Original Research Article

**First report on molecular diagnosis and phylogenetic analysis of *Hepatozoon canis* in naturally infected domesticated and stray dogs from Jhang, Pakistan**

**Running Title: Molecular and phylogenetic analysis of *H*. *canis* in dogs**

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**Statement of Novelty**

This is the first report describing the prevalence of *H. canis* and its phylogenetic characterization in the common locally kept dog breeds as the studies on this protozoon in the country are few. There is no reliable update about the prevalent tick-borne diseases in the study area. This study will inform the stakeholders about the true status of the protozoon in the local dogs as well as helpful in obtaining the specific treatment and prevention of *H. canis*. Besides, disease mapping can be another added advantage of the study.

**Abstract:**

**Back ground**

Canine diseases, particularly caused by tick-borne hepatozoons are responsible for high morbidity and mortality, and are the reason for attracting significant focus.

**Aims**

The current study was aimed to survey the occurrence of *H. canis* in domesticated and stray dogs of Jhang city (Punjab) with its molecular identification.

**Methods**

For this, blood samples from 300 dogs (n=200 domesticated; n=100 stray) were collected and assayed through PCR for the detection of *H. canis* supported by sequencing analysis.

**Results**

The results demonstrated, 15.66% (47/300) of samples positive for *H. canis*. A significantly (P<0.05) higher occurrence of *H. canis* was observed in stray dogs (27%) than domesticated dogs (10%). Evaluation of the various risk factors showed that the age, sex, breed, dog category (domestic or stray), body coat, environmental settings (rural or urban) and ectoparasitic infestation were significantly (P<0.05) associated with the occurrence of infection. The phylogenetic analysis of the PCR confirmed specimens revealed a very close homology of the detected strains with the ones diagnosed earlier in China and Malta.

**Conclusion**

It was concluded that present moderate prevalence of *H. canis* among the dog populations in the area of Jhang may rise with stray dogs being most vulnerable hosts and potential source of vectors spread.

Key words: *H. canis*; PCR and phylogenetic analysis; prevalence; stray dogs

**Introduction:**

Canine hepatozoonosis is a tick-borne disease of carnivores affecting both the wild and domestic animals. More than 300 hepatozoon species have been known so far, out of which 46 infect mammals. Hepatozoon spp. belonging to phylum hepatozoid apicomplexa are the blood parasites of vertebrate intermediate hosts (Baneth *et al*. 2003). These intracellular protozoans affect the leukocytes chiefly neutrophils and monocytes of animals (Baneth 2011). *Hepatozoon canis (H. canis)* and *Hepatozoon americanum (H. americanum)* are the two reported species acting as sole source of infection among dogs (Baneth *et al*. 2000). *H. canis* is the causes of Old World canine hepatozoonosis and has been transmitted by *Amblyomma ovale* (Forlano *et al*. 2005; Rubini *et al*. 2009), *Haemaphysalis (H.) longicornis, H. flava* (Murata *et al*. 1995), and *Rhipicephalus sanguineus sensu lato* (Baneth *et al*. 1998). Epidemiological studies have reported the prevalence of *H. canis* in Asia, Europe, Southeast Asia, Africa, Middle East, and South America, while *H. americanum* has been limited to the United States (Ewing and Panciera, 2003). *H. americanum* can only be transmitted by *Amblyomma maculatum* and has been found in the Central and South American countries (Vincent-Johnson 2003).

Pathogenesis of *H. canis* is considered relatively weaker as subclinical infections are predominant, manifesting milder disease affecting the spleen, lymph nodes, and bone marrow, culminating in anemia and lethargy (Baneth and Weigler 1997). Transplacental transmission of *H. canis* is possible (Murata *et al*. 1993). Infection can be diagnosed by PCR or sequencing (Baneth *et al*. 2003; Criado-Fornelio *et al*. 2007). Only a limited studies on *H. canis* have been reported in Pakistan till to date (Qamar *et al*. 2017; Ahmad *et al*. 2018). It was hypothesized that *H. canis* is prevalent in the dogs of this region and the current study was planned to investigate the prevalence and risk factors associated with the protozoon infection in domestic and stray dogs from Jhang, Punjab, Pakistan. It is one of the very few studies exploring the phylogenetic sequence of 18S rRNA gene of *H. canis* in domestic and stray dogs from Pakistan and provide baseline information for effective control of this malady in dogs.

**Materials and methods:**

**Study area and Blood Sampling:**

Blood samples (n= 300) were collected randomly from 03 different dog breeds i.e.; German Shepherd (n=100), **Pointer** (n=100) and non-descript stray dogs (n=100) from Jhang, Pakistan. About 5ml of blood was collected aseptically from cephalic or saphenous venipuncture using 5 ml disposable plastic syringe. The collected blood samples were immediately transferred to purple capped vacutainer (BD Vacutainer® spray-coated K2 EDTA) tubes and appropriately labeled. Subsequently, the samples were transported in cold chain to Postgraduate Medicine Laboratory at College of Veterinary and Animal Sciences (CVAS), Jhang for initial analysis, and were preserved at -20°C till the DNA was extracted. The study design was permitted by the Committee on Animal Ethics at CVAS (Sub-campus University of Veterinary & Animal Sciences, Lahore), initially with the final approval of the content by Directorate of Advanced Studies (DAS/7550 dated 23-07-2019) of the University. Verbal and written consents were acquired by each dog owner prior to c blood sampling of their animals. Data pertaining to possible contributing risk factors such as age (evaluated the age via canine teeth and incisor changes), sex, breed, dog category either domestic or stray, environmental settings (rural or urban) and ectoparasite control practices were collected using a predesigned questionnaire proforma.

**Molecular detection:**

The extraction of genomic DNA of protozoan (*H. canis*) was carried out from 200 µl of EDTA anticoagulated blood specimens using a commercially available QIAamp DNA Mini Kit (QIAGEN GmbH, Hilden, Germany) as per manufacturer’s instructions. The quality of DNA was measured by electrophoresis on an agarose gel. The primers PIRO-A1(50-AGGGAGCCTGAGAGACGGCTACC-30) and PIROB (50-TTAAATACGAATGCCCCCAAC-30) (manufactured by Gene Link™) were used to amplify an approximately 450 bp region of the 18S rRNA gene (Földvári *et al*. 2005). PCR was performed in a total of 25µl volume of reaction mixture having 12µl Master mix (VizPure™ PCR 2X Master), 2µl forward and reverse primers each, 4µl of DNA and 5µl of nuclease free water.

The PCR amplification was accomplished in a thermal cycler (Applied Biosystems® Veriti®, Foster city, California). The initial denaturing temperature was set at 95°C for 10 min with subsequent 40 cycles at 94°C for 30 sec, annealing at 59°C for 30 sec, extension at 72 °C for 30 sec, and the final extension was obtained at 72°C after 7 min. The amplified DNA (Fig.1) was examined through 1.3% agarose gel electrophoresis. A 100 bp marker was also run to ascertain the size of amplified DNA (Thermo Scientific®, Waltham, Massachusetts).

**Sequencing and phylogenetic analysis:**

For the confirmation of PCR results, a total of 10 randomly selected samples were subjected to sequencing, out of which 4 were recognized as *H. canis*. The PCR selected products were cleaned up using a commercial kit method. For DNA sequencing reaction, Big Dye® Terminator v3.1 Cycle Sequencing Kit (Perkin-Elmer, Applied Biosystems® Division) was used. For examination of sequencing reactions, ABI Prism® 3730xl Genetic Analyzer (Applied Biosystems®, Foster city, California) was used. The sequences obtained were checked with Chromas v.1.45 and compared to sequence data available in the GenBank1, using the BLAST at NCBI (<http://www.ncbi.nlm.nih.gov/BLAST/>). The newly identified sequences of the partial 18S rRNA gene of *H. canis* identified in the current study were submitted to GenBank (Accession numbers: MN900602, MN900603, MN900610 and MN900692).

The phylogenetic analysis was completed using the software MEGA X 10.0.5 to compare the DNA sequences of the current study with the ones previously deposited in the GenBank from the studies conducted in the other countries. The neighbor-joining algorithms using the Tamura 3 Parameter trees were formulated. Nodes with bootstrap values of greater than 30% after 1,000 replicates are indicated (Fig. 2).

**Statistical analysis:** The data pertaining to prevalence of *H. canis* among dogs were analyzed using Pearson Chi Square statistic at 95% confidence interval using the OpenEpi program (<https://www.openepi.com/TwobyTwo/TwobyTwo.htm>).

**Results:**

Overall, 15.66% (47/300, ± 4.1 at 95% C.I.) of the samples amplified exhibited 450-bp band specific for 18S rRNA gene of *H. canis*. Analysis of the possible risk factors associated with *H. canis* occurrence was carried out using Chi-square statistics (Table.1) It showed that the prevalence of *H. canis* was significantly (P<0.05) associated with various risk factors, namely, age, sex, breed, dog category (domestic or stray), body coat, environmental (rural or urban) settings and ectoparasitic infestation. The prevalence was high in the males and young dogs of age below one year with long body coat and dogs kept in the rural areas. The male dogs depicted relatively higher prevalence (P<0.05) than females. The stray or abandoned dogs infested with ticks represented a significantly (P<0.05) higher prevalence than the domestic dogs kept as pets by the owners irrespective of their area of living i.e., either in rural or urban ambiance.

A total of 10 PCR amplicons were randomly sorted out for performing the DNA sequencing. The outcome of sequencing of the amplicon displayed 4 distinct 18S rRNA sequences (466–496bp). The nucleotide BLAST analysis confirmed the similarity among the obtained sequences at large (i.e., sequence homology >92%) to already existing *H. canis* spp. in the data bases. The alignment of 4 confirmed sequences was submitted to GenBank (GenBank accession numbers MN900602, MN900603, MN900610 and MN900692).

**Discussion:**

The current study enabled the first insight of the genetic characterization of *H. canis* from domesticated and stray dogs in the oldest district of Jhang, Punjab (Pakistan). Canine hepatozoonosis is a tick-borne disease of increasing importance in dogs worldwide. Besides the microscopic and serological methods of diagnosis, molecular techniques are quite specific and sensitive. In the current study, dogs reared in the Jhang district were investigated showing a prevalence of 15.66%. The prevalence of *H. canis* recorded in the current study was significantly (P<0.05) higher than an earlier study in Pakistan (Qamar *et al*. 2017) reporting a prevalence of 11.9% but lower than 45.5% Ahmad *et al*. (2018). This variation in the prevalence of *H. canis* may be attributed to many factors, including the distribution (Spolidorio *et al*. 2009), population status of the vector (Otranto *et al*. 2011), methodology of sampling, and the traits of the dog population being studied (de Azevedo Gomes *et al*. 2016). The differences of environmental settings either rural or urban, the status of look after extended by the owner to their pets and a stray category in the present study of dogs were observed as the significantly contributing risk factors in the incidence of this infection.

Surveys of *H. canis* in dogs in different countries have shown varying prevalence rates such as Brazil 3.8% (De Miranda *et al*. 2014), Croatia 11.8% (Vojta *et al*. 2009), Costa Rica 7.5% (Rojas *et al*. 2014), India 30% (Singla *et al*. 2016), Iran 23% (Dalimi *et al*. 2017), Qatar 1.6% (Alho *et al*. 2017), Thailand 11.4% (Jittapalapong *et al*. 2006) and Turkey 3.6% (Aydin *et al*. 2015). The prevalence recorded in the present study also lies in between the highest and lowest prevalence of 3.6% and 30%. However, further broad studies are required to make the scenario clearer.

Contrarily, some of the investigations from Brazil have reported alarmingly high prevalence (58.7 and 66.4%) of *H. canis* in dogs ( Spolidorio *et al*. 2009; de Castro Demoner *et al*. 2016). The variations in the reported prevalence may plausibly be owing to various risk factors including the traits of the target dog population under investigation, season of specimens collection, social and husbandry facilities (same species animals and tick preventive measures), geoclimatic characteristics influencing the abundance and spread of tick vector species (Stich *et al*. 2014).

As far as the role of various risk factors in the prevalence of canine hepatozoonsis is concerned, many of authors have reported higher prevalence among young dogs under the age of one year than older ones (Abdullahi *et al*. 1990; Vezzani *et al*. 2017) resembling with the findings of the current study. This may be due to deficient immune competency and vulnerable exposure of infection at young age. In pertinence to dogs’ categories as pets or stray, a significantly higher (P<0.05) prevalence among stray dogs was encountered than their pet counterparts. The most plausible reason in this scenario seems to be the keen observation and vigilance of domestic dogs by the owners in contrary to the sheer abandonment of ownership on the part of stray dogs. The stray dogs wander here and there having maximum chances of getting tick infestation and subsequent infection (Bashir *et al*. 2009). It has been also seen that contact with other animals (domestic or wild) can pose a high risk of tick infestation. Stray dogs have been mostly infected with vector borne diseases than other pet breeds ( Hornok *et al*. 2006; Amuta *et al*. 2010; Singh *et al*. 2014).

In terms of sex of the host, male dogs were found to be affected significantly (P<0/05) high than females being in consensus with a previous report (Vezzani *et al*. 2017). Male dogs, owing to their wandering, aggressive and fighting temperament seem to be affected higher while the females have been observed to remain isolated after mating during the term and post-whelping in fostering the pups. Here, it was seen that contact with other animals may be the source of transmission as the other livestock animals at the farm may already have tick load. Anyhow, this risk factor was not evidenced as a significant contributor possibly because the animals coming in contact with these dogs were either free of ticks or were least exposed owing to good management. Dog category either pet or stray was significantly (P<0.05) different in current study, and also is not in line with the findings of previous studies which may possibly be due to difference in the breeds as the susceptibility to the disease may be associated with the breed genetics.

As the coat of body is concerned, it was noted that dogs with long coat are more susceptible than short coated dogs. In the current study it was seen that environmental setting influences the prevalence of *H. canis* as the dogs in rural areas are more infected than the urban areas. The livestock population is significantly high in the rural areas and in contact dogs may get the ticks transferred from other animals and become the source of infection to nearby dogs as described by (Pacifico *et al*. 2020). The ticks attached hide themselves in long coat and remain unnoticed from the owner’s observation.

This is the very first report of molecular detection and characterization of *H. canis* in naturally infected dogs (pet and stray dogs) conducted in District, Jhang, Pakistan.

**Conclusion**

In conclusion, the prevalence of *H. canis* among the dog populations is considerable with a potential to rise with soaring trends of dog keeping in the region. PCR coupled with sequencing analysis provides a reliable confirmatory test for such emerging infections in the non-reported areas for undertaking effective therapeutic and control measures.

**Author contributions**

MA AN and AS planned the experiments, SEH and MAZ interpreted the results, MK statistically analyzed the data and made illustrations MA contributed in the write up.

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**Conflict of interest**

The authors declare no conflict of interest

**References:**

Abdullahi S, A Mohammed, A Trimnell, A Sannusi, R Alafiatayo (1990). Clinical and haematological findings in 70 naturally occurring cases of canine babesiosis. J Small*Anim Pract* 31: 145-147.

Ahmad AS, MA Saeed, I Rashid, K Ashraf, W Shehzad, RJ Traub, G Baneth, A Jabbar (2018). Molecular characterization of *Hepatozoon canis* from farm dogs in Pakistan. *Parasitol Res* 117: 1131-1138.

Alho AM, C Lima, MS Latrofa, V Colella, S Ravagnan, G Capelli, LM de Carvalho, L Cardoso, D Otranto (2017). Molecular detection of vector-borne pathogens in dogs and cats from Qatar. *Parasit Vector* 10: 1-5.

Amuta E, B Atu, R Houmsou, J Ayashar (2010). *Rhipicephalus sanguineus* infestation and *Babesia canis* infection among domestic dogs in Makurdi, Benue State-Nigeria. *Int J Acd Res* 2(3) 170-172.

Aydin MF, F Sevinc, M Sevinc (2015). Molecular detection and characterization of Hepatozoon spp. in dogs from the central part of Turkey. *Ticks Tick Borne Dis* 6: 388-392.

Baneth, G (2011). Perspectives on canine and feline hepatozoonosis. *Vet Parasitol* 181: 3-11.

Baneth G, JR Barta, V Shkap, DS Martin, DK Macintire, N Vincent-Johnson (2000). Genetic and antigenic evidence supports the separation of *Hepatozoon canis* and *Hepatozoon americanum* at the species level. *J Clin Microbiol* 38: 1298-1301.

Baneth G, JS Mathew, V Shkap, DK Macintire, JR Barta, SA Ewing (2003). Canine hepatozoonosis: two disease syndromes caused by separate Hepatozoon spp. *Trends Parasitol* 19: 27-31.

Baneth G; V Shkap, M Samish, E Pipano, I Savitsky (1998). Antibody response to *Hepatozoon canis* in experimentally infected dogs. *Vet Parasitol* 74: 299-305.

Baneth G, B Weigler (1997). Retrospective case‐control study of hepatozoonosis in dogs in Israel. *J Vet Intern Med* 11: 365-370.

Bashir I, Z Chaudhry, S Ahmed, M Saeed (2009). Epidemiological and vector identification studies on canine babesiosis. *Pak Vet J* 29(2) 51-54.

Criado-Fornelio A, C Rey-Valeiron, A Buling, J Barba-Carretero, R Jefferies, P Irwin, (2007.) New advances in molecular epizootiology of canine hematic protozoa from Venezuela, Thailand and Spain. *Vet Parasitol* 144(3-4): 261-269.

Dalimi A, F Jameie, A Mohammadiha, M Barati, S Molaei (2017). Molecular detection of *Hepatozoon canis* in dogs of Ardabil Province, Northwest of Iran. *Archive Rizvi Insti* 72(3): 197-201.

de Azevedo Gomes L, PHG Moraes, LDCS do Nascimento, LH O’Dwyer, MRT Nunes, ADRP Rossi, DCF Aguiar, EC Gonçalves (2016). Molecular analysis reveals the diversity of Hepatozoon species naturally infecting domestic dogs in a northern region of Brazil. *Tick Tick Borne Dis 7*:1061-1066.

de Castro Demoner, Larissa, NM Magro, MRL da Silva, JM Azevedo, de Paula Antunes, CIP Calabuig, L O’Dwyer (2016). Hepatozoon spp. infections in wild rodents in an area of endemic canine hepatozoonosis in southeastern Brazil. *Tick Tick Borne Dis* 7: 859-864.

Ewing SA, R Panciera (2003). American canine hepatozoonosis. *Clin Microbiol Rev* 16: 688-697.

Földvári G, E Hell, R Farkas (2005). *Babesia canis canis* in dogs from Hungary: detection by PCR and sequencing. *Vet Parasitol* 127(3-4): 221-226.

Forlano M, A Scofield, C Elisei, K Fernandes, S Ewing, C Massard (2005). Diagnosis of Hepatozoon spp. in *Amblyomma ovale* and its experimental transmission in domestic dogs in Brazil. *Vet Parasitol* 134(1-2): 1-7.

Hornok S, R Edelhofer, R Farkas (2006). Seroprevalence of canine babesiosis in Hungary suggesting breed predisposition. *Parasitol Res* 99(6): 638-642.

Jittapalapong S, O Rungphisutthipongse, S Maruyama, JJ Schaefer, RW Stich (2006). Detection of *Hepatozoon canis* in stray dogs and cats in Bangkok, Thailand. *Ann NY Acad Sci* 1081(1): 479-488.

Murata T, M Inoue, S Tateyama, Y Taura, S Nakama (1993). Vertical transmission of *Hepatozoon canis* in dogs. *J Vet Med Sci* 55(5): 867-868.

Murata T, M Inoue, Y Taura, S Nakama, H Abe, K Fujisaki (1995). Detection of *Hepatozoon canis* oocyst from ticks collected from the infected dogs. *J Vet Med Sci* 57(1): 111-112.

Otranto D, F Dantas-Torres, S Weigl, MS Latrofa, D Stanneck, D Decaprariis, G Capelli, G Baneth (2011). Diagnosis of *Hepatozoon canis* in young dogs by cytology and PCR. *Parasit Vector* 4(1): 1-6.

Pacifico L, J Braff, F Buono, M Beall, B Neola, J Buch, G Sgroi, D Piantedosi, M Santoro, P Tyrrell (2020). *Hepatozoon canis* in hunting dogs from Southern Italy: distribution and risk factors. *Parasitol Res* 119(9): 3023-3031.

Qamar M, MI Malik, M Latif, Qu Ain, M Aktas, RS Shaikh, F Iqbal (2017). Molecular detection and prevalence of *Hepatozoon canis* in dogs from Punjab (Pakistan) and hematological profile of infected dogs. Vector Borne Zoonotic Dis 17(3): 179-184.

Rojas A, D Rojas, V Montenegro, R Gutiérrez, D Yasur-Landau, G Baneth (2014). Vector-borne pathogens in dogs from Costa Rica: first molecular description of *Babesia vogeli* and *Hepatozoon canis* infections with a high prevalence of monocytic ehrlichiosis and the manifestations of co-infection. *Vet Parasitol* 199(3-4): 121-128.

Rubini A, K Paduan, T Martins, M Labruna, O’dwyer, L (2009). Acquisition and transmission of *Hepatozoon canis* (Apicomplexa: Hepatozoidae) by the tick *Amblyomma ovale* (Acari: Ixodidae). *Vet Parasitol* 164(2-4): 324-327.

Singh A, H Singh, N Singh, N Singh, J Rath (2014). Canine babesiosis in northwestern India: molecular detection and assessment of risk factors. *Bio Med Res Int*. Article ID 741785

Singla LD, D Sumbria, A Mandhotra, M Bal, P Kaur (2016). Critical analysis of vector-borne infections in dogs: *Babesia vogeli*, *Babesia gibsoni*, *Ehrlichia canis* and *Hepatozoon canis* in Punjab, India. *Acta Parasitol* 61(4): 697-706.

Spolidorio MG; MB Labruna, AM Zago, DM Donatele, KM Caliari, NH Yoshinari (2009). *Hepatozoon canis* infecting dogs in the State of Espírito Santo, southeastern Brazil. *Vet Parasitol* 163(4): 357-361.

Stich RW, BL Blagburn, DD Bowman, C Carpenter, MR Cortinas, SA Ewing, D Foley, JE Foley, H Gaff, GJ Hickling, RR Lash, SE Little, C Lund, R Lund, TN Mather, GR Needham, WL Nicholson, J Sharp, AV Stokes, D Wang (2014). Quantitative factors proposed to influence the prevalence of canine tick-borne disease agents in the United States. *Parasti Vector 7,* Article No. 417

Vezzani D, CF Scodellaro, DF Eiras (2017). Hematological and epidemiological characterization of *Hepatozoon canis* infection in dogs from Buenos Aires, Argentina. *Vet Parasitol Reg Stud Reports* 8: 90-93.

Vincent-Johnson, NA (2003). American canine hepatozoonosis. *Vet Clin North Am Small Anim Pract* 33(4): 905-920.

Vojta L, V Mrljak S Ćurković T Živičnjak, A Marinculić, R Beck (2009). Molecular epizootiology of canine hepatozoonosis in Croatia. *Int J Parasitol* 39(10): 1129-1136.

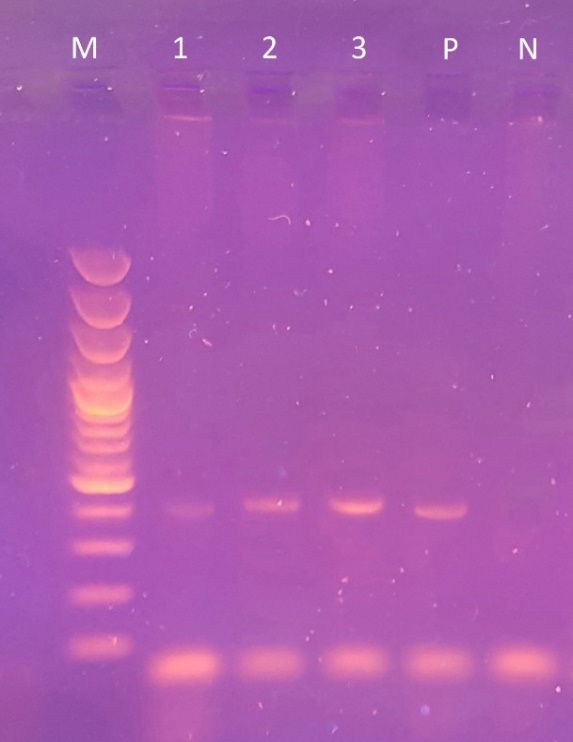


Figure 1: PCR amplification of 450 bp of 18S rRNA represent *H. canis*, Lane 1-3 represents *H. canis* samples M=100 bp DNA ladder/marker, P= Control positive and N= Control negative.

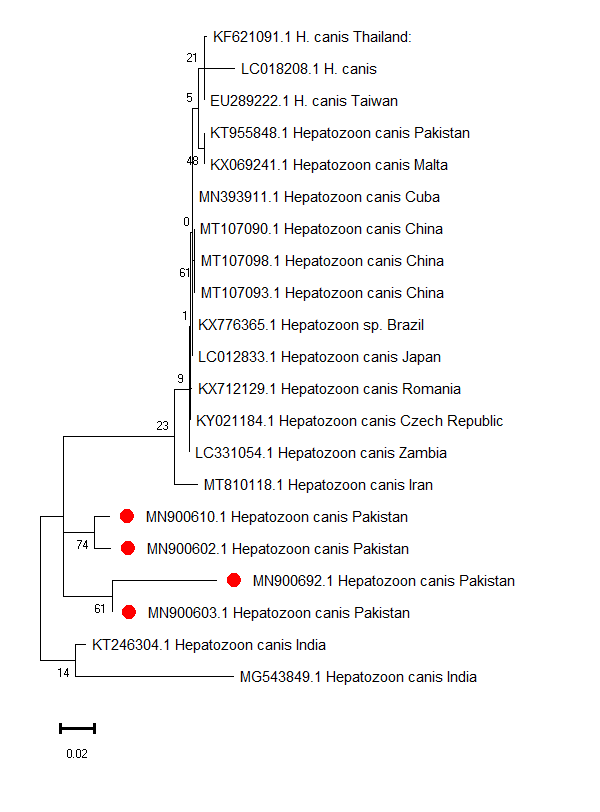


Figure 2: Phylogenetic relationship of *H. canis* detected during present study to *H. canis* (red dots) reported from other countries based on the partial sequence of the 18S rRNA gene. The evolutionary history was inferred by the Neighbor-Joining method based on the Tamura-Nei mode. Boot strap analysis, used to estimate the node reliability of the trees, was conducted with 1000 replicates as implemented in MEGA X 10.0.5. Hepatozoon spp., host species, country of origin from where these sequences were derived, and the GenBank accession numbers are included for each sequence.

**Table 1:** Descriptive statistics and results of a Chi-square testing for the association between selected potential risk factors and *H. canis* prevalence.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Risk Factors** | **Category** | **Samples Tested (n)** | **Positive (n)** | **% Prevalence ± S.E at 95% CI** | **P-Value** |
| Age | <1 Year  >1 Year | 166  134 | 34  13 | 20.48  9.70 | 0.010 |
| Sex | Male  Female | 214  86 | 40  7 | 18.69  8.13 | 0.022 |
| Breed | German Shepherd  **Pointer**  Non-descript | 100  100  100 | 14  8  25 | 14  8  25 | 0.003 |
| Dog Category | Pet Dogs  Mongrel Dogs | 200  100 | 20  27 | 10  27 | 0.000 |
| Body Coat | Medium to long  Short | 207  93 | 40  7 | 19.32  7.52 | 0.009 |
| Environmental setting | Urban  Rural | 193  107 | 23  24 | 11.91  22.42 | 0.016 |
| Ectoparasitic infestation | Yes  No | 185  115 | 35  12 | 18.91  10.43 | 0.049 |

P values < 0.05 are statistically significantly different

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