insect vector of *L. (Viannia) lainsoni*. In order to increase the chances of finding infected sand flies, captures were performed in the same areas where *L. (Viannia) lainsoni* was isolated for the first time and according to information given by the patients: Benevides city (state of Pará, Brazil) and the ecologically related forest area of Utinga (Belém city, state of Pará, Brazil). The capture allowed the collection of 1924 female sand flies, belonging to 27 species in Benevides and to 29 species in the Utinga forest. After dissection, no sand flies from Benevides presented infection by *L. (Viannia) lainsoni*, although infected by other flagellates. On the other hand, insects captured in the Utinga forest identified as *Lu. ubiquitalis* presented massive infection with *L. (Viannia) lainsoni*. Identification of the protozoa as *L. (Viannia) lainsoni* was done by isolation of the parasites in axenic medium, examination by light microscopy, reactivity to specific monoclonal antibodies, and isoenzyme profiles (Silveira et al. 1991a, b). Under normal forest conditions *Lu. ubiquitalis* is not antropophilic, but the finding of humans infected with *L. (Viannia) lainsoni* in the same region where infected sand flies were found suggests that this insect can bite man and transmit the parasites. Accordingly, in the laboratory *Lu. ubiquitalis* fed on human beings (Silveira et al. 1991b). A later study with sand flies captured at the Carajás forest (Pará, Brazil) confirmed the presence of *Lu. ubiquitalis* naturally infected with *L. (Viannia) lainsoni* (Lainson et al. 1992).

Furthermore, the presence of *L. (Viannia) lainsoni* has been detected in a pool of 25 *Lu. nuneztovari* anglesi females in the Sub-Andean region of Bolivia by kDNA-PCR amplification procedures followed by Southern blot and hybridization (Bastrenta et al. 2002). This sand fly species belongs to the verrucarum group, where several species are suspect vectors of leishmaniasis in other regions.
In the Caranavi province of Bolivia, region where the first case of cutaneous leishmaniasis due to *L. (Viannia) lainsoni* in this country was described, several naturally infected females of *Lu. velascoi* were detected at the end of the rainy season, but unfortunately the parasite could not be isolated (Martinez et al. 2001). Interestingly, this sand fly belongs to the same subgenus (*Trychopho-romyia*) as *Lu. ubiquitalis* and it is the only species of this subgenus in the region (Martinez et al. 2001). Further studies are needed to incriminate *Lu. velascoi* as the vector of *L. (Viannia) lainsoni* in Bolivia.

These data demonstrate that more information is needed on the vector capability of endemic sand flies species involved in transmission of this parasite.

**Geographical distribution**

In Brazil, *L. (Viannia) lainsoni* has been isolated in the states of Pará, Amapá, and Rondônia (Silveira et al. 1987, 1991a,b). Regarding South America, this flagellate was found in the sub-Andean region of Peru (Lucas et al. 1994, 1998) and Bolivia (Martinez et al. 2001, Bastrenta et al. 2002). These data demonstrate a wide distribution of this protozoan in South America.

An important detail regarding *L. (Viannia) lainsoni* in Peru is that this protozoan was not found in cities close to the Brazilian border (Loreto, Ucayali, and Madre de Dios), but in cities more inside the country (Cusco, Pasco, Ayacucho, Huanuco, and San Martin). These last locations are situated between 600 and 2000 m above the sea level, with annual mean temperature of 18.5-25.6ºC (Lucas et al. 1998), an environment totally different from that found in the Amazon plane land, site of the first isolation of *L. (Viannia) lainsoni*. These data suggest that in Peru this parasite can be transmitted to man by different insect vectors and possesses mammal reservoirs not yet identified. Although *Lu. ubiquitalis* has been found in the city of Madre de Dios, no record of infection caused by *L. (Viannia) lainsoni* has been made (Lucas et al. 1994).

**The wild mammal reservoir**

The first isolation of *L. (Viannia) lainsoni* from a wild mammal was made in 1991, from the rodent *Agouti paca* (Rodentia: Dasyproctidae), in the state of Pará, Brazil. The parasites were isolated from apparently normal skin samples obtained from three specimens of this rodent, captured in the Tucurui city (Tocantins island, state of Tocantins, Brazil). No isolation was obtained from the viscera of any captured animal. Identification of the isolates as *L. (Viannia) lainsoni* has been isolated in, but unfortunately the parasite could not be isolated (Martinez et al. 2001). Interestingly, this sand fly belongs to the same subgenus (*Trychopho-romyia*) as *Lu. ubiquitalis* and it is the only species of this subgenus in the region (Martinez et al. 2001). Further studies are needed to incriminate *Lu. velascoi* as the vector of *L. (Viannia) lainsoni* in Bolivia.

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**Classification by biochemical and molecular biology markers**

The systematic classification of New World *Leishmania* species was reviewed with the help of numeric zymotaxonomy, by comparing the electromorpho profiles of 270 *Leishmania* isolates with those of reference strains (Cupolillo et al. 1994). The 18 enzymatic loci analyzed showed a strong polymorphism and the 270 strains were grouped into 44 zymodemes. These zymodemes could be clustered in two larger groups that corresponded to the *Leishmania* and *Viannia* subgenera. This analysis demonstrated that *L. (Viannia) lainsoni* is so distant from the other *Leishmania* species that it could represent a new species group, independent of all species complexes described so far (Cupolillo et al. 1994).

The taxonomic position of *L. (Viannia) lainsoni* was reevaluated by using a molecular marker, a *Viannia*-specific oligonucleotide probe (16 nucleotides long) for mini-exon sequences (Fernandes et al. 1995, 1996). This probe did not hybridize with *L. (Viannia) lainsoni*, but hybridized with all other species with peripylary development in sand flies, which are grouped in the *Viannia* subgenus (Fernandes et al. 1995). This molecular aspect alone did not allow to remove *L. (Viannia) lainsoni* from the *Viannia* subgenus, but has evidenced a far relationship between this species and the other members of the *Viannia* subgenus, reinforcing its divergent position inside this group (Fernandes et al. 1995).

The divergent position of *L. (Viannia) lainsoni* was confirmed by electrophoresis analysis of kinetoplast DNA (kDNA) digested by the HaeIII restriction enzyme. Although the *Leishmania* species grouped in the *Viannia* subgenus presented very similar banding profiles, *L. (Viannia) lainsoni* presented a profile more similar to *L. (Leishmania) amazonensis*, a typical representative of the *Leishmania* subgenus (Eresh et al. 1995). However, hybridization of *L. (Viannia) lainsoni* nuclear DNA with a β-tubulin probe, followed by measurement of the kDNA density, suggested a molecular proximity between *L. (Viannia) lainsoni* and *Leishmania* species belonging to the *L. (Viannia) braziliensis* species complex (Eresh et al. 1995).

Amplification of kDNA under different annealing temperatures (60.5 and 67.5°C) resulted in the production of 300 base pairs in *L. (Viannia) lainsoni*, confirming the inclusion of this species in the *Viannia* subgenus, at it is known that at the annealing temperature of 60.5°C the used primers do not amplify kDNA from parasites of the *Leishmania* subgenus. On the other hand, amplification of kDNA from species from the *Viannia* subgenus usually generates a product of 750 base pairs. Thus, these data show that *L. (Viannia) lainsoni* is an isolated species inside the *Viannia* subgenus (Eresh et al. 1995).

The locus of the gene coding for the surface glycoprotein gp63 has been used as a high-resolution target for the genetic characterization of *Leishmania* (Victoir et al. 1998). Two distinct methods were applied: (1) restriction analysis of genomic DNA, followed by hybridization with probes possessing a conserved part of the gp63 gene (gp63-RFLP) and (2) PCR amplification of the intragenic part of gp63, combined with restriction fragments length polymorphism analysis of amplification products (PCR-RFLP). The gp63-RFLP method showed a high resolution, disclosing the phylogenetic relationships among the different *Leishmania* species, and confirming data obtained by other molecular techniques. This method sorted the *Leishmania* species into two groups, corresponding to the *Leishmania* and *Viannia* subgenera. Inside the *Viannia* sub-
Leishmania (Viannia) lainsoni

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The results showed the existence in minicircles of L. (Viannia) lainsoni kDNA of specific sequences. This parasite did not contain the requested sequences for correct annealing and amplification with the B1 and B2 primers used by Eresh et al. (1995), thus explaining the minor fragment length when compared with other species of the Viannia subgenus (McCann et al. 1999). The production of a SL3 primer (McCann et al. 1999) that together with the B1 primer (Eresh et al. 1995) could amplify L. (Viannia) lainsoni minicircles in lower stringency conditions (57ºC of annealing temperature) appear as a strong argument that the positioning of L. (Viannia) lainsoni inside the Viannia subgenus is substantially different from the other members of this group (McCann et al. 1999).

Conclusion

The data obtained so far on L. (Viannia) lainsoni demonstrate that this parasite presents a wide distribution in South America, being found in different ecological environments, but further studies are needed to better understand the transmission cycle in subtropical Andean regions, where mammal reservoirs and invertebrate vectors were not yet identified. As the human expansion in the Amazon and Sub-Andean regions is a reality and a leishmaniasis control program is very difficult to be organized due to the challenging conditions, the risk of new outbreaks of L. (Viannia) lainsoni infections is eminent.

L. (Viannia) lainsoni is the Leishmania species that presents the most distinct biological (morphology, growth in axenic culture medium), biochemical (enzymatic electrophoresis profile) and molecular biology characteristics, when compared to other species of the Viannia subgenus. A summary of the data obtained so far is shown in the Table. The development of promastigote forms of this parasite attached to the wall of the pyloric and hind gut regions of sand fly vectors is a solid characteristic that allows the positioning of L. (Viannia) lainsoni in the Viannia subgenus.

TABLE
A summary of the biological characteristics of Leishmania (Viannia) lainsoni

<table>
<thead>
<tr>
<th>Description</th>
<th>Characteristic</th>
<th>Reference</th>
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<tr>
<td>Lesion type</td>
<td>Single cutaneous lesion</td>
<td>Silveira et al. 1987</td>
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<td>2002</td>
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<tr>
<td>Axenic cultivation</td>
<td>Promastigotes with exuberant growth, easily maintained in different culture media</td>
<td>Corrêa et al. 2005</td>
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<tr>
<td>Size of tissue amastigote by light microscopy</td>
<td>3.49 ± 0.37 µm long; 1.4 ± 0.18 µm wide</td>
<td>Silveira et al. 1987</td>
</tr>
<tr>
<td>Size of tissue amastigote by transmission electron microscopy</td>
<td>2.24 µm long; 1.72 µm wide</td>
<td>Soares et al. 1990</td>
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<td>Aspect of intracellular amastigotes by transmission electron microscopy</td>
<td>A single amastigote per vacuole, with attachment between amastigote plasma membrane and fagolysosome membrane</td>
<td>Corrêa et al. 2005</td>
</tr>
<tr>
<td>Invertebrate vector</td>
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<td>Silveira et al. 1991a,b, Lainson et al. 1992</td>
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<tr>
<td>Development in insect host</td>
<td>Peripylarian</td>
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<td>Detection by PCR in sand flies</td>
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<td>Bastrenta et al. 2002</td>
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<tr>
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<td><em>Agouti paca</em> (Rodentia: Dasyproctidae)</td>
<td>Silveira et al. 1991a</td>
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<td>al. 2005</td>
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<tr>
<td>Zymodeme taxonomy</td>
<td>Isolated species in the sub-genus <em>Viannia</em></td>
<td>Cupolillo et al. 1994</td>
</tr>
<tr>
<td>PCR-RFLP of the intragenic part of gp63</td>
<td>Isolated species in the sub-genus <em>Viannia</em></td>
<td>Victoir et al. 1998</td>
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<td>Hibrizdation with mini-exon sequence probe specific for the sub-genus <em>Viannia</em></td>
<td>Negative</td>
<td>Fernandes et al. 1995, 1996</td>
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<tr>
<td>Electrophoresis analysis of kinetoplast DNA digested by the HaeII restriction enzyme</td>
<td>Profile similar to that of species belonging to the Leishmania sub-genus</td>
<td>Eresh et al. 1995</td>
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</table>
The biochemically and biologically divergent behavior of *L. (Viannia) lainsoni* can be used in novel approaches to the development of antigens for the diagnosis of leishmaniasis, as this species is easily maintained under in vitro conditions. Studies on new and different *Leishmania* species, such as *L. (Viannia) lainsoni*, might bring new insights on metabolic pathways, parasite-cell interactions in vertebrate and invertebrate hosts, new proteins or any other biological/biochemical aspects that can be useful for the control and better understanding of leishmaniasis and the parasite life cycle.

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