Reference Point

Guidelines for treatment of leishmaniasis in dogs

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Drug treatment of leishmaniasis in dogs is a challenge for veterinary practitioners. Because of its complex pathogenesis, leishmaniasis may manifest with various clinical signs, ranging from mild and nonspecific to those reflecting severe involvement of several organs. The immune response plays an important role in the development, outcome, and response to treatment of Leishmania infection in dogs. All known anti-Leishmania drugs used in dogs can lead to temporary or permanent remission of clinical signs, but none are sufficient to eliminate the infection. Indeed, all anti-Leishmania drugs currently used in dogs were discovered and developed to treat leishmaniasis in humans. Most therapeutic protocols were developed through human clinical studies and thereafter adapted to dogs, often without sufficient pharmacokinetic information relevant to dogs.

In dogs, the objectives of anti-Leishmania treatment are typically to induce a general reduction of the parasite load, to treat organ damage caused by the parasite, to restore efficient immune responses, to stabilize a drug-induced clinical improvement, and to treat clinical relapse. The most widely used drugs are described in the present report. In addition, we propose a 5-class staging of leishmaniasis that can help in choosing the most appropriate anti-Leishmania treatment. As with our guidelines for diagnosis of leishmaniasis in dogs, the guidelines reported here are an updated version of those originally published in Italian in Veterinaria, the official journal of the Italian Society of Veterinarians.

Methods—The PubMed database was searched by use of the following combination of search terms: (dog* OR canine) AND (drug OR treat* OR therap* OR efficacy* OR effect* OR action* OR activity* OR against OR versus) AND (leishm* OR antileishm*) NOT vaccin*.

Results of the literature review indicated that the most commonly investigated anti-Leishmania drugs for treatment of leishmaniasis in dogs have been, in descending order of citations, antimonial compounds; allopurinol, aminosidine (paromomycin), enrofloxacin, marbofloxacin, miltefosine, pentamidine, spiromycin combined with metronidazole, miltefosine, enrofloxacin, and domperidone.

Abbreviation

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<td>Sbv</td>
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Review of the Veterinary Literature

Antimonial compounds—At the time of writing, antimonial compounds were not licensed by the US FDA for use in dogs. N-methyl-glucamine (meglumine) anti-

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moniate is the most used Sbv compound for treating leishmaniasis in dogs and humans. The drug selectively inhibits leishmanial glycolysis and fatty acid oxidation. In 94% to 95% of dogs with leishmaniasis, a dose of 20 mg of Sbv (approx 60 mg of salt)/kg/d (27.3 mg/lb/d) for 28 days results in a parasitological and clinical cure. Meglumine antimoniate has a short half-life in dogs: 21, 42, and 122 minutes when it is administered IV, IM, and SC, respectively. By 6 to 9 hours after administration, 80% to 95% of meglumine antimoniate is eliminated through the kidneys. Most studies in dogs have revealed that the drug has good clinical efficacy. During treatment, clinical amelioration is usually observed after a period of 1 or more weeks together with improvement in hematologic and serum biochemical values. However, restoration of serum protein electrophoresis abnormalities to within reference limits can be slow and is usually dose dependent. Several authors have described that treatment with meglumine antimoniate does not result in full elimination of Leishmania organisms from infected dogs. Rather, a few months after treatment, parasites can still be detected in tissues of clinically cured dogs. Clinical relapses commonly occur after treatment in a period ranging from months to 1 or 2 years and are more common when the duration of treatment is shorter than 4 weeks.

Treatment with Sbv compounds induces a generalized reduction of the parasite load, together with a temporary restoration of cell-mediated immunologic response. A decrease in specific serum antibody titers also develops. Pain and swelling of the injection site are the most common adverse effects of antimonials. Fever, diarrhea, and loss of appetite have been reported, and a case of acute pancreatitis attributable to antimonial treatment has also been described. To date, there has been no evidence of renal damage induced by antimonials in dogs. Transient elevation of serum alanine aminotransferase and amylase activities has been reported.

The most commonly reported treatment regimen is 100 mg of meglumine antimoniate/kg (45.3 mg/lb), once a day for 4 weeks. Because of the pharmacokinetic properties of Sbv compounds, the dosage might be better divided in 2 daily doses of 50 mg/kg (22.7 mg/lb). Initiation of antimonial treatment at the onset of leishmaniasis, together with correct management of clinical relapses, can result in survival for 4 years in 75% of treated dogs. Certain antimonial treatment regimens reportedly select for Leishmania strains that are resistant to Sbv. A liposomal formulation of Sbv has been tested, revealing good evidence of efficacy, but such a formulation is not yet commercially available.

Allopurinol (FDA approved for use in dogs)—Allopurinol is a structural analogue of hypoxantine that inhibits the activity of xanthine oxidase, an enzyme that catalyzes the production of xanthine from hypoxantine and uric acid from xanthine. Its anti-Leishmania activity is attributable to the inability of the parasite to synthesize purines ex novo, thereby requiring purines to be supplied by the host. When incorporated by intracellular Leishmania amastigotes, allopurinol is transformed into a toxic compound (4-amino-pyrazole-pyrimidine) that kills the parasite. In humans with leishmaniasis, allopurinol has poor efficacy when administered as monotherapy. The low activity is probably attributable to the insufficient transformation of allopurinol into oxypurinol, which is the chemical form producing the aforementioned toxic compound. In humans treated for leishmaniasis, the combination of allopurinol and antimonials allows a reduction of the dosage of Sbv.

When administered to dogs as a single anti-Leishmania agent for a minimum period of 2 to 3 months, allopurinol usually leads to moderate clinical improvement and partial restoration of some laboratory analytes to within reference ranges, such as acute-phase proteins of inflammation. Similar to treatment of leishmaniasis with antimonial drugs, treatment with allopurinol does not result in a full parasitological cure and relapses occur when treatment is interrupted. For this reason, allopurinol is usually administered for periods as long as several months. The tolerability of the drug is excellent and seems to slow the deterioration of renal function in dogs with proteinuria but without renal insufficiency. The most commonly prescribed dosages of allopurinol range between 5 and 20 mg/kg (2.3 and 9.1 mg/lb), PO, every 12 hours for 2 to 24 months.

Meglumine antimoniate–allopurinol combination—The combination of meglumine antimoniate and allopurinol is the most common treatment for leishmaniasis in dogs, although it does not result in a complete parasitological cure. Dogs treated with the combination reportedly have a longer period of clinical remission than when treated with either drug alone. The most common protocol consists of meglumine antimoniate administered SC at the dose of 100 mg/kg, once a day for 1 to 2 months in combination with allopurinol administered PO at 10 mg/kg (4.5 mg/lb) every 12 hours for several months. Adverse effects associated with the combination are the same as those reported for administration of either agent alone.

Aminosidine (FDA approved for use in dogs)—Aminosidine (also called paromomycin) belongs to the class of aminoglycosides and possesses antimicrobial and antiprotozoal activity. Although developed in the 1960s as an anti-Leishmania agent, it remained neglected until the 1980s when topical and systemic formulations were found effective in treating humans with leishmaniasis. Aminosidine acts against Leishmania donovani by impairing ribosomal subunit association. In addition, it induces respiratory dysfunction in L donovani promastigotes. Aminosidine had been successfully used in the treatment of humans with leishmaniasis, 95% of whom are parasitologically cured when treated with a dosage of 11 mg/kg (5 mg/lb), IM, once a day for 21 days. The drug has been used in dogs as a single agent and in combination with meglumine antimoniate. The most commonly used aminosidine protocol in dogs is 5 mg/kg, SC, once a day for 3 weeks, plus 60 mg of meglumine antimoniate/kg (27.3 mg/lb), IM, every 12 hours for 4 weeks. The combination allows better clinical and parasitological results than either drug alone. One severe limitation for more widespread use of aminosidine is related to its renal and vestibular toxic effects.

Amphotericin B (FDA approved for use in dogs)—The polyene amphotericin B interacts with fungal membrane sterols and preferentially with ergosterol. As
with fungi, Leishmania spp have ergostane-based sterols as a major membrane sterol, which likely explains the efficacy of amphotericin B in treating leishmaniasis.⁶⁵ Although highly effective, amphotericin B is toxic and associated with severe adverse effects. Particular adverse effects include impairment of renal function, pyrexia, vomiting, and anorexia. A daily dosage of 0.5 mg/kg (0.23 mg/lb), IV, on alternate days for 4 weeks results in a parasitological cure in 97% of humans with leishmaniasis.⁶⁵

In dogs, amphotericin B dilute with sterile saline (0.9% NaCl) solution and emulsified with soybean oil has been administered IV.⁶⁵,⁶⁶ Although the formulation allows the clinical cure of most treated dogs, it is generally not used as routine treatment because of complexity in preparation and administration. Since the early 1990s, a liposomal formulation of amphotericin B has been the first-line anti-Leishmania drug for the treatment of humans in Western countries. Because it is expensive, use of amphotericin B is limited in developing countries. Liposomal amphotericin B is by far less toxic than the conventional formulation, while maintaining the same cure rate as in humans with leishmaniasis.⁶⁷ When administered in dogs, the same liposomal formulation results in a rapid clinical cure, although the improvement is invariably followed by relapses.⁶⁸ To avoid the occurrence of amphotericin B-resistant Leishmania strains, the World Health Organization has discouraged its use in the treatment of dogs with leishmaniasis.

Moltefosine—Moltefosine, an alkylphosphocholine, is not FDA approved for use in dogs with leishmaniasis. In humans, it was developed as an anti-cancer agent and later used to treat leishmaniasis.⁶⁹ The drug was recently registered for oral administration in dogs with leishmaniasis in several European countries. The in vitro and in vivo anti-Leishmania activity of moltefosine is attributable to impairment of signaling pathways and cell membrane synthesis that lead to parasite death.⁶⁷ In animals, the drug has anti-Leishmania activity after oral administration.⁶⁸ In humans, moltefosine induces a rapid clinical and parasitological cure in 91% to 95% of leishmaniasis patients; dosages of 100 to 150 mg/d (or 2.5 mg/kg [1.14 mg/lb]) for 28 days are the most effective.⁶⁹,⁷⁰

At present, there are few published reports regarding the efficacy of moltefosine for treatment of leishmaniasis in dogs. The drug has been administered alone (2 mg/kg [0.91 mg/lb], q 24 h, for 28 days) or in combination with allopurinol (10 mg/kg, q 12 h, for several months). Similar to all anti-Leishmania drugs used in dogs, moltefosine administration is not able to fully eliminate the parasite from infected dogs, although a drastic and progressive reduction of the parasite load in lymph node aspirates has been reported.⁵¹–⁵⁵ Despite partial or good resolution of clinical signs, clinical relapses have also been reported when the drug is used alone. The clinical efficacy of moltefosine improves when given together with allopurinol.⁵³,⁵⁴ This combination reportedly has the same clinical and parasitological efficacy as the combination of meglumine antimoniate and allopurinol. During a follow-up period of 7 months, neither relapses nor severe adverse effects were reported in dogs treated with moltefosine.⁵⁵ Minor adverse effects consist of self-limited vomiting or diarrhea.⁵²,⁵³ Whether treatment with moltefosine can lead to selection of drug-resistant Leishmania strains in dogs requires investigation.

Pentamidine (FDA approved for use in dogs)—Pentamidine is an aromatic diamidine that has been used as a second line of treatment for humans with leishmaniasis, but its precise mode of action remains to be elucidated. The leishmanicidal activity of the drug may be mediated via its influence on polyamine biosynthesis and mitochondrial membrane potential.⁵⁴ Pentamidine was initially found useful in the treatment of humans with Sv resistance to leishmaniasis in India, but treatment-limiting factors were the cost of treatment and the risk of inducing irreversible insulin-dependent diabetes mellitus. In addition, because of its low effectiveness (only 70% of affected humans cured), use of the drug has been abandoned.⁵³ Pentamidine was used to treat dogs with leishmaniasis during the 1980s, but administration of the drug resulted in severe adverse effects such as vomiting, diarrhea, hypersalivation, systemic hypotension, and anaphylactic shock. Some benefits were observed in affected dogs.⁵⁴

Spyramicin—Metronidazole combination—Metronidazole but not spyramicin has been FDA approved for use in dogs. Because of the anti-Leishmania activity of metronidazole in vitro, some researchers evaluated a combination of metronidazole (150,000 U/kg [68,182 U/lb], PO, q 24 h) and metronidazole (25 mg/kg [11.4 mg/lb], PO, q 24 h) in 13 dogs with leishmaniasis.⁵⁵ Results were compared with those in 14 infected dogs treated with an antimonal–allopurinol combination. All dogs were treated for 90 days, and proportions of dogs that clinically improved were not significantly different between treatment groups.

Marbofloxacin (FDA approved for use in dogs)—Marbofloxacin is a synthetic third-generation fluoroquinolone developed for veterinary use. It has potent activity against several species of bacteria and is commonly administered to treat a wide range of gram-negative and gram-positive bacterial infections. Like other quinolones, marbofloxacin inhibits the bacterial enzyme DNA gyrase. Trypanosomatidae such as Leishmania infantum have a genomic structure that shares major similarities with bacteria. An in vitro study revealed direct and indirect leishmanicidal activity of marbofloxacin via tumor necrosis factor-α and nitric oxide pathways. A clinical study involving a limited number of dogs was conducted to compare the safety and efficacy of 4 treatment regimens with marbofloxacin administered PO at the dosage of 2 mg/kg, once a day. Results suggested that marbofloxacin administered at that dosage for 28 days improves clinical signs of leishmaniasis in dogs.

Enrofloxacin (FDA approved for use in dogs)—Enrofloxacin is a fluoroquinolone with the capability of enhancing the macrophage killing activity against Leishmania spp in vitro through generation of nitric oxide. The anti-Leishmania activity of enrofloxacin, alone or in combination with metronidazole, has been evaluated in dogs, all of which had short-lasting, partial clinical improvement.

Domperidone—Domperidone, a dopamine D2 receptor antagonist with gastric prokinetic and antiemetic activity, has not been approved by the FDA for
use in dogs. The antipaminergic effect results in the release of serotonin, which in turn stimulates prolactin production. Prolactin has been classified as a proinflammatory lymphocyte-derived cytokine, but whether this may mediate the effect against Leishmania spp is unknown. In a recent study, the effects of domperidone administration were evaluated in dogs naturally infected with L. infantum. Ninety-eight dogs were orally treated with domperidone as a single agent at 1 mg/kg (0.45 mg/lb), every 12 hours for 1 month. Domperidone was effective in reducing clinical signs and antibody titers in most treated dogs. No adverse effects were observed during the study.

**Treatment According to Clinical Stage**

Therapeutic options and choice of drug regimen for dogs with leishmaniasis should be considered in light of the different clinical forms of the disease. As described in the guidelines for diagnosis and clinical classification of leishmaniasis, dogs with positive results of serologic tests or in which the parasite has been identified via direct diagnostic methods such as cytologic or real-time PCR analysis can be classified in 4 clinical stages: A, exposed dogs; B, infected dogs; C, sick dogs (dogs with clinically evident leishmaniasis); and D, severely sick dogs (Table 1). For therapeutic purposes, we suggest an additional stage (stage E), which includes dogs unresponsive to recommended treatment (stage E-a) or dogs that have a relapse of clinical disease soon after completion of recommended treatment (stage E-b).

**Stage A (exposed dogs)**—Dogs in this stage do not need any treatment. They should be serologically monitored for 2 to 4 months after the first detection of low-titer antibodies against Leishmania spp. If abnormal clinical findings develop, additional evaluation is indicated, including parasitological testing performed with a direct method.

**Stage B (infected dogs)**—Dogs in this stage need treatment if the direct detection of parasites is associated with an increase in antibody titers a few weeks after the first serologic diagnosis. If the infected dogs do not seroconvert, treatment is not indicated. In this situation, dogs should be monitored serologically every 2 to 3 months.

**Stage C (sick dogs: dogs affected by clinically evident leishmaniasis)**—Dogs in this stage need treatment with an appropriate anti-Leishmania drug regimen. A complete clinicopathologic examination may also suggest the need for ancillary treatment.

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<th>Stage of leishmaniasis</th>
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<td>A: Exposed</td>
<td>Includes dogs with negative cytologic, histologic, parasitological, and molecular findings and low-titer antibodies against Leishmania spp. Dogs are clinically normal or have signs associated with other diseases. Usually, dogs in this category are those living or that have lived during 1 or more transmission seasons in a geographic region in which the presence of Leishmania vectors (sand flies) has been confirmed.</td>
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<tr>
<td>B: Infected</td>
<td>Includes dogs in which parasites have been detected through direct diagnostic methods (eg, microscopic evaluation, organism culture, or PCR assay) and with low-titer antibodies against Leishmania spp. Dogs are clinically normal or have signs associated with other diseases. In endemic areas, detection of Leishmania DNA via PCR assay in skin or peripherally obtained blood samples collected during the infection transmission period, in the absence of evident lesions, may not be sufficient to consider a dog infected.</td>
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<td>C: Sick (clinically evident disease)</td>
<td>Includes dogs with positive cytologic results regardless of serologic results, dogs with high antibody titers against Leishmania spp, and rarely, infected dogs. One or more clinical signs common to leishmaniasis are present. Given the varied clinical manifestations of the disease, observed signs suggestive of disease can differ from the common clinical signs, as long as they can be clearly associated with ongoing infection. When physical examination does not reveal clinical signs, dogs in this category should still be defined as sick when hematologic, biochemical, and urinary alterations common to leishmaniasis are detected. Laboratory changes other than those considered common can also be indicative of disease, provided that they are associated with the infection.</td>
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<td>D: Severely sick</td>
<td>Includes sick dogs with severe clinical illness, as indicated by 1 of the following: evidence of proteinuric nephropathy or chronic renal failure; presence of concurrent problems (eg, ocular disease causing functional loss or joint disease impairing mobility) related or unrelated to leishmaniasis that require immunosuppressive treatment; severe concomitant conditions including various coinfections or neoplastic, endocrine, or metabolic diseases; and clinical unresponsiveness to repeated courses of anti-Leishmania drugs.</td>
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<td>E-a: Sick-unresponsive</td>
<td>Includes sick dogs unresponsive to recommended anti-Leishmania treatment.</td>
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<tr>
<td>E-b: Sick–early relapse</td>
<td>Includes sick dogs treated in accordance with the recommended anti-Leishmania protocol but that relapse soon after treatment ceases.</td>
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Stage D (severely sick dogs)—Dogs in this stage need both anti-Leishmania treatment and ancillary treatment, depending on the affected organ or organs (eg, renal failure or hepatopathy).

Stage E-a (sick dogs unresponsive to recommended treatment)—To clinically manage dogs in this stage, several factors need to be taken into account. First, the dog owner’s compliance in administration of medications should be verified and the adopted treatment regimen should be reevaluated to ensure drug doses, frequencies of administration, and durations of treatment are as recommended. Clinical and laboratory findings should also be reassessed to verify whether the abnormalities may suggest a concomitant disease and to rule out disorders sharing main clinical signs with leishmaniasis (eg, other types of infection, neoplasia, or immune-mediated diseases). When diagnosis was made solely on the basis of serologic findings, serologic testing should be repeated or PCR assay for detection of Leishmania DNA should be performed. If the aforementioned actions confirm leishmaniasis and treatment has been correctly administered, then an alternative specific anti-Leishmania treatment regimen should be considered.

Stage E-b (sick dogs that relapse soon after recommended treatment ceases)—The same considerations indicated for stage E-a should be applied to dogs in this stage. The main steps should be to reevaluate the diagnostic scheme and rule out other metabolic or infectious disorders. If leishmaniasis is confirmed and treatment has been administered as recommended, similar to dogs in stage E-a, dogs in this stage should be treated in accordance with an alternative anti-Leishmania protocol.

Recommended treatment protocol—The most widely used treatment protocol for dogs with leishmaniasis is the combination of meglumine antimoniate and allopurinol. This combination may be administered to all dogs in stage B, C, or D, with meglumine antimoniate given at 100 mg/kg, SC, once a day for 4 weeks and allopurinol at 10 mg/kg, PO, every 12 hours for at least 6 months. The dosage of meglumine antimoniate can be divided in 2 equal doses of 50 mg/kg (q 12 h) or administered for a period ranging from 4 to 8 weeks. Because meglumine antimoniate is not FDA approved for use in the United States, practitioners in that country should refer to alternative treatment protocols.

In most dogs in stages B and C, this protocol, if correctly applied, should result in a clinical cure that is stable for >1 year. Adverse effects are reported with either drug of the combination, as previously mentioned. In addition, the protocol should result in a considerable decrease in parasite load for several months, which is necessary for reducing transmission of the parasite to phlebotomine vectors (sand flies).

For dogs in stage D with a severe clinical form of the disease, the aforementioned treatment protocol should yield a good chance of improvement but may not result in a clinical cure. In stage D dogs, particularly if renal insufficiency is present, the need for ancillary treatments and prognosis are strictly dependent on pre-existing clinical conditions.

Alternative treatment protocols—Unresponsiveness to a previous course of treatment (ie, recommended treatment protocol), occurrence of relapse soon after treatment, development of severe adverse effects, poor owner compliance with drug administration, and non–governmental approval or availability of drugs in a given country are the main reasons for choosing a treatment protocol other than meglumine antimoniate–allopurinol. Choice of an alternative anti-Leishmania drug or drug combination should be based on the following criteria: anti-Leishmania efficacy as established via clinical trials, few potential adverse effects, and owner compliance with administration. The few alternative regimens that fulfill the aforementioned requirements include allopurinol, administered alone for at least 6 months (10 mg/kg, PO, q 12 h), and allopurinol, for at least 6 months and at the same dosage, administered in combination with miltefosine given for 28 days (2 mg/kg, PO, q 24 h); however, miltefosine is not FDA approved. Whether miltefosine can be safely administered for protracted periods or whether more cycles can be administered needs further study in dogs. Amphotericin B, aminosidine, and pentamidine are other drugs that could be used to treat leishmaniasis, but their use is strongly limited by severe adverse effects.

Follow-up Evaluation

Protocols for managing leishmaniasis in dogs once treatment has begun have not been published. In general, dogs are followed up according to individual needs, which are primarily driven by pretreatment and post-treatment health status. To simplify treatment, the following scheme is proposed for application to most dogs with leishmaniasis after treatment has started.

Dogs in stage B or C—Clinical and laboratory findings may suggest that dogs in stage B or C of leishmaniasis do not need ancillary treatment. In these dogs, performance of a complete physical examination, CBC, serum biochemical analysis, and urinalysis is recommended after treatment with meglumine antimoniate concludes or after 1 month of treatment with allopurinol. If results of laboratory tests are within reference limits, dogs should continue receiving allopurinol for at least 5 additional months. Dogs in this category should be reevaluated every 6 months after treatment concludes, including serologic testing of antibody titers against Leishmania spp. When a clinical relapse develops, as revealed by clinical signs or abnormal laboratory findings related to leishmaniasis, treatment should be reinitiated with the drug initially used or with one of the drugs previously listed as an alternative treatment. If treatment does not result in clinical recovery or a relapse occurs soon after treatment, dogs should be considered in stage E-a or E-b and action should be taken accordingly.

Dogs in stage D—The degree of follow-up required for dogs in stage D of leishmaniasis is strictly related to clinical conditions. Usually, it is necessary to perform both clinical and laboratory evaluations during the course of treatment, particularly if a dog has renal impairment. At the end of treatment, follow-up should be performed at 1- to 2-month intervals, with particular emphasis on evaluating affected organs (eg, kidneys and liver).
Dogs with Leishmaniasis in Nonendemic Regions

Because dogs with leishmaniasis are the main reservoir of the parasite, reducing the parasite load through adequate treatment should represent the most important objective of practitioners in regions in which Leishmania is nonendemic (eg, the United States). Following treatment, dogs become not infective or low infective to phlebotomine vectors for 4 to 5 months.7,10,31,33,34,36 Therefore, in nonendemic areas with competent vector species, a course of anti-Leishmania treatment should be suggested for affected dogs, particularly at the beginning of or during peak vector activity. However, treatment is also necessary if established vector species have not been detected because the potential for nonvectorial transmission of Leishmania spp has not been excluded.

Conclusion

Treatment of dogs with leishmaniasis is a challenge for veterinarians because of the unpredictable course of disease. On the basis of the reviewed literature and the authors’ experience, some aspects of the present guidelines should be highlighted to help practitioners manage affected dogs. Correct determination of the clinical stage of leishmaniasis is important because treatment recommendations vary accordingly. Anti-Leishmania drugs should be used only if their efficacy has been validated in scientific studies. If the clinical condition of diseased dogs requires it, ancillary therapy should be added. Veterinarians should verify that anti-Leishmania drugs have been correctly administered by dog owners. Finally, dogs should be examined during and after completion of anti-Leishmania treatment.

References


