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Research Article

The Protective Effects of Slow-Release Dog Collars Impregnated with Imidacloprid (10%) and Flumethrin (4.5%) for Prevention of Canine Visceral Leishmaniasis

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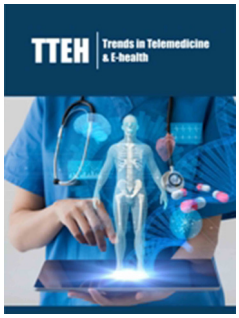

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Abstract

Objectives: Canine Visceral Leishmaniasis (CVL) is a zoonotic disease prevalent in world. The aim of this study was to investigate the effect of Stersco® collars on the main reservoirs of diseases.

Methods: Cross-sectional study was performed on 20 dogs in a hyper-endemic area for *L. infantum*. Dogs were divided into two homogeneous groups. Dogs in both groups were checked against the *L. infantum* parasite by DAT test. The effect of Stersco® 90% collars on domestic dogs as the main reservoirs of visceral leishmaniasis for a six-month period was appropriate.

Result: The results showed, all untreated dogs in the control group were infected by Visceral Leishmaniasis agent at the end of experiment.

Discussion: This study showed that the Stersco® collars could protect dogs from infection for six months, which equals the activity period of vectors. Therefore, it is recommended that it should be applied in endemic areas before the start of the vector's activities.

Keywords: Canine visceral leishmaniasis; Collars; Imidacloprid; Flumethrin; Ardabil

Introduction

Leishmaniasis is an ancient disease mostly occurring in Europe, Asia, Africa and America. Leishmaniasis are worldwide zoonotic infectious diseases caused by obligate protozoa of *Leishmania* genus which among them, approximately 20 species are pathogenic for humans [1,2]. Natural transmission to mammalian hosts is usually by the bite of female *Phlebotomus* or *Lutzomyia* sandflies depending on geography [1]. There are three main clinical manifestations with different degrees of severity count on the species of parasite involved and elicited host immune response. These features include cutaneous, mucocutaneous and visceral [1,3,4]. Currently, World Health Organization (WHO) lists leishmaniasis amongst the nine most important tropical and subtropical diseases which has been reported in all continents except Oceania [1,3]. This category of zooanthroponoses occurs in 98 countries or territories around the world with 12million cases at risk and 20,000-40,000 deaths per year, pursuant

to the WHO reports [5,6]. Canine Visceral Leishmaniasis (CVL) is a zoonotic parasitic disease prevalent around the globe [7,8]. The cause of the disease is *Leishmania donovani* and *L. infantum* in the ancient world, but *L. chagasi* occur in the new world [9,10].

Currently, CVL is prevalent in more than 50 countries around the world, most of which belong to the Eastern Mediterranean countries and North America [11,12]. The prevalence rate of CVL in endemic foci is 50-80% as determined by molecular methods and 10-30% as determined by serological methods. In Iran, human leishmaniasis is sporadic in general, but in some areas in northwestern and southern regions, the disease is endemic and 100-300 new cases are reported every year [13-15]. Dogs are the most important reservoirs of visceral leishmaniasis in Iran and the world [16,17].

In Iran, visceral leishmaniasis is of the Mediterranean kind with dogs and other canines as the main reservoirs of the disease and female sand flies as the vectors [18,19]. CVL is generally chronic in nature with no clear symptoms. The incubation period of the disease varies among animals, ranging from two months to seven years [20]. The clinical symptoms of the CVL disease range from asymptomatic form to limitable infection and deadly infection, and its incubation period may take several months up to a few years, depending on the parasite and the genetic capability of the host [21]. About 90% of infected dogs have dermal lesions in the forms of alopecia, desquamation, dermatitis, ulcerative, nodular and postural dermatitis [22]. The prevalence rate of CVL usually ranges from 14.2% to 17.4% in Iran [16], yet the infection rate among dogs with no symptoms is quite high, too [23]. There is a direct relationship between the prevalence rate of visceral leishmaniasis among people and infected dogs; thus, in endemic foci, even domestic dogs are an important risk factor for transmission of visceral leishmaniasis among people [24] (Figure 1). The first occurrence of CVL in Tehran was reported in 1913, followed by a surge of studies in endemic foci the most noteworthy of which were conducted by Mohebali et al. in Ardabil, Eastern Azerbaijan, Qom, Chaharmahal Bakhtiari, Khuzestan and Bushehr provinces [25-27]. One appropriate way to control CVL among dogs is using collars that have been impregnated with insecticides. Such impregnated collars can protect dogs from the bites of sand flies.

Figure 1: Infected dog and child with visceral leishmaniasis.

One study has shown that dogs wearing collars impregnated with deltamethrin can be protected against the bites of sand flies [28]. Canine visceral leishmaniasis appears in a wide range from asymptomatic to acute and fatal forms [29,30], with unspecific, variable, multisystemic signs [31]. Cachexia, ocular lesion, anemia, diarrhea, weight loss, anorexia, epistaxis, dermatitis, alopecia, lymphadenopathy, and cutaneous ulcerations are the clinical manifestations of infected dogs [32-34]. Asymptomatic sheepdogs as permanent and unnoticed reservoirs in endemic areas can affect the populations of infected dogs and humans through sandflies. These seropositive asymptomatic dogs can develop clinical signs throughout their lives [35]. Furthermore, male dogs can infect female dogs through the semen during mating [36]. Sand flies from genus Phlebotomus including *Ph. kandelakii*, *Ph. neglectus*, *Ph. keshishiani*, *Ph.perfiliewi transcaucasicus*, *Ph. Alexandriand*, *Ph. tobbi*, *Ph. major s.l.*, *Ph. Keshishianiand* , *Ph. Alexandri* mainly transmit *L. infantum*, the causative agent of VL, from the infected canines to humans. This parasite usually infects children under the age of 10 years. Ardabil Province is the most important endemic focus of VL in Iran, and in recent years, 25-50% of visceral leishmaniasis cases have been found to occur in this province [37]. Figure 2 demonstrate the geographical distribution of visceral leishmaniasis in Iran [13].

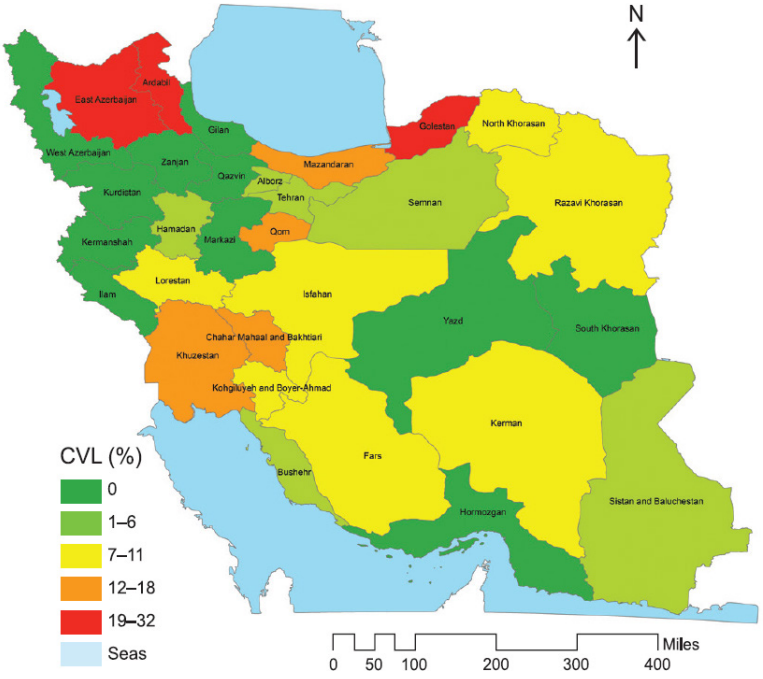

Figure 2: Geographical distribution of visceral leishmanasis in Iran.

There are several measure for vector control including Indoor residual spraying with WHO recommended insecticides, Using impregnated bednets, fogging around the houses, Use of *Bacillus thuringiensis* for larval control in breeding sites, mixture of Bt and sugar spraying for adult control, use of fungi *Beauveria bassiana*, plantation of toxic plants where their nectar is used by sandfly around the dwellings, use of sex pheromones, use of Insect Growth Regulators and Integrated Vector Control (IVM). Recently Nicotinic insecticides is recommended for dog collar. Nicotinic insecticides, which originate from nicotine, act on nicotinic acetylcholine receptors (nAChRs) and are effective against a wide range of pests at low doses. Nicotinic insecticides are classified into "first generation" (nicotine, anabasine), "second generation" (imidacloprid, thiacloprid, nitenpyram, clothianidin, acetamiprid, thiamethoxam, dinotefuran), and "third generation" (sulfoxaflor, flupyradifurone, flupyrimin, triflumezopyrim, dicloromezotiaz) [38].

Seresto collars are made of plastic impregnated with insecticides that are released over time and coat the animal's fur. The active ingredients are imidacloprid (10%) and flumethrin (4.5%). Imidacloprid, which affects the central nervous system of fleas, is a member of the neonicotinoid class of insecticides; flumethrin, which repels and kills ticks, is in the pyrethroid class.

Materials and Methods

Study area

The study was carried out at Ardabil province, Iran during 2019 (Figure 3).

Figure 3: Study area, Ardabil Province, Iran.

Dog Collar Evaluation

To evaluate the protective effect of wearing impregnated collars on the prevalence rate of CVL among domesticated dogs, a total of 20 dogs were selected from a northwestern endemic focus in Iran:10 dogs were considered in the control group and 10 dogs in the treatment group. After making necessary arrangements with the dogs owners, their specifications were all written down, and they were codified, being studied from March 2019 to December 2019. Initially, dogs in both groups were checked against the *L. infantum* parasite by taking the DAT test, and only dogs with negative results entered the study. Then, 10 dogs in the case group wore impregnated collars and were monitored for nine months (Figure 4). At the end of the activity season, all the dogs in both groups took the DAT test again and were checked in terms of clinical symptoms so that the effect of wearing impregnated collars on the prevalence of CVL in dogs was determined. Insecticides to dogs in a northwestern endemic focus in Iran.

Figure 4: Attaching collars impregnated with Imidacloprid (10%) and Flumethrin (4.5%).

Result

This study investigated the protective effect of wearing Stersco® 90% collars by domesticated dogs as the main reservoirs of visceral leishmaniasis for a six-month period. The results showed that only one dog out of 10 dogs in the case group contracted the CVL disease as proved by the DAT test whereas all the 10 dogs in the control group were infected by CVL at the end of the experiment. As for clinical symptoms, 100% of dogs in the case group (those wearing impregnated collars) lacked any symptoms while 70% of dogs in the control group showed clinical symptoms with 30% having no symptoms (Table 1).

Table 1: The results of the effect of wearing Stersco® collars on the prevalence rate of CVL among dogs in a northwestern endemic focus in Iran, 2019.

Treated Group				Control Group			
Gender	Age	DAT Results	Clinical Symptoms	Gender	Age	DAT Results	Clinical Symptoms
Female	5	Negative	NO	Male	1	1:20480	Emaciation, dermatitis, eye infection
Female	1	Negative	NO	Male	3	1:5120	Emaciation, paralysis, hair loss
Male	2	Negative	NO	Female	5	1:1280	-
Male	1	1.320	NO	Male	3	1:5120	Dermatitis, emaciation
Male	10	Negative	NO	Male	2	1:20480	Hair loss, Cheshm eynaki
Male	5	Negative	NO	Male	3	1:5120	Weakness, emaciation
Female	2	Negative	NO	Male	3	1.1280	-

Male	1	Negative	NO	Female	3	1:20480	Emaciation, itch
Female	1	Negative	NO	Male	3	1.1280	-
Male	5	Negative	NO	Male	1	1:20480	Emaciation, paralysis, dermatitis, eye infection

Discussion

Using poisons and repellants is a popular method to control CVL vectors. Accordingly, the results of previous studies conducted in the same endemic focus have shown that using collars impregnated with permethrin and flumethrin insecticides can prevent CVL contraction among dogs and livestock [39,40]. In one study carried out in 2015, the effect of flumethrin on repelling sand flies away from CVL reservoir dogs was investigated in Meshkin Shahr as an important endemic focus in Iran. The results revealed that the fatality rate of CVL vectors was 90-100% and the insecticide remained effective up to 2.5 months [41]. In another study conducted in 2012, flumethrin poison in powder form was used to control ectoparasites among the livestock in the northwest of Iran. The results showed that the fatality rate of this insecticide was 95-100% for ectoparasites such as soft and hard ticks. Moreover, the repelling rate of the insecticide was found to be 90-97% with a two-month protection period [42]. Some studies in Europe have also demonstrated that flumethrin poison is effective against tick and flea bites among dogs by 94% and among cats by 97% [43]. In another study, using collars impregnated with flumethrin insecticide by dogs proved effective against the bites of *Lxodes Holocyclus* ticks by 97.9% for a protective period of 16 weeks [24].

In the current study, the insecticide-impregnated collars were used, and it was found that they produced a 90% effectiveness against CVL infection among domestic dogs with a protection period of more than six months. Such a result can be considered impressive given the alpine climate of the northwestern regions in Iran. Therefore, it can be argued that using this technique for longer periods (three times more) can result in preventing and controlling CVL in this endemic focus. Clinical symptoms are one of the most prevalent identification methods of CVL in endemic foci. In some studies, however, asymptomatic dogs have been also identified to be infected with the disease [26-29,44]. In this study, 70% of dogs in the control group had different CVL-related symptoms, and 30% had no clear symptoms but had high titer in the DAT test (1:1280). In the case group, however, none of the dogs showed any symptoms, and the results of their DAT test were negative. The imidacloprid/flumethrin collar proved to reduce tick counts by at least 90% and flea counts by at least 95% for a period of at least 7-8 months in cats and dogs under field conditions. Therefore, it can be used as sustainable long-term preventative, covering the whole flea and tick season [26]. Seresto® is a new collar for dogs and cats, provides long term broad spectrum parasiticidal activity by combining the insecticidal properties of imidacloprid with the acaricidal properties of flumethrin. The neonicotinoid imidacloprid interacts with the Nicotinic Acetylcholine Receptors (nAChRs) on the post-synaptic membrane while flumethrin, as an a-cyano- (type II)-pyrethroid, exhibits excitatory efficacy by blocking the voltage gated axonic sodium channels. As recently described in laboratory studies imidacloprid and flumethrin have synergistic efficacy on insects, in particular fleas. Both active ingredients are well known for the ectoparasiticide [26]. In a study It is demonstrates that the imidacloprid/flumethrin collar is efficacious against flea and tick infestation as well as tick-borne pathogen transmission to dogs under field conditions. The slow-release collar tested in a study showed safe and highly effective in preventing *L. infantum* infection in a large population of dogs. Protection conferred by a single collar (up to eight months) spanned an entire sand fly season in a hyper-endemic area of southern Italy [45].

Application of the 10% imidacloprid/4.5% flumethrin collar prevented *Amblyomma Americanum* from attaching and feeding on treated cats preventing transmission of *Cytauxzoon Felis* [46]. The Seresto® collar provided significant risk reduction against *Bartonella spp*. infection in outdoor cats under field conditions [47]. The estimated LT50 values for DDT (4%), Malathion (5%), Propoxur (0.1%), and Lambda-cyhalothrin (0.05%) for *Ph. kandelakii* were 15.1,13.4,15.4 and 5.8 minutes respectively, and for *Ph. perfiliewi transcaucasicus* were 11.9,15.6,15.9 and 5.8 minutes respectively [48]. insecticide-impregnated dog collars could be a valid alternative for inclusion in public health measures for reducing the incidence of CanL, which may in turn help to mitigate humans' zoonotic visceral leishmaniasis.

Further large-scale studies that would evaluate and monitor the effectiveness of insecticide-impregnated dog collars are needed to provide a clearer picture of how much insecticide-impregnated dog collars may influence CanL incidence taking into account various socio-demographic and environmental factors [49]. 4% Deltamethrin-Impregnated Collared (DMC) dogs were successfully protected (63%) against Canine Visceral Leishmaniasis (CVL) compared to control dogs. DMC showed higher efficacy in low-income areas (76%) than in the high-income ones (45%) [50].

Conclusion

Dogs are among the most important reservoirs of visceral leishmaniasis in Iran, and the increase in the prevalence rate of CVL in the northwestern regions of Iran has raised serious concerns. Thus, one way to fight with and prevent CVL and HVL in such regions is to use some methods and techniques to protect dogs from being infected in the activity season. This study proved that using Stersco® collars that have been impregnated with Imidacloprid (10%) and Flumethrin (4.5%) insecticides can protect dogs from infection for six months, which equals the activity period of vectors.

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References

1. Torres GE, Quintanilla CMR, Ruiz EJ, Arenas R (2017) Leishmaniasis: A review. F1000 Research 750(6): 1-15.
2. Oryan A, Akbari M (2016) Worldwide risk factors in leishmaniasis. Asian Pac J Trop Med 9(10): 925-932.
3. Salam N, Waleed M, Azzi A (2014) Leishmaniasis in the middle east: Incidence and epidemiology. Plos Negl Trop Dis 8(10): 1-8.
4. Postigo JAR (2010) Leishmaniasis in the world health organization eastern mediterranean region. Int J Antimicrob Agents 36S: S62-S65.
5. Azizi MH, Bahadori M, Dabiri S, Meymandi SS, Azizi F (2016) A history of leishmaniasis in Iran from 19th century onward. Arch Iran Med 19(2): 153-162.
6. World Health Organization (WHO) (2020) Leishmaniasis.
7. Baneth G, Itamar A (2008) Canine leishmaniasis: A diagnostic and clinical challenge. Vet J 175(1): 14-15.
8. Moreno J, Alvar J (2002) Canine leishmaniasis: Epidemiological risk and the experimental model. Trends Parasitol 18(9): 399-405.
9. Palatnik CB, Renata DSW, Carlos FSJ, Da Costa RT, Palatnik M, et al. (2001) Impact of canine control on the epidemiology of canine and human visceral leishmaniasis in Brazil. Am J Trop Med Hyg 65(5): 510-517.
10. World Health Organization (WHO) (2010) Control of leishmaniases. Technical report series 793 of WHO expert committee, Geneva, Switzerland.
11. Solano GL, Koutinas A, Miro J, Cardoso L, Pennisi MG, et al. (2009) Directions for the diagnosis, clinical staging, treatment and prevention of canine leishmaniosis. Vet Parasitol 165(1-2): 1-18.
12. Dantas TF, Solano GL, Baneth G, Ribeiro VM, Otranto D, et al. (2012) Canine leishmaniasis in the old and new worlds: Unveiled similarities and differences. Trends Parasitol 28(12): 531-538.
13. Mohebali M, Moradi AE, Rassi Y (2018) Geographic distribution and spatial analysis of *Leishmania infantum* infection in domestic and wild animal reservoir hosts of zoonotic visceral leishmaniasis in Iran: A systematic review. J Vector Borne Dis 55(3): 173-183.
14. Fakhar M, Rahmati B, Gohardehi S, Mohebali M, Akhoundi B, et al. (2011) Molecular and sero epidemiological survey of visceral leishmaniasis among humans and domestic dogs in Mazandaran province, North of Iran. Iran J Parasitol 6(4): 51-59.
15. Barati M, Daie PMH, Sharifi I (2008) Epidemiological and clinical aspects of Kala-Azar in hospitalized children of Kerman province, during 1991-2006. J Kerman Med Sci 15(4): 148-155.
16. Cortes S, Vaz Y, Neves R, Maia C, Cardoso L, et al. (2012) Risk factors for canine leishmaniasis in an endemic Mediterranean region. Vet Parasitol 189(2-4): 189-196.
17. Da Silva AV, de Paula AA, de Pita PD, Brazil RP, Carreira JC (2009) Canine leishmaniasis in Brazil: Serological follow-up of a dog population in an endemic area of American visceral leishmaniasis. J Parasitol Res 2009: 680790.
18. Adham D, Moradi-Asl E, Dorosti A, Khaiatzadeh S (2020) Spatial autocorrelation and epidemiological survey of visceral leishmaniasis in an endemic area of Azerbaijan region, the Northwest of Iran. PloS One 15(8): e0236414.
19. Moradi AE, Rassi Y, Adham D, Hanafi-Bojd AA, Saghafipour A, et al. (2019) Spatial distribution of sand flies (Diptera: *Psychodidae*; Larroussius group), the vectors of visceral leishmaniasis in Northwest of Iran. Asian Pacific J Trop Biomed 8(9): 425-430.
20. Saul J, Semiao S (1996) Canine Visceral leishmaniasis in Évora District: A sero-epidemiological study. ACR/Academic Press, Amesterdam, Netherlands 9: 74-80.
21. Nadim A, Javadian E, Mohebali M, Zamen Momeni A (2008) *Leishmania* parasite and leishmaniasis. Markaze Nashre Daneshgahi Publ, Iran.
22. Moradi-Asl E, Mohebali M, Rassi Y, Vatandoost H, Saghafipour A (2020) The environmental variables associated with distribution of canine visceral leishmaniasis in dogs in Ardabil Province, Northwestern Iran: A systematic review. Iran J Public Health 49(6): 1033-1044.
23. Vatandoost H, Moradi Asl E, Telmadarreiy Z, Mohebali M, Masoumi Asl H, et al. (2012) Field efficacy of flumethrin pour-on against livestock ticks in Iran. Int J Acarol 38(6): 457-464.
24. Jalilnavaz MR, Abai MR, Vatandoost H, Mohebali M, Akhavan AA, et al. (2016) Application of flumethrin pour-on on reservoir dogs and its efficacy against sand flies in endemic focus of visceral leishmaniasis, Meshkinshahr, Iran. J Arthropod-Borne Dis 10(1): 78-86.
25. Moradi Asl E, Vatandoost H, Telmadarreiy Z, Mohebali M, Abai MR (2019) Repellency effect of flumethrin pour-on formulation against vectors of Crimean-Congo haemorrhagic fever. East Mediterr Health J 24(11): 1082-1087.
26. Stanneck D, Rass J, Radeloff I, Kruedewagen E, Le Sueur C, et al. (2012) Evaluation of the long-term efficacy and safety of an imidacloprid 10%/flumethrin 4.5% polymer matrix collar (Seresto®) in dogs and cats naturally infested with fleas and/or ticks in multicentre clinical field studies in Europe. Parasites & Vectors 5(1): 66.
27. Smith WM, Ahlstrom LA, Rees E (2013) Long-term efficacy of an imidacloprid 10%/flumethrin 4.5% polymer matrix collar (Seresto®, Bayer) against the Australian paralysis tick (*Ixodes holocyclus*) in dogs. Parasitol Res 112(1): 1-10.
28. Fakhar M, Motazedian MH, Asgari Q, Kalantari M (2012) Asymptomatic domestic dogs are carriers of leishmania infantum: Possible reservoirs host for human visceral leishmaniasis in southern Iran. Comp Clin Path 21(5): 801-807.
29. Shokri A, Fakhar M, Teshnizi SH (2017) Canine visceral leishmaniasis in Iran: A systematic review and meta-analysis. Acta Trop 165: 76-89.
30. Alborzi A, Rasouli M, Shamsizadeh A (2006) *Leishmania* tropica-isolated patient with visceral leishmaniasis in Southern Iran. Am J Trop Med Hyg 74(2): 306-307.
31. Velez R, Ballart C, Domenech E, Abras A, Gomez SA, et al. (2019) Seroprevalence of canine leishmania infantum infection in the Mediterranean region and identification of risk factors: The example of North-Eastern and Pyrenean areas of Spain. Prev Vet Med 162: 67-75.
32. Abbaszadeh Afshar MJ, Sharifi I, Bamorovat M, Mohebali M, Bahreini MS, et al. (2018) Canine visceral leishmaniasis; A seroepidemiological survey in Jiroft district, Southern Kerman province, Southeastern Iran in 2015. Iran J Parasitol 13(1): 67-71.
33. Cardoso L, Rodrigues M, Santos H, Schoone GJ, Carreta P, et al. (2004) Sero-epidemiological study of canine *Leishmania spp*. Infection in the municipality of Alijo (Alto Douro, Portugal). Vet Parasitol 121(1-2): 21-32.
34. Desjeux P (2004) Leishmaniasis: Current situation and new perspectives. Comp Immunol Microbiol Infect Dis 27(5): 305-318.
35. Baneth G, Koutinas AF, Solano GL, Bourdeau P, Lluis F (2008) Canine leishmaniosis-new concepts and insights on an expanding zoonosis: Part one. Trends Parasitol 24(7): 324-330.
36. Serie A (2014) Visceral leishmaniasis surveillance and control manual. In: Secretariat HS (Ed.), Standards and technical manuals. Ministry of Health, Brazil, p. 121.
37. Moradi AE, Hanafi BAA, Rassi Y, Vatandoost H, Mohebali M, et al. (2017) Situational analysis of visceral leishmaniasis in the most important endemic area of the disease in Iran. J Arthropod Borne Dis 11(4): 482-496.

38. Umetsu N, Shirai Y (2020) Development of novel pesticides in the 21st century. J Pestic Sci 45(2): 54-74.

39. Gavgani MS, Mohit H, Edrissian GH, Mohebali M, Davies CR (2002) Domestic dog ownership in Iran is a factor for human infection with *Leishmania infantum*. Am J Trop Med Hyg 67(5): 511-515.

40. Reiner SH, Locksley RM (1995) Domestic dog ownership in Iran is a factor Ann Rev Immunol 13: 151-177.

41. Neligan A (1913) Canine Leishmaniasis. J Trop Med Hyg 16: 156-164

42. Mohebali M, Hajjaran H, Hamzavi Y, Mobedi I, Arshi S, et al. (2005) Epidemiological aspects of canine visceral leishmaniosis in the Islamic Republic of Iran. Vet Parasitol 129(3-4): 243-251.

43. Mazloumi GAS, Hodjati MH, Mohite H, Davies CR (2002) Effect of insecticide-impregnated dog collars on incidence of zoonotic visceral Leishmaniasis in Iranian Children: A matched cluster randomized trial. Lancet 360(9330): 374-379.

44. Dantas TF, Capelli G, Giannelli A, Antonio R, Ramos N, et al. (2013) Efficacy of an imidacloprid/flumethrin collar against fleas, ticks and tick-borne pathogens in dogs. Parasites & Vectors 6(1): 245.

45. Brianti E, Gaglio G, Napoli E, Falsone L, Prudente C, et al. (2014) Efficacy of a slow-release imidacloprid (10%)/ flumethrin (4.5%) collar for the prevention of canine leishmaniosis. Parasites & Vectors 7: 327-334.

46. Reichard MV, Thomas JE, Arther RG, Hostetler G, Raetzel KL, et al. (2013) Efficacy of an imidacloprid 10%/ flumethrin 4.5% collar (seresto®, bayer) for preventing the transmission of *Cytauxzoon Felis* to domestic cats by *Amblyomma Americanum*. Parasitol Res 112: 11-20.

47. Greco G, Brianti E, Buonavoglia C, Carelli G, Pollmeier M, et al. (2019) Effectiveness of a 10% imidacloprid/4.5% flumethrin polymer matrix collar in reducing the risk of *Bartonella spp*. infection in privately owned cats. Parasites & Vectors 12: 69-75.

48. Rassi Y, Moradi AE, Vatandoost H, Abazari H, Saghafipour A (2020) Insecticide susceptibility status of wild population of phlebotomus kandelakii and phlebotomus perfiliewi transcaucasicus collected from visceral leishmaniasis endemic foci in Northwestern Iran. J Arthropod Borne Dis 14(3): 277-285.

49. Yimam Y, Mohebali M (2020) Effectiveness of insecticide-impregnated dog collars in reducing incidence rate of canine visceral leishmaniasis: A systematic review and meta-analysis. PLoS One 15(9): e0238601.

50. Patricia SSM, Helena HT, Virgínia BRP, Roberto MH, Karla LSR (2022) Efficacies of insecticide dog collars against visceral leishmaniasis in low and high-income areas and the effects for non-collared neighbor dogs. Acta Trop 235: 106626.