Detection of *Babesia canis rossi*, *B. canis vogeli*, and *Hepatozoon canis* in Dogs in a Village of Eastern Sudan by Using a Screening PCR and Sequencing Methodologies

Maremichi Oyamada,¹ Bernard Davoust,² Mickaël Boni,³ Jacques Dereure,⁴ Bruno Bucheton,⁵ Awad Hammad,⁶ Kazuhito Itamoto,¹ Masaru Okuda,¹ and Hisashi Inokuma⁷*

Faculty of Agriculture, Yamaguchi University, 753-8515 Yamaguchi, Japan; Direction du Service de Santé en Region Sud-Est, BP16, 69998 Lyon Armees, France; Groupe de Secteurs Vétérinaires Interarmees de Saint Germain en Laye, BP220, 00492 Saint Germain en Laye Armees, France; Laboratoire de Parasitologie, Faculté de Médecine, 34090 Montpellier, France; Laboratoire d’immunologie Parasitaire, Faculté de Médecine, Université de la Méditerranée, Marseille Cedex 5, France; Département de Microbiologie et Parasitologie, Faculté de Médecine, University of Khartoum, P.O. Box 102, Khartoum, Republic of the Sudan; and Obihiro University of Agriculture and Veterinary Medicine, 080-8555 Obihiro, Japan

Received 13 July 2005/Returned for modification 18 August 2005/Accepted 19 August 2005

*Babesia* and *Hepatozoon* infections of dogs in a village of eastern Sudan were analyzed by using a single PCR and sequencing. Among 78 dogs, 5 were infected with *Babesia canis rossi* and 2 others were infected with *B. canis vogeli*. Thirty-three dogs were positive for *Hepatozoon*. *Hepatozoon canis* was detected by sequence analysis.

Both *Babesia* and *Hepatozoon* infections are important tick-borne protozoan diseases of dogs (2, 8). The diagnosis of infections with these protozoa is usually based on the detection of pathogens in peripheral blood under a microscope. However, such morphology-based methods are labor- and time-consuming because of their low sensitivities. Recently, molecular techniques, including PCR and sequence analysis, have been used for the diagnosis and epidemiological studies of canine *Babesia* and *Hepatozoon* infections (1, 3, 10, 11, 21, 22). The advantages of the molecular methods over other techniques are their higher sensitivities and specificities for the detection of the target pathogens in peripheral blood. *Babesia canis* is divided into three subspecies, *B. canis canis*, *B. canis vogeli*, and *B. canis rossi* (7, 14, 19). By using these molecular methods, the diagnosis of *Babesia* infection is easily performed at the subspecies level. *Hepatozoon* has also been analyzed by using molecular technologies to identify two species, *Hepatozoon* canis and *H. americanum* (1, 2, 20). Because most epidemiological studies of protozoal infections in African countries are performed based on morphology, little information is available on canine *Babesia* and *Hepatozoon* infections in Africa (5, 9, 17). Thus, the objective of this study was to clarify the infection rates and subspecies of *Babesia* and *Hepatozoon* in dogs in a village in eastern Sudan, by using a combination of screening PCR and the sequencing methodology. We used a screening PCR to detect both *Babesia* and *Hepatozoon* simultaneously, followed by sequencing to identify the organisms to the species or subspecies level.

Peripheral blood was obtained from 78 randomly selected dogs in the village during May 1997, May 1998, April 1999, and January 2000 (6). As these dogs were all free roaming around the village, the ages and histories of dogs were unknown. The sex and health status of the dogs were not recorded. Ticks were recovered from 61 dogs for identification. *Rhizophagus sanguineus* was the most dominant tick species: it was recovered from 44 of 61 dogs (72.1%), in agreement with the findings presented in a previous report (12), followed by *Rhizophagus evertsi evertsi* (3 of 61 dogs [4.9%]) and *Amblyomma lepidum* (4 of 61 dogs [6.6%]). Total DNA was extracted from each sample of canine blood with a QIAamp DNA Mini kit (QIAGEN GmbH, Hilden, Germany), adjusted to 200 µl with TE (Tris-EDTA) buffer, and stored at −20°C until it was used. Detection of DNA fragments of *Babesia* and *Hepatozoon* was attempted by PCR with primers of *Babesia*-F (GTG-AAA-CTG-CGA-ATG-GCT-CA) and *Babesia*-R (CCA-TGC-TGA-AGT-ATT-CAA-GAC). This primer set was previously reported to be specific for the genus *Babesia* (11), but it could amplify both *Babesia* and *Hepatozoon* simultaneously in our preliminary experiments. To confirm the results of PCR and to identify the infectious agents at the species or subspecies level, selected products of the PCR were purified with a QIAPCR purification kit (QIAGEN) or QIAquick gel extraction kit (QIAGEN) for direct sequence analysis. A fluorescence-labeled dideoxynucleotide technology was used for the DNA sequencing reactions (Perkin-Elmer, Applied Biosystems Division, Foster City, CA). The samples were then sequenced by using a Perkin-Elmer ABI Prism 377 automated DNA sequencer at the DNA Core Facility of the Center for Gene Research, Yamaguchi University. The sequences of the agent determined were analyzed for phylogenetic relationships with other sequences registered in GenBank. Multiple-sequence alignment analysis, the determination of pairwise percent identities of the sequences, distance matrix calculations, and the construction of phylogenetic trees were all performed with the ClustalW program (18), version 1.8, in the DNA data bank of Japan (DDBJ; Mishima, Japan [http://www.ddbj.nig.ac.jp/htmls/E-mail/clustalw-e.html]), as described in a previous report (11). The distance matrices for the aligned sequences with

---

* Corresponding author. Mailing address: Obihiro University of Agriculture and Veterinary Medicine, 080-8555 Obihiro, Japan. Phone and fax: (81)-155-49-5370. E-mail: inokuma@obihiro.ac.jp.
and is transmitted by a known to be the most pathogenic among the three subspecies has a different pathogenesis in canine hosts. B. canis rossi and B. canis vogeli.

B. canis canis, GenBank accession no. AY072926; no. AF175301; B. gibsoni, GenBank accession no. AF175300; B. gibsoni Asia-2, GenBank accession no. AF175301; B. canis vogeli, GenBank accession no. AY072925; B. canis canis, GenBank accession no. AY072926; Babesia caballi, GenBank accession no. Z15104; Babesia bigemina, GenBank accession no. X59607; Babesia bovis, GenBank accession no. L19078; Theileria sergenti, GenBank accession no. AB000271; Hepatozoon canis Japan, GenBank accession no. AF418558; Hepatozoon canis Italia, GenBank accession no. AF176835; Hepatozoon americanum, GenBank accession no. AF176836; Hepatozoon catesbianae, GenBank accession no. AF176837; and Neosporum caninum, GenBank accession no. U03069.

Among the 78 dogs examined, 7 (9.0%) dogs (dogs 44, 55, 59, 69, 74, 76, and 78) showed a band positive for Babesia at about 645 bp. A total of 33 (42.3%) dogs were positive for Hepatozoon with a band of about 780 bp. Among these, three dogs (dogs 59, 74, and 78) showed dual positivity for bands at both 645 and 780 bp (Fig. 1). By analyzing the seven sequences of the Babesia 645-bp PCR products, excluding the primer region, five were identified as B. canis rossi (GenBank accession no. L19079) with percent identities of 99.7 to 99.8% (Fig. 2). The other two were very similar to B. canis rossi (GenBank accession no. AY072925), with percent identities of 99.8% (Fig. 2). Nine PCR products were randomly selected from among 33 Hepatozoon-positive PCR products for sequence analysis. All nine samples examined showed higher similarities with H. canis (GenBank accession no. AF176835), with percent identities of 99.1 to 100% (Fig. 2).

B. canis has three subspecies: B. canis canis, B. canis rossi, and B. canis vogeli. Each subspecies has a different vector and has a different pathogenesis in canine hosts. B. canis rossi is known to be the most pathogenic among the three subspecies and is transmitted by Hemaphysalis leachi (7). The pathogenesis of B. canis vogeli is comparatively weaker than those of the other two subspecies, and it is transmitted by Rhipicephalus sanguineus (7). In the present study, the predominant tick species recovered from dogs was R. sanguineus, and H. leachi was not detected. Babesia canis rossi may also be transmitted by ticks, such as R. sanguineus, R. evertsi evertsi, or A. lepidum, which were recovered from dogs in this study. Although the clinical symptoms of the infected dogs were not recorded in this study, infection with B. canis rossi might cause clinical disease in the canine host. The findings reported here are the first evidence of infection with B. canis rossi and B. canis vogeli in dogs in Sudan.

Our findings are also the first evidence of Hepatozoon canis infection in dogs in Sudan. H. canis is also known to be transmitted by R. sanguineus (4), which was the most common tick found in the present study. The rate of infection with H. canis was higher than that with B. canis in the present study. The weak pathogenesis of H. canis infection in canine hosts might contribute to the higher infection rate in this group, although the clinical symptoms of the infected dogs were not recorded.

Infections with B. canis rossi, B. canis vogeli, and H. canis in dogs may have a clinical impact on the quality of dogs’ lives in this area. Dogs may also be reservoirs for continued propagation or may be the cause of increased infection rates. Furthermore, R. sanguineus may play an important role in the transmission of Babesia and Hepatozoon in Sudan.

In the present study, a single PCR was successfully used to detect Babesia and Hepatozoon simultaneously in canine blood samples. This provided an easy screening method for the detection of both Babesia and Hepatozoon in a single PCR. In combination with subsequent sequence analysis, this PCR assay may provide accurate information about the infectious agents. There were no difficulties in determining the subspecies of Babesia or the species of Hepatozoon in the sequence analysis in the present study. A dog might be infected with more than one subspecies of Babesia or more than one species of Hepatozoon at the same time. In such a case, the results of subsequent sequence analysis would be more difficult to interpret, because the results of the direct sequencing of the PCR products could not be read accurately. A subspecies-specific PCR for Babesia canis and a species-specific PCR for Hepato-
would be required to evaluate the infection rate with more accuracy in those cases.

**Nucleotide sequence accession number.** The nucleotide sequences of the 18S rRNA genes of the following *Babesia* and *Hepatozoon* isolates detected from dogs in this study have been deposited in the GenBank database under the indicated accession numbers: *Babesia canis rossi* Sudan-44, GenBank accession no. DQ111760; *Babesia canis rossi* Sudan-55, GenBank accession no. DQ111761; *Babesia canis rossi* Sudan-69, GenBank accession no. DQ111762; *Babesia canis rossi* Sudan-74, GenBank accession no. DQ111763; and *Babesia canis rossi* Sudan-76, GenBank accession no. DQ111764; *Babesia canis*
vogeli Sudan-59, GenBank accession no. DQ111765; Babesia canis vogeli Sudan-78, GenBank accession no. DQ111766; Hepatozoon canis Sudan-8, GenBank accession no. DQ111751; Hepatozoon canis Sudan-12, GenBank accession no. DQ111752; Hepatozoon canis Sudan-13, GenBank accession no. DQ111753; Hepatozoon canis Sudan-26, GenBank accession no. DQ111754; Hepatozoon canis Sudan-33, GenBank accession no. DQ111755; Hepatozoon canis Sudan-68, GenBank accession no. DQ111756; Hepatozoon canis Sudan-69, GenBank accession no. DQ111757; and Hepatozoon canis Sudan-78, GenBank accession no. DQ111758.

We acknowledge the technical expertise of the DNA Core Facility of the Center for Gene Research, Yamaguchi University.

Our study was supported by grants from the Ministry of Education, Science, Sports and Culture of Japan, the Institut National de la Sante et de la Recherche Medicale, and the Japan Society for the Promotion of Science.

REFERENCES