

# Splenitis in 33 Dogs

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## Abstract

Splenitis is uncommonly reported in dogs. Herein, the authors describe its prevalence, clinical findings and outcomes, histologic patterns, and causes. Splenic samples of dogs diagnosed with splenitis between 2005 and 2013 were collected and stained with hematoxylin and eosin, Gram, green-Gram, Giemsa, periodic acid-Schiff, and Ziehl-Neelsen. Samples were processed for polymerase chain reaction (PCR) to detect bacteria, fungi, and protozoa (*Leishmania infantum*, *Hepatozoon canis*). Thirty-three of 660 splenic samples (5%) had splenitis. Clinical findings and outcomes were available in 19 dogs (58%); 49% had weakness, 33% had fever, and 84% survived. The most frequent inflammatory patterns included purulent splenitis (27%), pyogranulomatous splenitis (24%), and neutrophilic perisplenitis (15%). One dog had a putative diagnosis of primary splenitis; in 8 dogs, microorganisms were identified histologically or by PCR in the spleen without obvious comorbidities. Twenty-four dogs (73%) had concurrent diseases; a permissive role in the development of splenitis was suspected in 21 of these cases. Histologic examination identified the cause of splenitis in 10 dogs. Bacteria were identified by PCR in 23 cases, but the bacteria were confirmed histologically in only 6 of these. *Leishmania* was detected with PCR in 6 dogs. *Leishmania* was identified in 1 dog and *H. canis* in another histologically, but both were PCR negative. Fungi were identified in 8 spleens by PCR and in 1 by histology. This study suggests that splenitis is uncommon in dogs and is frequently associated with systemic diseases. Prognosis is favorable in most cases. Identification of bacteria, fungi, and protozoa in the spleens of affected dogs with PCR should be interpreted cautiously, because the findings are not confirmed histologically in many cases.

## Keywords

dog, spleen, PCR, histology, inflammation, splenitis, prognosis, *Rasamsonia argillacea*, *Pseudomonas*

The spleen is a secondary lymphoid organ as are lymph nodes and mucosa-associated lymphoid tissues. It is formed by the red and white pulp; the first harbors numerous macrophages and dendritic cells that are part of the reticuloendothelial system, whereas the latter contains B and T lymphocytes and dendritic cells. Both take part in the immune response and react to pathologic insults, ranging from infectious to neoplastic diseases.<sup>51</sup> Non-neoplastic diseases of the spleen are commonly described in dogs; on the basis of the current literature, their prevalence among all splenic diseases ranges from 35% to 70%.<sup>7,10,11,20,47</sup> Amyloidosis, congestion, hemorrhage, hematomas, infarction, necrosis, siderotic plaques, splenitis, thrombosis, torsions, and traumatic ruptures are included among non-neoplastic disorders.<sup>47</sup>

Splenitis is an inflammatory process of the splenic parenchyma that is uncommon in dogs. Survey studies of splenic diseases in this species have reported a prevalence of splenitis ranging from 0.9% to 8%.<sup>7,20</sup> Among its causes, splenitis was described in only single case reports associated with fungal,<sup>2,5,14,25,34,45,46,52</sup> protozoan,<sup>3,18,29,39</sup> or bacterial<sup>1,2,6,12,17,31,40,42,48</sup> infections.

The cases related to fungal infections invariably had poor prognosis. In these dogs, necropsy identified splenomegaly and

multiple foci of necrosis, while histology documented pyogranulomatous inflammation, multinucleated giant cells, and, in some cases, fungal hyphae. Fungi that have been identified in dogs with splenitis are *Monocillium indicum*,<sup>25</sup> *Scedosporium*

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*prolificans*,<sup>14</sup> *Scopulariopsis chartarum*,<sup>52</sup> *Aspergillus terreus*,<sup>34</sup> *Cryptococcus neoformans*,<sup>8</sup> *Candida albicans*,<sup>5</sup> *Ochroconis gallopavum*,<sup>46</sup> *Xylohypha bantiana*,<sup>43</sup> and *Acremonium* spp.<sup>45</sup>

The protozoa identified in dogs with splenitis include *Neospora caninum*,<sup>18</sup> *Hepatozoon canis*,<sup>3,16</sup> *Trypanosoma cruzi*,<sup>29</sup> and *Leishmania chagasi*.<sup>36,39,50</sup> *L. chagasi* and *Leishmania infantum*, responsible for leishmaniasis in the New World and Old World, respectively, are considered genomically indistinguishable and therefore synonymous.<sup>27</sup> Lesions of the spleen of dogs with leishmaniasis are characterized by thickening of trabecular regions, granulomatous reaction and hemorrhagic areas, atrophy of lymphoid follicles and marginal zone, abundant macrophages with amastigotes in the cytoplasm, and perisplenitis.<sup>36,39,50</sup>

Considering bacterial splenitis, dogs with *Staphylococcus* spp.,<sup>1</sup> *Mycobacterium avium* *Mycobacterium tuberculosis*,<sup>6,17,26,31</sup> *Listeria monocytogenes*,<sup>42</sup> *Bartonella henselae*, and *Bartonella vinsonii*,<sup>40</sup> *Clostridium* spp.,<sup>2</sup> *Bacillus anthracis*,<sup>28</sup> *Burkholderia pseudomallei*,<sup>48</sup> and multiple bacterial infection<sup>11</sup> have been described; in these cases, histologic lesions of the spleen are generally pyogranulomatous<sup>6,40</sup> or neutrophilic.<sup>2</sup> Splenic abscesses, likely due to bacterial infection, have been described in some dogs.<sup>1,10,12</sup> Interestingly, in one study, it was shown that bacteria were cultured from 35% of surgically excised spleens irrespective of the disease affecting the organ, and the most commonly identified bacteria include *Staphylococcus* spp., *Enterococcus* spp., and *Klebsiella pyogenes*.<sup>37</sup> Prognosis for bacterial and protozoan splenitis is generally better than that of fungal origin, although it may vary according to the causative microorganism and individual factors.

The aims of this study were to define the prevalence of splenitis in dogs, describe clinical findings and outcomes, characterize histologic patterns of splenic inflammation, and investigate possible causes.

## Materials and Methods

### Cases and Clinical Data

Splenic biopsies and case histories of dogs collected at necropsy or at surgery after splenectomy and partially or entirely submitted to the Department of Comparative Biomedicine and Food Sciences of the University of Padua between 2005 and 2013 with histologic diagnoses of splenitis were retrieved from the archives and included in the study. Because of the retrospective nature of the study and because most dogs were not admitted at authors' institutions, clinical data were often incomplete or entirely missing. Owners were therefore contacted to retrieve further information. In particular, a telephone-based questionnaire was used, with the following questions: (1) What clinical signs did the dog present at admission? (2) Was the dog affected by other diseases? (3) what was the final diagnosis, other than splenitis? (4) what was the treatment of the dog after splenectomy? and (5) How long did the dog survive following surgery?

### Histology

From each paraffin-embedded splenic sample previously fixed in 10% neutral-buffered formalin, 6 consecutive sections of 4 µm were obtained and mounted on slides. The first section was stained with hematoxylin and eosin, and the others were stained with Giemsa, and/or periodic acid–Schiff, Ziehl–Neelsen, Gram, and green-Gram (see Supplemental Materials). Findings were classified according to the type and localization of inflammation (Supplemental Table 1). Tissue sections were also examined to identify bacteria, protozoa, or fungi. All slides were assessed by 2 pathologists (S.F., M.C.), and any difference in diagnosis was resolved by consensus.

### Molecular Analysis

Total deoxyribonucleic acid (DNA) from splenic samples was purified (see Supplemental Materials) from formalin-fixed paraffin-embedded splenic tissue.

Polymerase chain reaction (PCR) was used to assess the presence of microorganism in the spleen. Detection of bacterial and protozoan infections was achieved as previously described.<sup>21,22,32</sup> The protocol for fungal PCRs was as follows: 15 minutes of denaturation at 95°C, 40 cycles at 94°C for 1 minute, 51°C for 1 minute, and 72°C for 1 minute, and a 10-minute final extension at 72°C. Amplified ribosomal DNA restriction analysis was used to amplify the 16 S ribosomal ribonucleic acid (rRNA) of bacteria. Identification of bacteria was performed on an approximately 310-bp fragment of the 16 S rRNA gene using primers 16SUNI-L and 16SRNAV-S, and sequencing was performed according to a previously established protocol.<sup>21</sup>

Fungal internal transcribed spacers (ITSs), highly conserved RNA sequences located between 2 areas of rRNA, were amplified to detect mycotic agents.<sup>15</sup> In addition, identification of fungi was performed on an approximately 330-bp fragment of the ITS region 2 using primers ITS3 and ITS4.<sup>35</sup>

For protozoa, the analysis was performed to identify *L. infantum* and *Hepatozoon* spp. The target sequence for *Leishmania* was LT1 of the conserved region of the circular kinetoplast DNA; the primers used were RV1 (forward, 5'-CTTTTCTGGTCCCGCGGGTAGG-3') and RV2 (reverse, 5'-CCACCTGGCCTATTTTACACCA-3'), with a reported sensitivity of 100% in detecting *Leishmania* infections.<sup>22</sup> To detect the presence of *Hepatozoon* spp., a partial sequence of 18 S rRNA, common to different species of *Hepatozoon*, was amplified. The primers used were HepF (forward, 5'-ATACATGAGCAAAATCTAAC-3') and HepR (reverse, 5'-CTTATTCCATGCTGCAG-3').<sup>32</sup> All PCR products were submitted to electrophoresis in an 0.8% agarose gel and stained with ethidium bromide; an ultraviolet transilluminator was used to visualize the different bands.

### Immunohistochemistry

A monoclonal mouse anti-KMP11 antibody (dilution 1:300; Abcam, Cambridge, UK) was used to confirm the presence

of *L. infantum* in all PCR-positive cases. Sections were incubated with the antibody for 24 minutes at room temperature. A canine splenic biopsy specimen previously proved to have *Leishmania* spp. amastigotes in macrophages served as a positive control. Immunohistochemistry was performed with an automatic immunostainer (Ventana Benchmark XT; Roche Diagnostics, Monza, Italy) using a secondary antibody with a horseradish peroxidase-conjugated polymer (ultraViews Universal DAB; Ventana Medical Systems, Tucson, AZ).

## Results

### Clinical Findings

Thirty-three dogs were included in the study, with a median age of 8.5 years (range, 2–15 years). Seventeen dogs were intact males (51%), 7 were intact females (21%), 6 were spayed females (18%), and 2 were neutered males (6%); sex was unknown in 1 dog. Ten dogs were mixed breed dogs (30%) and 23 were pure breeds (70%), including 6 German Shepherds (18%); 2 (6%) each Great Dane, Italian Hound, Boxer, Rottweiler, and Labrador Retriever; and 1 (3.0%) each English Bulldog, English Setter, Dachsbrake, Griffon, Airedale Terrier, Doberman, and Doberman Pinscher.

According to the available clinical data and questionnaires, presenting signs at the time of splenectomy or necropsy were known for 28 dogs. Severe and acute weakness was observed in 16 dogs (48%), hyperthermia in 11 (33%), weight loss in 6 (18%), and painful abdomen and vomiting in 4 (12%). Twenty-five animals underwent abdominal ultrasound that identified splenic masses or nodules in 14 dogs (56%); peritoneal effusions in 8 (32%), consistent with purulent peritoneal exudate in 2; altered echotexture of the spleen or nonsplenic abdominal masses in 4 each (16%); pyometra or endometritis, splenic torsion, or testicular nodules in 3 dogs each (12%); and portal vein and splenic vein thrombosis, prostatic nodules, hepatomegaly, and hypoechoic hepatic nodules in 1 dog each (4%). Twelve dogs had more than 1 ultrasonographic alteration. In the remaining dogs, abdominal ultrasound was not performed, because physical examination allowed diagnosis of gastric dilation-volvulus or abdominal masses were palpated.

Among the 33 dogs, 24 (73%) were diagnosed with additional non-splenic conditions, including 8 (24%) with peritoneal effusion, 6 (18%) with neoplastic diseases (1 dog each with peritoneal hemangiosarcoma, testicular seminoma, fibrohistiocytic nodule, hepatic cystadenoma with concurrent testicular seminoma, metastatic mammary carcinoma, and hepatocellular carcinoma), 5 (15%) with gastric dilatation-volvulus, 3 (9%) with pyometra or endometritis, 3 (9%) with splenic torsion, 2 (6%) with granulomatous hepatitis (in 1 case due to leishmaniasis), and 1 (3%) each with idiopathic hepatic lobar torsion, gastric ulcer, systemic fungal infection, immune-mediated hemolytic anemia, recent trauma, hemorrhagic gastroenteritis, cholangiohepatitis, and portal vein thrombosis. Eight dogs were concurrently affected by more

diseases, and 9 dogs (27%) did not show any disease other than splenitis.

Information on outcomes was available for 19 dogs. The dog with systemic mycosis died a few days after admission. The remaining 18 dogs underwent surgery and were then treated with different antibiotics; 16 (89%) survived to discharge, and 2 (11%) died during hospitalization because of surgical complications at 7 and 40 days after surgery, respectively. Of the 16 surviving dogs, 6 (38%) are still alive at the time of writing, and 10 (62%) died of causes unrelated to splenitis, with a median survival of 2.5 years (range 1–3.5 years).

### Histologic Findings

The 33 cases of splenitis were classified histologically (Supplemental Table 1). In particular, 9 dogs (27%) had purulent splenitis (Figure 1), 8 (24%) had pyogranulomatous splenitis (Figure 2), 5 (15%) had neutrophilic perisplenitis (Figure 3), 4 (12%) had neutrophilic perisplenitis and splenitis, 3 (9%) had granulomatous splenitis (Figure 4), 2 (6%) had neutrophilic splenitis (Figure 5), and 1 dog each (3%) had fibrinous-suppurative perisplenitis and splenitis, and fibrinous-suppurative perisplenitis (Figure 6). In 1 dog affected by purulent splenitis and in 1 affected by pyogranulomatous splenitis, splenic abscesses were identified.

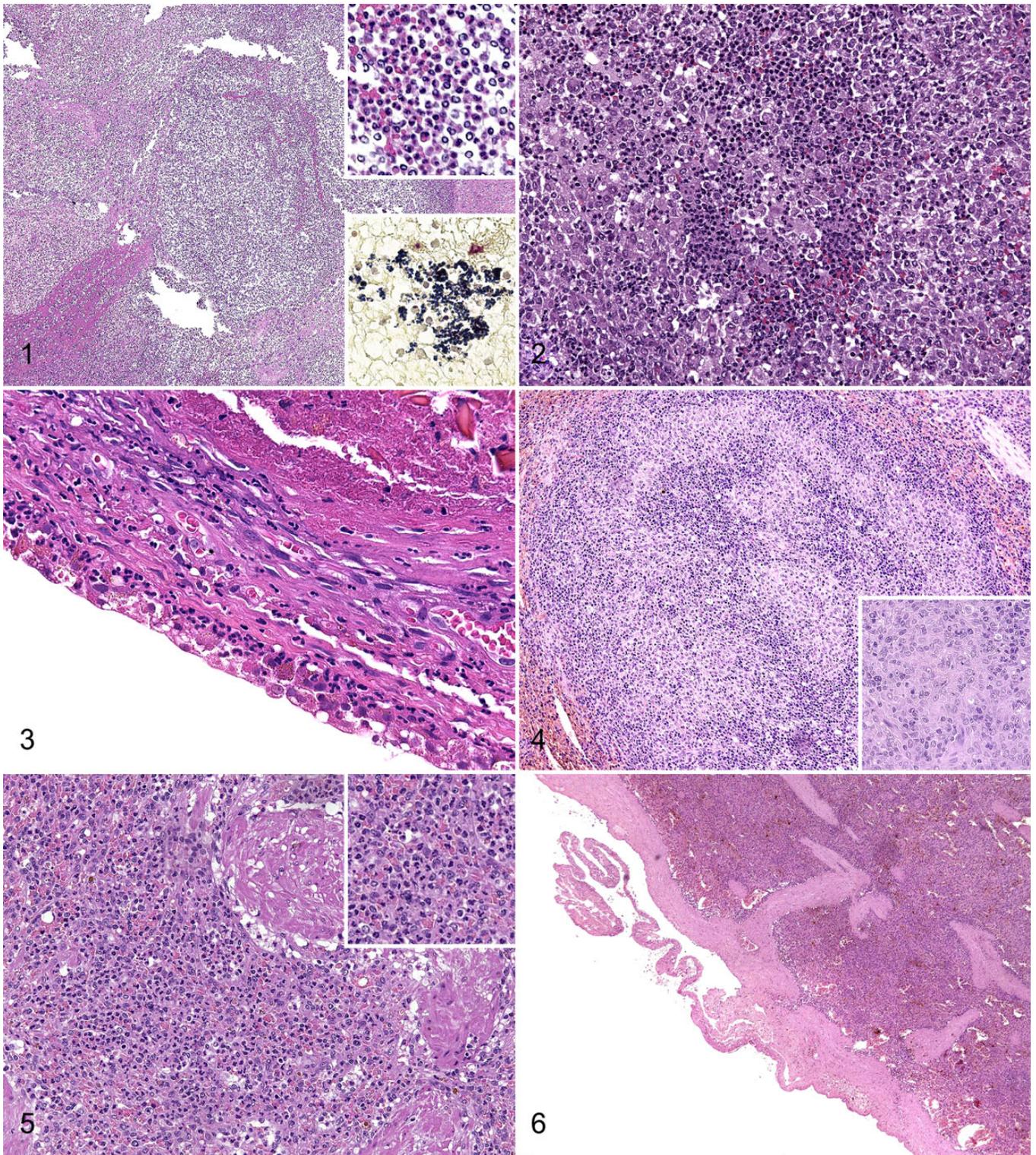
Of the 9 dogs with purulent splenitis, 6 yielded positive results with Gram staining (67%) (Figure 1); in particular, Gram-positive cocci were identified in 3 dogs and Gram-negative cocci, concurrent Gram-positive cocci and bacilli, and concurrent Gram-negative and positive cocci in 1 dog each.

Among the 8 cases of pyogranulomatous splenitis, meronts of *Hepatozoon canis* were identified in 1 dog (Figure 7) and intra- and extracellular material compatible with exogenous material in another dog (Figure 8). Among the 3 cases of granulomatous splenitis, amastigotes of *L. infantum* (Figure 9) and fungal hyphae (Figure 10) were identified in 1 dog each. Twenty-four splenic samples yielded negative results for infectious agents on the basis of microscopic examination.

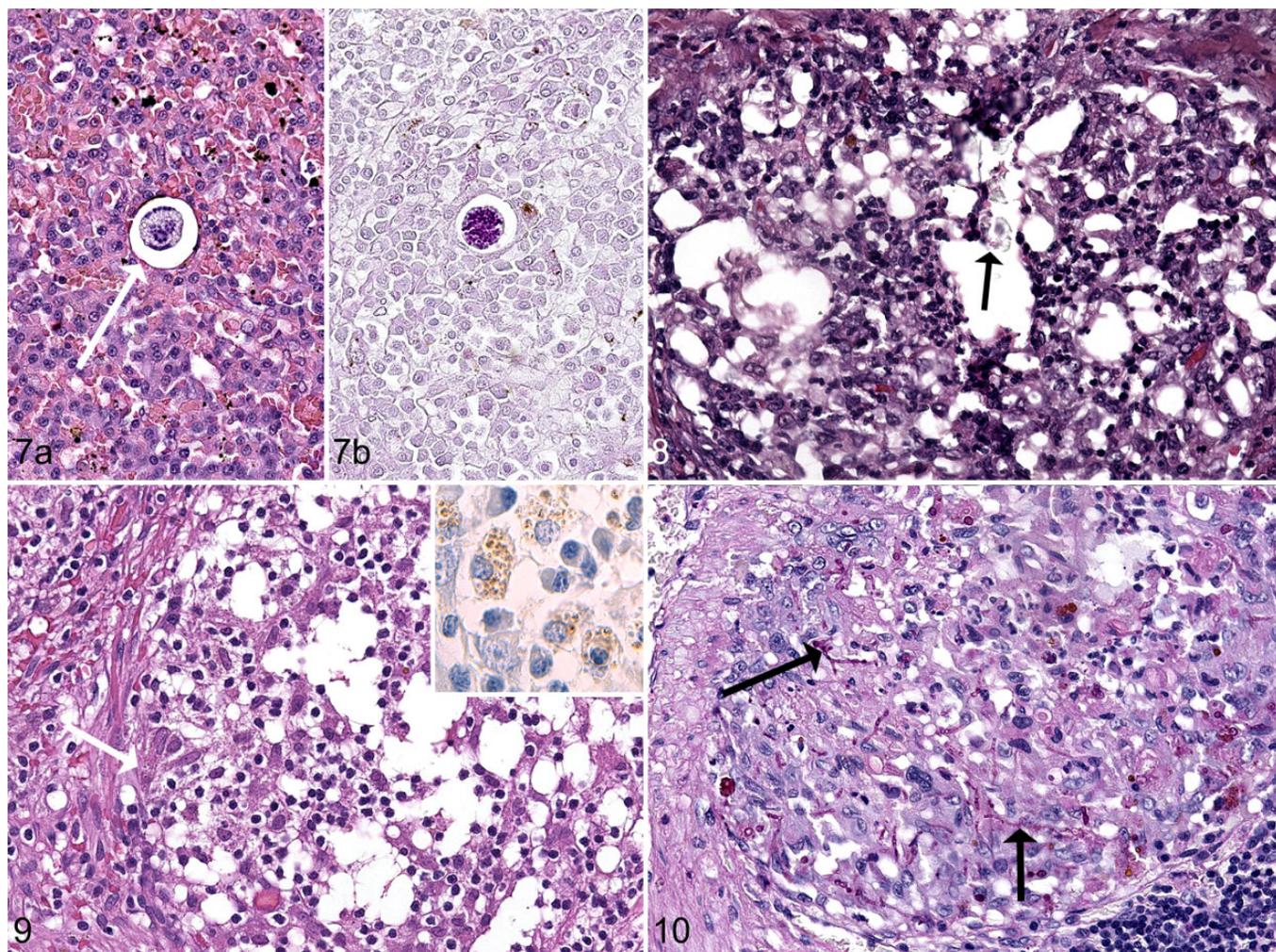
In total, 11 dogs presented histologic signs of altered splenic circulation consistent with splenic hemorrhage, splenic hematomas, splenic vein thrombosis, and splenic torsion. In particular, these conditions affected 4 dogs with neutrophilic perisplenitis and splenitis, 3 dogs with neutrophilic perisplenitis, and 1 dog each with fibrinous-suppurative perisplenitis and splenitis, granulomatous splenitis, fibrinous-suppurative perisplenitis, and pyogranulomatous splenitis.

### PCR

Bacterial pathogens were identified by PCR in 23 dogs (Supplemental Table 2). *Pseudomonas* spp. DNA was identified in 19 dogs, *Propionibacterium* spp. and *Clostridium haemolyticum* in 1 dog each, and mixed bacterial populations in 2 dogs. Among these 23 dogs, histologic diagnoses were neutrophilic or purulent-suppurative perisplenitis and splenitis in 12 dogs



**Figures 1–6.** Spleen, dog; Hematoxylin and eosin. **Figure 1.** Purulent splenitis. Presence of a purulent infiltrate. Upper inset: higher magnification of the infiltrate shows degenerated neutrophils and macrophages. Lower inset: blue-stained coccoid bacteria (Gram stain). **Figure 2.** Pyogranulomatous splenitis. A granuloma with macrophages and neutrophils. **Figure 3.** Neutrophilic perisplenitis. The capsule is infiltrated by neutrophils, and the mesothelium is reactive and hyperplastic. **Figure 4.** Granulomatous splenitis. Nodular aggregate of macrophages, lymphocytes, and plasma cells. Inset: higher magnification. **Figure 5.** Neutrophilic splenitis. Numerous nondegenerated, nonlytic neutrophils invade the splenic parenchyma. Inset: higher magnification. **Figure 6.** Fibrinous perisplenitis. Organized fibrin as pseudomembranous deposit on the capsular surface.



**Figures 7–10.** Spleen, dog. **Figure 7a.** *Hepatozoon canis*. A round meront (arrow) in the splenic parenchyma with “wheel spoke” arrangement of the merozoites. Hematoxylin and eosin (HE). **Figure 7b.** The merozoites stain strongly, and the capsule is negative. Periodic–acid Schiff (PAS). **Figure 8.** Crystalloid 3-dimensional acellular material (arrow) in the center of a pyogranuloma. **Figure 9.** Leishmaniasis. A granuloma composed of macrophages, lymphocytes and plasma cells with very small intracytoplasmic vacuoles containing amastigotes (arrow). HE. Inset: Immunolabeling of intracytoplasmic amastigotes in macrophages. Immunohistochemistry for KMPII. **Figure 10.** A granuloma containing numerous branching fungal hyphae (arrows). PAS.

(52%), granulomatous or pyogranulomatous splenitis in 9 dogs (39%), and fibrinous-suppurative inflammation in 2 dogs (9%).

On the basis of histologic findings, bacterial infection was confirmed in only 3 of these 23 dogs: in particular, 1 Great Dane affected by gastric dilation-volvulus had mixed bacterial infection identified by PCR analysis, and histology identified Gram-positive cocci; 1 Griffon with purulent peritoneal exudate and free abdominal gas had *C. haemolyticum* identified by PCR analysis, while histology identified cocci; and 1 Doberman Pinscher affected by endometritis had *Pseudomonas* spp. infection identified by PCR analysis, and histology identified both Gram-positive and Gram-negative cocci.

Of the 19 *Pseudomonas* spp. PCR-positive dogs, 8 had concurrent infections on the basis of PCR analysis or histology: 4 dogs with *L. infantum* and 4 with fungal infection (*Cryptococcus* spp. in 2 dogs, *Cladosporium* spp. and *Rasamsonia argillacea* in 1 dog each). One of the 2 dogs with a mixed DNA

bacterial population was positive for *Exophiala xenobiotica* by PCR. Other fungi identified by PCR in dogs with concurrent bacterial infection were *Truncatella angustata* and *Bipolaris cynodontis* (1 dog each).

Overall, fungal DNA was amplified in 8 dogs (24%); in addition to the 7 above described, the DNA of a not previously cultured fungus was identified in a dog. The corresponding histologic diagnoses of these 8 spleens were consistent with purulent splenitis in 4, granulomatous or pyogranulomatous splenitis in 3, and neutrophilic perisplenitis in 1.

Six dogs (18%) were positive for *L. infantum* DNA; 4 presented concurrent infections, including *Pseudomonas* spp. in 3 dogs and *Cladosporium* spp. in 1 on the basis of PCR, and histologically visible Gram-positive cocci in 1 dog. The histologic diagnoses suggested neutrophilic perisplenitis in 2 dogs and neutrophilic perisplenitis and splenitis, purulent splenitis, fibrino-suppurative, and pyogranulomatous splenitis in 1 dog

each. None of these dogs was positive by immunohistochemistry for *L. infantum* infection, and it was not possible to identify *L. infantum* amastigotes histologically. None of the dogs yielded positive results for *Hepatozoon* spp. using PCR.

## Discussion

To our knowledge, this is the first comprehensive study of splenitis in dogs. In the present series, 33 dogs had histologic diagnoses of splenitis, representing 5% of all submitted spleens. This prevalence is similar to that previously described by other investigators and confirms that splenitis is uncommon in dogs.<sup>7,20</sup> Clinical and diagnostic findings of splenitis are unspecific or related to the associated disease, and therefore, its diagnosis relies on histology.

Only 1 dog with splenitis of the present series had no concurrent systemic disease and yielded negative results in all tests. Hence, the dog had a tentative diagnosis of primary splenitis. In 8 other dogs, although no obvious systemic disease was present, PCR and histology identified bacterial, fungal, or protozoan infection of the spleen. In these dogs, PCR identified *Pseudomonas* spp., an unknown fungus, *Cladosporium* spp., or *L. infantum*, and histology allowed observation of meronts of *H. canis*. The actual role of the above microorganisms in the pathogenesis of splenitis remains unclear because systemic involvement was not identified. Thus, it cannot be excluded that in some the microorganisms merely represented passive bystanders or contaminant, rather than the cause of splenitis.

Concurrent diseases were very frequent, present in 24 cases (73%). For most, an explanation for splenitis was deemed possible. Six dogs had neoplastic diseases that might be considered to play a causative role in the development of splenitis. For instance, hemangiosarcoma and mammary adenocarcinoma have been shown to predispose to thrombosis and to alter vascular anatomy, possibly favoring bacterial engraftment.<sup>23</sup> In the present series, 2 dogs had these tumors, and both had vascular splenic lesions detected together with splenitis. Two other dogs had liver neoplasia; hepatic tumors have been sometimes associated with liver abscesses in dogs, likely because of increased tissue susceptibility to bacterial growth, which in turn might cause bacteremia and subsequent splenitis.<sup>44</sup> Five dogs presented gastric dilation-volvulus, and all had splenitis along with splenic vascular abnormalities. We hypothesize that in these cases, as gastric dilatation-volvulus develops, normal splenic vascularity and blood supply is progressively compromised, thus generating splenic inflammation. In addition, bacterial translocation from the gut, which is observed in up to 43% of cases with gastric dilatation-volvulus,<sup>53</sup> might have had a primary role in the establishment of splenitis. In addition, splenic inflammation was likely associated with bacterial translocation in the 6 dogs affected by pyometra, endometritis, hemorrhagic gastroenteritis, gastric ulcer, purulent peritoneal effusion, and hepatic lobar torsion. *Propionibacterium* spp. DNA was amplified in 1 dog affected by pyometra; this bacterium has been previously associated with pyometra in a woman and was shown to translocate into the bloodstream in healthy

dogs undergoing ovariohysterectomy.<sup>9,55</sup> It is remarkable that the blood reaching the spleen originates only from the arterial supply of the systemic circulation (ie, splenic artery), and, differently from the liver, no venous blood from the gastrointestinal tract flows directly through the organ in dogs; hence, if pathogens translocate from the gut, to reach the spleen and cause splenitis, they have to pass the liver, lungs, and heart and eventually reach the systemic circulation.<sup>4</sup>

One dog presented laboratory signs compatible with intravascular hemolysis. This dog had splenic torsion and was PCR positive for *L. infantum*; both conditions might have triggered splenitis because of altered vascularity and blood supply or activation of the reticuloendothelial system and likely caused anemia.<sup>33,41</sup> Five other dogs had granulomatous hepatitis with *L. infantum* amastigotes or *Pseudomonas* spp., exogenous material, systemic *R. argillacea*, and abdominal trauma; all of these conditions might have led to splenitis. A clear association between the concurrent disease and splenitis was not evident in only 3 dogs.

The potential cause of splenitis was identified histologically in 10 dogs. Specifically, in 4 cases with pyogranulomatous or granulomatous splenitis, exogenous material, fungal hyphae, *H. canis*, and *L. infantum* were identified. It is interesting to note that of the latter 3, PCR yielded *R. argillacea* in the dog affected by systemic mycosis, whereas in the other 2 it did not amplify *H. canis* or *L. infantum* DNA. Searching for the 2 protozoa failed, probably because of the paucity of microorganisms in the sample. In 6 dogs with purulent splenitis, bacteria were histologically visible. Of these, only 3 had bacterial DNA amplified by PCR, including 1 each with *Pseudomonas* spp., *C. haemolyticum*, and a mixed population. In the remaining 23 dogs, showing a variety of histologic patterns, no pathogens were identified histologically within the splenic parenchyma. Therefore, on the basis of these findings, histology is able to identify the cause of splenitis in only about one third of cases.

Conversely, PCR amplified bacterial DNA in 23 dogs, but bacteria were observed by histology in only 3 cases, as already mentioned. It is therefore possible that PCR performed on paraffin-embedded splenic samples leads to various positive results because of its elevated sensitivity. However, some of the positive results might have been due to contamination of samples with environmental bacteria or to the presence of DNA fragments within macrophages and other cells of the spleen. The fact that 3 dogs had splenic bacteria on the basis of histology, but not PCR, indicates that false-negative results can occur with the latter. It is possible that DNA damage caused by formalin fixation and paraffin embedding of samples also reduced the sensitivity of the assay.

With regard to mycosis, in 8 dogs, fungal DNA was found by PCR, but the presence of hyphae was confirmed by histology in only 1 case; the large majority (ie, 7 of 8) presented neutrophilic or pyogranulomatous splenitis. The explanation for false-positive or false-negative PCR results for fungal infection is likely similar to those mentioned for bacteria. Concerning *R. argillacea*, it is worth noting that this fungus is

considered an emerging pathogen in humans, causing chronic granulomatous disease and cystic fibrosis.<sup>24,49</sup> *R. argillacea* has been reported in only 2 dogs to date.<sup>13,38</sup> Other fungi identified in the present series were *B. cynodontis*, *Cladosporium* spp., *Cryptococcus* spp., *E. xenobiotica*, *T. angustata*, and an uncharacterized fungus. Among those that have never been described in dogs, *B. cynodontis* is a dematiaceous hyphomycete widely distributed in soil and normally associated with plant infection. It was recently associated with clinical disease in humans.<sup>30</sup> *E. xenobiotica* is an opportunistic fungus responsible for phaeohyphomycosis, in particular in immunocompromised humans.<sup>56</sup> *T. angustata* is a coelomycetous fungus, recently reported to cause subcutaneous infection in an immune-competent humans.<sup>19</sup> Because none has been reported in dogs, it cannot be excluded that they resulted from contamination of samples.

In relation to protozoa and PCR, 6 dogs yielded amplification of *L. infantum* DNA, and histologic diagnosis was neutrophilic splenitis and perisplenitis in 3 cases and fibrinosuppurative perisplenitis and splenitis, pyogranulomatous splenitis, and purulent splenitis with visible bacteria in 1 dog each. Except for the last case, similar histologic findings have been described in previous studies.<sup>34,37,48</sup> It is noteworthy that all PCR-positive dogs had negative results with immunohistochemistry. It is thus possible that some splenic macrophages had phagocytosed DNA fragments, but that intact amastigotes were not detectable. The amplification methods used with PCR allow positive results with very small amounts of DNA, while this is not achievable by means of immunohistochemistry. In a prior study of canine skin biopsies, PCR testing for leishmaniasis yielded sensitivity of 82.8%, whereas the sensitivity of immunohistochemistry was 62.1%.<sup>54</sup> None of the dogs in the present study were *H. canis* positive with PCR. The single dog with *H. canis* on histology did not display obvious clinical signs, perhaps because of the low parasitic burden.

In 19 dogs, it was possible to collect data on outcomes. Of these, 84% survived surgery and 37% are alive at the time of writing. The median survival of dogs that were followed until death was 2.5 years (range, 1–3.5 years); in these dogs, deaths were unrelated to the previous disease. The prognosis for dogs affected by splenitis can therefore be considered good.

There were some limitations to the present study that need to be mentioned. Because of the retrospective nature of the investigation and the fact the cases came from different institutions, information gathered from available medical records were often incomplete. In addition, samples were retrieved from archives, and prior contamination cannot be excluded.

## Conclusion

Splenitis is an uncommon disease in dogs; clinical signs are vague, and concurrent diseases that might predispose to splenic inflammation are generally present. Prognosis is favorable in the majority of cases. Identification of bacteria, fungi, and protozoa in the spleens of dogs with splenitis should be interpreted cautiously if PCR is used, because histology does not

provide supportive evidence of infection in many cases. Furthermore, the histologic classification used in the present study is expected to be helpful for future investigations, either for clinicians or pathologists.

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## References

1. Abdellatif A, Günther C, Pepler C, Kramer M. A rare case of splenic abscess with septic peritonitis in a German shepherd dog. *BMC Vet Res*. 2014;**10**:201.
2. Ballegeer EA, Forrest LJ, Dickinson RM, Schutten MM, Delaney FA, Young KM. Correlation of ultrasonographic appearance of lesions and cytologic and histologic diagnoses in splenic aspirates from dogs and cats: 32 cases (2002–2005). *J Am Vet Med Assoc*. 2007;**230**(5):690–696.
3. Baneth G, Weigler B. Retrospective case-control study of hepatozoonosis in dogs in Israel. *J Vet Intern Med*. 1997;**11**(6):365–370.
4. Bezuidenhout AJ. The lymphatic system. In: Evans HE, de Lahunta A, eds. *Miller's Anatomy of the Dog*. 4th ed. St. Louis, MO: Elsevier Saunders; 2013: 535–559.
5. Brown MR, Thompson CA, Mohamed FM. Systemic candidiasis in an apparently immunocompetent dog. *J Vet Diagn Invest*. 2005;**17**(3):272–276.
6. Campora L, Corazza M, Zullino C, Ebani VV, Abramo F. Mycobacterium avium subspecies hominissuis disseminated infection in a Basset Hound dog. *J Vet Diagn Invest*. 2011;**23**(5):1083–1087.
7. Christensen N, Canfield P, Martin P, Krockenberger M, Spielman D, Bosward K. Cytopathological and histopathological diagnosis of canine splenic disorders. *Aust Vet J*. 2009;**87**(5):175–181.
8. Collett MG, Doyle AS, Reyers F, Kruse T, Fabian B. Fatal disseminated cryptococcosis and concurrent ehrlichiosis in a dog. *J S Afr Vet Assoc*. 1987;**58**(4): 197–202.
9. Dahlinger J, Marks SL, Hirsh DC. Prevalence and identity of translocating bacteria in healthy dogs. *J Vet Intern Med*. 1997;**11**(6):319–322.
10. Day MJ, Lucke VM, Pearson H. A review of pathological diagnoses made from 87 canine splenic biopsies. *J Small Anim Pract*. 1995;**36**(10):426–433.
11. Eberle N, von Babo V, Nolte I, Baumgärtner W, Betz D. Splenic masses in dogs. Part 1: epidemiologic, clinical characteristics as well as histopathologic diagnosis in 249 cases (2000–2011). *Tierarztl Prax Ausg K Kleintiere Heimtiere*. 2012;**40**(4):250–260.
12. Ginel PJ, Lucena R, Arola J, Martin MP, Mozos E. Diffuse splenomegaly caused by splenic abscessation in a dog. *Vet Rec*. 2001;**149**(11):327–329.
13. Grant DC, Sutton DA, Sandberg CA, et al. Disseminated *Geosmithia argillacea* infection in a German Shepherd dog. *Med Mycol*. 2009;**47**(2):221–226.
14. Haynes SM, Hodge PJ, Tyrrell D, Abraham LA. Disseminated *Scedosporium prolificans* infection in a German Shepherd dog. *Aust Vet J*. 2012;**90**(1):34–38.
15. Hendolin PH, Paulin L, Koukila-Kähkölä P, et al. Panfungal PCR and multiplex liquid hybridization for detection of fungi in tissue specimens. *J Clin Microbiol*. 2000;**38**(11):4186–4192.
16. Hervás J, Carrasco L, Gómez-Villamandos JC, Méndez A, Sierra MA. Acute fatal hepatozoonosis in a puppy: histopathological and ultrastructural study. *Vet Rec*. 1995;**137**(20):518–519.
17. Horn B, Forshaw D, Cousins D, Irwin PJ. Disseminated *Mycobacterium avium* infection in a dog with chronic diarrhoea. *Aust Vet J*. 2000;**78**(5):320–325.

18. Hoskins JD, Bunge MM, Dubey JP, Duncan DE. Disseminated infection with *Neospora caninum* in a ten-year-old dog. *Cornell Vet*. 1991;**81**(3):329–334.
19. Jagielski T, Žak I, Tyrak J, Bryk A. First probable case of subcutaneous infection due to *Truncatella angustata*: a new fungal pathogen of humans? *J Clin Microbiol*. 2015;**53**(6):1961–1964.
20. Johnson KA, Powers BE, Withrow SJ, Sheetz MJ, Curtis CR, Wrigley RH. Splenomegaly in dogs. Predictors of neoplasia and survival after splenectomy. *J Vet Intern Med*. 1989;**3**(3):160–166.
21. Kuhnert P, Frey J, Lang NP, Mayfield L. Phylogenetic analysis of *Prevotella nigrescens*, *Prevotella intermedia* and *Porphyromonas gingivalis* clinical strains reveals a clear species clustering. *Int J Syst Evol Microbiol*. 2002;**52**(Pt 4):1391–1395.
22. Lachaud L, Marchegui-Hammami S, Chabbert E, Dereure J, Dedet JP, Bastien P. Comparison of six PCR methods using peripheral blood for detection of canine visceral leishmaniasis. *J Clin Microbiol*. 2002;**40**(1):210–215.
23. Laurenson MP, Hopper K, Herrera MA, Johnson EG. Concurrent diseases and conditions in dogs with splenic vein thrombosis. *J Vet Intern Med*. 2010;**24**(6):1298–1304.
24. Machouart M, Garcia-Hermoso D, Rivier A, et al. Emergence of disseminated infections due to *Geosmithia argillacea* in patients with chronic granulomatous disease receiving long-term azole antifungal prophylaxis. *J Clin Microbiol*. 2011;**49**(4):1681–1683.
25. Mackie JT, Padhye AA, Sutherland RJ, Lamb WA, Davis S. Granulomatous lymphadenitis and splenitis associated with *Monocillium indicum* infection in a dog. *J Vet Diagn Invest*. 2004;**16**(3):248–250.
26. Martinho AP, Franco MM, Ribeiro MG, et al. Disseminated *Mycobacterium tuberculosis* infection in a dog. *Am J Trop Med Hyg*. 2013;**88**(3):596–600.
27. Mauricio IL, Howard MK, Stothard JR, Miles MA. Genomic diversity in the *Leishmania donovani* complex. *Parassitology*. 1999;**119**(3):237–246.
28. McGee ED, Fritz DL, Ezzell JW, Newcomb HL, Brown RJ, Jaax NK. Anthrax in a dog. *Vet Pathol*. 1994;**31**(4):471–473.
29. Nabity MB, Barnhart K, Logan KS, et al. An atypical case of *Trypanosoma cruzi* infection in a young English Mastiff. *Vet Parasitol*. 2006;**140**(3–4):356–361.
30. Nath R, Barua S, Barman J, Swargiary P, Borgohain M, Saikia L. Subcutaneous mycosis due to *Cladosporium cladosporioides* and *Bipolaris cynodontis* from Assam, North-East India and review of published literature. *Mycopathologia*. 2015;**180**(5–6):379–387.
31. O'Toole D, Tharp S, Thomsen BV, Tan E, Payeur JB. Fatal mycobacteriosis with hepatosplenomegaly in a young dog due to *Mycobacterium avium*. *J Vet Diagn Invest*. 2005;**17**(2):200–204.
32. Otranto D, Dantas-Torres F, Weigl S, et al. Diagnosis of *Hepatozoon canis* in young dogs by cytology and PCR. *Parasit Vectors*. 2011;**4**(1):55.
33. Paltrinieri S, Solano-Gallego L, Fondati A, et al. Guidelines for diagnosis and clinical classification of leishmaniasis in dogs. *J Am Vet Med Assoc*. 2010;**236**(11):1184–1191.
34. Pastor J, Pumarola M, Cuenca R, Lavin S. Systemic aspergillosis in a dog. *Vet Rec*. 1993;**132**(16):412–413.
35. Rampazzo A, Kuhnert P, Howard J, Bornand V. *Hormographiella aspergillata* keratomycosis in a dog. *Vet Ophthalmol*. 2009;**12**(1):43–47.
36. Reis AB, Teixeira-Carvalho A, Giunchetti RC, et al. Cellular immunophenotypic profile in the splenic compartment during canine visceral leishmaniasis. *Vet Immunol Immunopathol*. 2014;**157**(3–4):190–196.
37. Richardson EF, Brown NO. Hematological and biochemical changes and results of aerobic bacteriological culturing in dogs undergoing splenectomy. *J Am Anim Hosp Assoc*. 1996;**32**(3):199–210.
38. Salguero R, Borman AM, Herrtage M, et al. *Rasamsonia argillacea* mycosis in a dog: first case in Europe. *Vet Rec*. 2013;**172**(22):581.
39. Santana CC, Vassallo J, De Freitas LAR, Oliveira GG, Pontes-de-Carvalho LC, dos-Santos WL. Inflammation and structural changes of splenic lymphoid tissue in visceral leishmaniasis: a study on naturally infected dogs. *Parasite Immunol*. 2008;**30**(10):515–524.
40. Saunders GK, Monroe WE. Systemic granulomatous disease and sialometaplasia in a dog with *Bartonella* infection. *Vet Pathol*. 2006;**43**(3):391–392.
41. Schnier LM. A case of splenic torsion with progressive anemia and thrombocytopenia. *Can Vet J*. 2010;**51**(5):527–529.
42. Schroeder H, van Rensburg IB. Generalised *Listeria monocytogenes* infection in a dog. *J S Afr Vet Assoc*. 1993;**64**(3):133–136.
43. Schroeder H, Jardine JE, Davis V. Systemic phaeohyphomycosis caused by *Xylohypha bantiana* in a dog. *J S Afr Vet Assoc*. 1994;**65**(4):175–178.
44. Schwarz LA, Penninck DG, Leveille-Webster C. Hepatic abscesses in 13 dogs: a review of the ultrasonographic findings, clinical data and therapeutic options. *Vet Radiol Ultrasound*. 1998;**39**(4):357–365.
45. Simpson KW, Khan KN, Podell M, Johnson SE, Wilkie DA. Systemic mycosis caused by *Acremonium* sp in a dog. *J Am Vet Med Assoc*. 1993;**203**(9):1296–1299.
46. Singh K, Flood J, Welsh RD, Wyckoff JH, Snider TA, Sutton DA. Fatal systemic phaeohyphomycosis caused by *Ochroconis gallopavum* in a dog (*Canis familiaris*). *Vet Pathol*. 2006;**43**(6):988–992.
47. Spangler WL, Culbertson MR. Prevalence, type, and importance of splenic diseases in dogs: 1,480 cases (1985–1989). *J Am Vet Med Assoc*. 1992;**200**(6):829–834.
48. Stedham MA. Histopathology of melioidosis in the dog. *Lab Invest*. 1977;**36**:358.
49. Steinmann J, Giraud S, Schmidt D, et al. Validation of a novel real-time PCR for detecting *Rasamsonia argillacea* species complex in respiratory secretions from cystic fibrosis patients. *New Microbes New Infect*. 2014;**2**(3):72–78.
50. Tasca KI, Buzetti WA, Tenorio Mda S, et al. Parasitological, immunohistochemical and histopathological study for *Leishmania chagasi* detection in splenic tissues of dogs with visceral leishmaniasis. *Rev Bras Parasitol Vet*. 2009;**18**(1):27–33.
51. Tizard IR. Organs of the immune system. In: Tizard IR, ed. *Veterinary Immunology*. 9th ed. St. Louis, MO: Elsevier Saunders; 2013:124–126.
52. Welsh RD, Ray WE. *Scopulariopsis chartarum* systemic mycosis in a dog. *J Clin Microbiol*. 1999;**37**(6):2102–2103.
53. Winkler KP, Greenfield CL, Schaeffer DJ. Bacteremia and bacterial translocation in the naturally occurring canine gastric dilatation-volvulus patient. *J Am Anim Hosp Assoc*. 2003;**39**(4):361–368.
54. Xavier SC, de Andrade HM, Monte SJ, et al. Comparison of paraffin-embedded skin biopsies from different anatomical regions as sampling methods for detection of Leishmania infection in dogs using histological, immunohistochemical and PCR methods. *BMC Vet Res*. 2006;**2**:17.
55. Yamada E, Ueda T, Mori A, Haraguchi H, Nagata Y. Clinical experience with aztreonam in the field of obstetrics and gynecology. *Jpn J Antibiot*. 1985;**38**(12):3695–3699.
56. Zeng JS, Sutton DA, Fothergill AW, Rinaldi MG, Harrak MJ, Hoog GS. Spectrum of clinically relevant *Exophiala* species in the United States. *J Clin Microbiol*. 2007;**45**(11):3713–3720.