First Report of Babesia gibsoni in Cats in China

Fangyuan Yin 1, Daoe Mu 1, Zhuoja Tian 1, Dong Li 1, Xiting Ma 1, Jinming Wang 2, Hong Yin 2,* and Facai Li 1,*

1 College of Veterinary Medicine, Southwest University, Chongqing 400715, China
2 State Key Laboratory of Veterinary Etiological Biology, Lanzhou Veterinary Research Institute, Chinese Academy of Agricultural Science, Lanzhou 730046, China
* Correspondence: yinhong@caas.cn (H.Y.); lifacai@swu.edu.cn (F.L.)

Abstract: As there are few studies of Babesia spp. infection in cats in China, or anywhere in the world, the aim of this study was to explore the epidemiologic features of babesiosis in pet cats in China. In total, 429 blood samples were randomly collected in four different geographical regions. The 18S rRNA gene fragment of Babesia spp. was amplified by nest polymerase chain reaction (PCR), and haplotype and phylogenetic analysis of Babesia were performed to analyze the relationship of this protozoa. The total positive rate of infection was 2.8%. BLAST analysis indicated that Babesia gibsoni was detected in 12 cats. Among these, 4.3%, 3.1%, 0.8% and 2.0% were from Chongqing, Fujian, Hubei and Shandong, respectively. Haplotype and phylogenetic analysis showed that there were nine haplotypes and no obvious genetic variation among B. gibsoni populations. This is the first report of B. gibsoni in cats in China. These findings will be helpful for understanding the epidemiology of Babesia spp. in China, and provide a foundation for developing effective preventative strategies.

Keywords: Babesia gibsoni; Babesia spp. in feline; pet cats; 18S rRNA; China

1. Introduction

Tick-borne diseases are recognized as important infectious diseases, posing a potential threat to the health of humans and animals. Tick-borne infections in companion animals have been increasing worldwide, which could be due to the distribution of vectors influenced by climate change, environmental and artificial factors [1] and increased detection capacity with the popularization of molecular biology. In China, there were 74 million dogs and 67 million cats as companion pets at the end of 2018 [2]. As potential reservoir hosts of tick-borne causative agents, domestic dogs and cats can transfer zoonotic diseases to humans [3,4], so the risk of feline and canine tick-borne pathogens has drawn attention from veterinary and public health research organizations.

Babesiosis, caused by the intracellular hemoprotozoa of the genus Babesia, is transmitted by ixodid ticks and has been widely described [5,6]. The severity of this disease ranges from mild infections to severe illness characterized by anorexia, fever, icterus, pallor, splenomegaly, hemolytic anemia and hemoglobinuria [7–9]. The species of Babesia are divided into the large types, including Babesia canis, Babesia rossi and Babesia vogeli and small types, including Babesia conradae, Babesia gibsoni and Babesia vulpes [10–13]. In China, B. canis, B. gibsoni and B. vogeli have been described in dogs and are endemic in the central,
southern and eastern regions [14–18]. Feline babesiosis has been reported sporadically in Europe and Asia, whereas it was found to be more common in South Africa [19]. Several Babesia species have been detected in domestic and stray cats, including B. canis, B. catti, B. felis, B. gibsoni, B. hongkongensis, B. lengai, B. leo, B. microti, B. presentii, B. vogeli and unidentified Babesia spp. [20–22]. In China, B. vogeli has been reported in cats in Shenzhen and B. hongkongensis was found in cats in Hong Kong and Hunan [22–24].

Information on the prevalence and distribution of feline babesiosis in China remains limited. Therefore, the aim of this study was to investigate the incidence of Babesia spp. in blood samples in domestic cats from southwestern, central and southeastern regions of China, and describe its genetic relationship according to the regions of collection.

2. Materials and Methods

2.1. Sample Collection and DNA Extraction

A total of 429 blood samples were randomly collected from domestic cats in pet clinics. These samples were from five cities, including 188 from Chongqing, 51 from Linyi, 64 from Quanzhou, 25 from Wuhan and 101 from Xiangyang, as seen in Figure 1. The age range of the cats were from two months to eight years. Samples were obtained from cats with no obvious clinical signs of Babesia infection and no ticks were found on the bodies of these pet cats. Peripheral blood samples were collected in EDTA vacutainers and genomic DNA samples were extracted from 250 µl thawed blood using the Blood DNA Mini Kit (Omega, Norcross, GA, USA) according to the manufacturer’s instructions. DNA samples were stored at −20 °C until use.

![Figure 1. Geographical distribution of sampling sites. Feline blood samples from three provinces (Fujian, Hubei and Shandong) and one municipality (Chongqing) in China.](image)

2.2. PCR Amplification and Sequencing

To identify the Babesia infection in cats, a nested PCR was employed to amplify a region of the 18S rRNA gene as previously described [16,18,25]. Primary amplification was conducted using Piro1-S: 5′-CTTGACGCTAGGTATTGGC-3′, Piro3-AS: 5′-CCTTCTTAAAGTGATAAGGTCC-3′ to amplify a gene fragment of 1379 bp, and sec-
ondary amplification was performed using Piro-A: 5′-ATTACCAATMCGACACVGGK-3′ and Piro-B: 5′-TTAAATACGAATGCCCCCAAC-3′ to amplify a gene fragment of 405 bp. The PCR reaction conditions were described previously [25]. All PCR products were analyzed on 1.5% agarose gels stained with GoldView II dyes (Solarbio, Beijing, China) and visualized under ultraviolet light. A sick dog was clinically diagnosed as babesiosis-positive by microscopic analysis and a positive PCR test for B. gibsoni. Genomic DNA extracted from the blood sample of the sick dog was used as a positive control and distilled water was used as negative control.

The positive amplicons were purified using a Hipure Gel Pure DNA Mini Kit (Magen, Guangzhou, China). The purified products were cloned into the pMD19-T vector (TaKaRa, Dalian, China), and then transformed into Escherichia coli Trans5α competent cells (TransGen, Beijing, China). Three positive clones were sequenced using universal M13 forward and reverse primers (PRISM3730XL, ABI).

2.3. Sequences Analysis

The obtained 18S rRNA sequences were analyzed using the NCBI BLASTN program (https://blast.ncbi.nlm.nih.gov, accessed on 27 January 2022 and 22 June 2022) and the sequences were deposited in GenBank under the accession numbers OM403679-OM403682 and ON810481-ON810488.

Multiple sequences were aligned using Clustal W within MEGA 11 software [26]. Nucleotide sequence analysis was performed by Genedoc program [27]. A haplotype network was drawn using the TCS network within PopArt software [28,29]. To evaluate the phylogenetic relationships, the sequences were compared with the registered sequences from different countries in the GenBank database. A phylogenetic tree was constructed using the neighbor-joining method based on the Tamura 3-parameter substitution model with gamma distributed (G) rates in MEGA 11, with bootstrap values of 1000 replicates [26]. A 50% cut-off value was performed for the consensus tree.

3. Results

3.1. Detection and Identification of Babesia spp.

The results showed that the total prevalence of Babesia spp. infection was 2.8% (12/429) of sample cats, shown in Table 1. Among these 12 positive samples, 4.3%, 3.1%, 4.0% and 2.0% were from Chongqing, Quanzhou, Wuhan and Linyi cities, respectively, but there were no positive samples found in Xiangyang city. All the positive pet cats were under one year of age. Blast analysis showed that the obtained sequences were 98.8% to 99.8% identical to that of B. gibsoni from dogs in China (KP666166), India (MN134517), Japan (AB478328) and the USA (DQ184507). Compared with the sequences from China, India, Japan and the USA, these results showed 11 substitutions at nucleotide sites 11, 13, 19, 83, 109, 163, 198, 250, 285, 289 and 360, as seen in Figure 2. All obtained 18S rRNA sequences showed 98.5% to 100% nucleotide identity with each other. Haplotype analysis indicated that nine haplotypes existed in B. gibsoni isolates in this study, as shown in Figure 3.

Table 1. Prevalence of Babesia gibsoni in cats in China.

<table>
<thead>
<tr>
<th>Locations</th>
<th>No. of Samples</th>
<th>No. of Positive Samples</th>
<th>Positive Rate (%, 95%CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Province/Municipality</td>
<td>City</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chongqing</td>
<td>Chongqing</td>
<td>188</td>
<td>8</td>
</tr>
<tr>
<td>Fujian</td>
<td>Quanzhou</td>
<td>64</td>
<td>2</td>
</tr>
<tr>
<td>Hubei</td>
<td>Wuhan</td>
<td>25</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Xiangyang</td>
<td>101</td>
<td>0</td>
</tr>
<tr>
<td>Shandong</td>
<td>Linyi</td>
<td>51</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>429</td>
<td>12</td>
</tr>
</tbody>
</table>
Table 1. Prevalence of Babesia gibsoni in cats in China.

<table>
<thead>
<tr>
<th>Locations, Province/Municipality</th>
<th>City</th>
<th>No. of Samples</th>
<th>No. of Positive Samples</th>
<th>Positive Rate (%, 95%CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chongqing</td>
<td>Chongqing</td>
<td>188</td>
<td>8</td>
<td>4.3 (95%CI: 1.85–8.21%)</td>
</tr>
<tr>
<td>Fujian</td>
<td>Quanzhou</td>
<td>64</td>
<td>2</td>
<td>3.1 (95%CI: 0.38–10.84%)</td>
</tr>
<tr>
<td>Hubei</td>
<td>Wuhan</td>
<td>25</td>
<td>1</td>
<td>4.0 (95%CI: 0.10–20.35%)</td>
</tr>
<tr>
<td></td>
<td>Xiangyang</td>
<td>101</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Shandong</td>
<td>Linyi</td>
<td>51</td>
<td>1</td>
<td>2.0 (95%CI: 0.05–10.45%)</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>429</td>
<td>12</td>
<td>2.8 (95%CI: 1.45–4.84%)</td>
</tr>
</tbody>
</table>

Figure 2. Multiple sequence alignments of B. gibsoni in cats in China. The sequences obtained from this study were compared with the related sequences deposited in GenBank, KP666166 (China), MN134517 (India), AB478328 (Japan) and DQ184507 (USA). The nucleotide substitutions occurred at 11 positions including 11, 13, 19, 83, 109, 163, 198, 250, 285, 289 and 360. Abbreviations: CQ (Chongqing), FJ (Fujian), HB (Hubei), LY (Linyi).

Figure 3. TCS haplotype network of B. gibsoni isolates in cats in China. The different coloured dots represent haplotypes from the different locations.
3.2. Phylogenetic Analysis of B. gibsoni Using 18S rRNA Sequences

A neighbor-joining (NJ) tree was constructed using the 18S rRNA sequences of 12 B. gibsoni isolates derived from cats, together with the data deposited in GenBank (see Figure 4). The results showed that no obvious sub-clusters were observed among B. gibsoni isolates from this study and those from other geographic regions including China, India, Japan and the USA. The NJ tree also indicated that there was no apparent genetic variation among the B. gibsoni isolates between dogs and cats. The other Babesia species such as B. felis, B. hongkongensis, B. leo, B. microti and B. vogeli formed separate clades with high bootstrap support (Figure 4).

![Phylogenetic tree](image)

**Figure 4.** Phylogenetic tree constructed using 18S rRNA sequences from Babesia spp. by neighbor-joining. The sequences obtained from this study were compared with the related sequences deposited in GenBank. The bootstrap values of >50% were displayed at each branch point. GenBank accession numbers, the isolate, countries and host were shown alongside species names. The sequence of *Plasmodium falciparum* (M19172) was used as outgroup. Representative isolates in this study were indicated by bold circles. Abbreviations: CQ (Chongqing), FJ (Fujian), HB (Hubei), LY (Linyi).
4. Discussion

For feline Babesia species, B. vogeli was found in three of 203 cats in China [20], and has been reported in Thailand, Portugal and Brazil [30–32]. In other studies, one cat was diagnosed with B. hongkongensis in Hong Kong and two cats were positive for B. hongkongensis in Hunan [23,24]. For the presence of B. gibsoni in cat, there was just one reported in St Kitts [21], and B. gibsoni was considered to be a species responsible for canine babesiosis in China, including Shanghai, Jiangsu, Shandong, Anhui, Zhejiang, Jiangxi, Fujian, Hubei and Shaanxi with positivity 0.72% to 64.2% [15,33,34].

In the present study, a small-scale survey was conducted in pet animals to investigate the epidemiology of babesiosis. BLAST analysis showed that the obtained 18S rRNA sequences shared high identity with the 18S rRNA of B. gibsoni, indicating that only B. gibsoni was found in cats and the total prevalence of B. gibsoni infection was 2.8%, indicating that the prevalence of B. gibsoni infection in cats was lower than in dogs in China. According to clinical records, the pet cats spent most of their time indoors and had limited chance to roam around outside, so were exposed to a low-risk environment with regard to active Haemaphysalis longicornis and Rhipicephalus sanguineus. All 12 positive cats were under one year of age, which was consistent with a previous study indicating young animals were susceptible to B. gibsoni infection [22]. This is the first report of molecular evidence for the existence of B. gibsoni in cats in China.

Nucleotide sequence analysis suggested that nucleotide variations were found within 18S rRNA sequences of B. gibsoni (Figure 2). Haplotype analysis demonstrated that genetic differences were observed among B. gibsoni sequences (Figure 3). Phylogenetic analysis displayed that all B. gibsoni 18S rRNA genes from cats belonged to a clade consisting of those from dogs in other parts of China, India, Japan and the USA (Figure 4). These data were in agreement with previous studies, showing a limited genetic relationship of B. gibsoni populations in Asia and the USA [35]. B. gibsoni has been detected in dogs from Fujian, Shandong and Hubei in the previous studies [15,33]. In this study, B. gibsoni was also found in cats from the same three regions. H. longicornis occurred in Hubei and Shandong and R. sanguineus was endemic in Fujian and Shandong [36,37]. Therefore, it is hypothesized that B. gibsoni might be circulating in dogs and cats in these three sampling sites. These results provided evidence of the occurrence of cross-species transmission in the different hosts, which could be related to the movement of humans carrying pets, the mobility of hosts with ticks and shared habitats between different hosts. No ticks were found on the bodies of these pet cats, and what causes Babesia infection in pets will be examined in further research. Possibilities include that the ticks had already dropped off the cats before they were taken to the clinic, and it can be inferred that cats could become positive from direct transmission such as fighting and blood transfusion according to the transmission routes of B. gibsoni [38,39].

5. Conclusions

B. gibsoni was found in a low proportion of asymptomatic cats in China for the first time, as nine haplotypes found among 12 isolates. Phylogenetic analysis indicated that there was no obvious genetic variation among B. gibsoni populations based on 18S rRNA sequences. These findings can provide greater insight into the distribution of Babesia and its genetic relationship in these four regions of China, and will be also useful for making effective control approaches to improve the health and welfare of companion animals.

Author Contributions: F.Y., H.Y. and F.L. conceived the project. D.L. and X.M. collected blood samples. F.Y., D.M., Z.T. and X.M. carried out laboratory work. F.Y. and J.W. performed the data analyses. F.Y. prepared the manuscript with the support from G.G. and F.L. All authors have read and agreed to the published version of the manuscript.
Funding: This study was supported by the National Natural Science Foundation of China (Grant No. 32102695), the State Key Laboratory of Veterinary Etiological Biology, Lanzhou Veterinary Research Institute, Chinese Academy of Agricultural Sciences (Grant No. SKLVEB2021KFKT008), Fundamental Research Funds for the Central Universities (Grant No. SWU-KT20214).

Institutional Review Board Statement: This study was approved by the Institutional Animal Care and Use Committee of Southwest University (permit number IACUC-20211125-01). All pet cats were handled in accordance with the Animal Ethics Procedures and Guidelines of the People’s Republic of China. All samples were collected under the permission of the owners of pet cats.

Informed Consent Statement: Not applicable.

Data Availability Statement: All data generated or analyzed during this study are included in this published article.

Acknowledgments: Thanks to the veterinary practitioners for assistance with sample collection.

Conflicts of Interest: The authors declare no conflict of interest.

References

13. Baneth, G.; Florin-Christensen, M.; Cardoso, L.; Schnittger, L. Reclassification of Theileria annae as Babesia vulpes sp. nov. Parasit. Vectors 2015, 8, 207. [CrossRef] [PubMed]
19. Pennthorn, B.L.; Oosthuizen, M.C. Babesia species of domestic cats: Molecular characterization has opened pandora’s box. Front. Vet. Sci. 2020, 7, 134. [CrossRef]


