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ORIGINAL RESEARCH

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Diagnostic imaging descriptions and prevalence of presumed phrenic lymph nodes in dogs

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Abstract

The phrenic lymph node (PLN) has been described in bovine, equine, and feline anatomic references but descriptions in canine anatomic references are currently lacking. Authors have observed a well-defined, soft tissue attenuating, contrast-enhancing structure in a location consistent with previous anatomic descriptions of the PLN in dogs that underwent thoracic CT for neoplastic staging. The aims of this two-part, retrospective/prospective, anatomic, prevalence study were (1) to describe the presence of a soft tissue structure close to the thoracic caudal vena cava, defined as the presumed PLN, in a series of dogs that underwent CT as part of the staging for metastatic disease; (2) to confirm the lymphatic origin of the presumed PLN in a dog through postmortem examination; (3) to assess the prevalence of the presumed PLN in a population of dogs that underwent thoracic CT or MRI for different clinical purposes; and (4) to assess the possibility to visualize the presumed PLN with ultrasonography. The lymphatic origin of the presumed PLN was confirmed by postmortem examination in one dog. The presumed PLN was visible in 29 of 777 canine CT examinations (prevalence 3.7%). The presumed PLN was not visible in 9 of 10 prospectively recruited ultrasound cases. Most dogs with visible presumed PLNs were large-medium breeds that were presented for neoplastic staging purposes. Findings indicated that a structure consistent with the previously reported anatomic features of PLN in cattle, horses, and cats may be detected with a low prevalence in canine CT and MRI examinations.

KEYWORDS
CT, diaphragm, dog, lymphatic, thorax

1 | INTRODUCTION

Anatomic reference texts describe the thoracic lymph nodes of dogs as the following: sternal LNs (SLNs), located dorsal to the sternum (only cranial SLNs are present in dogs), cranial mediastinal LNs (CrMLNs), located in the cranial mediastinum, tracheobronchial LNs (TBLNs), typically three (left, right and middle), at the level of the carina and close to the main bronchi, aortic thoracic LNs (ATLNs) located ventral to the

thoracic vertebrae, and pulmonary LNs (PuLNs) on the dorsal aspect of the principal bronchi.[1–3] The assessment of thoracic LNs is important in the clinical setting of veterinary medicine, particularly when staging for thoracic, nonthoracic, or systemic neoplasia. In a previous study performed on dogs without thoracic disease, the SLNs, CrMLNs, and TBLNs were visualized in computed tomographic studies for almost 100% of the dogs included.[4]

According to anatomic literature, including "Nomina Anatomica Veterinaria (NAV)", an additional lymph node is present in equine, bovine, and feline species on the thoracic side of the diaphragm close to the caudal vena cava, and this is referred to as the phrenic lymph node (PLN).[3,5,6] The presence of this lymph node in dogs was only described in a few drawings published in a study from 1929, where a small lymph node, called the diaphragmatic lymph node, was visible at the level of diaphragm within a lymphatic channel from the diaphragm courses along the phrenic artery and nerve towards the cranial mediastinum.[7] In bovine species, the PLN receives afferents from the diaphragm and the mediastinum and gives efferents to the caudal mediastinal lymph nodes.[6] In dogs, this lymph node has been described as the lymphatic drainage from the peritoneal cavity as a secondary route, and from the peritoneal cavity to lymph nodes in cranial mediastinum.[7]

The authors of the current study have anecdotally observed a structure compatible with the anatomic features of a PLN in thoracic CT examinations of several dogs. Therefore, the aims of the current study were (1) to describe the presence of a soft tissue structure close to the thoracic caudal vena cava, defined as the presumed PLN, in a series of dogs that underwent CT as part of the staging for metastatic disease; (2) to confirm the lymphatic origin of the presumed PLN in a dog through postmortem examination; (3) to assess the prevalence of the presumed PLN in a population of dogs that underwent thoracic CT or MRI for different clinical purposes; (4) to assess the possibility to visualize the presumed PLN with ultrasonography.

2 | METHODS

2.1 | Selection and description of subjects

This retrospective/prospective, anatomic, prevalence study consisted of two phases. The first phase of the study described cases in which the presence of a well-defined, soft-tissue attenuating, contrast-enhancing structure at the level of the diaphragm was reported at the time of the CT examination. This structure was defined as the presumed PLN. Included were dogs who underwent CT examination as part of a staging protocol for neoplasia at Ghent University (Belgium) in the period between April 2021 and March 2022. A CT examination of the thorax and abdomen was also performed postmortem for a dog that died for reasons unrelated to the study and this was followed by anatomical dissection performed by an experienced anatomist (P.C.). The second phase of the study consisted of the retrospective evaluation of the thoracic and abdominal CT examination of dogs presented at Queen Mother Hospital for Animals for different clinical purposes in 1 year (April 2022-March 2023) to assess the prevalence of the presumed PLN. The thoracolumbar MRI examinations performed during the same period at the same institution were also reviewed in order to assess the prevalence of presumed PLN with this imaging modality. In addition, an ultrasonographic (US) approach was also attempted in order to visualize this region in dogs that underwent US examination of the abdomen for different clinical purposes, and for this part of the study 10 dogs, randomly selected, were prospectively evaluated. For both phases of the study, final decisions for subject inclusion or exclusion were made by an ECVDI-certified veterinary radiologist (A.C.).

2.2 | Data recording and analyses

Clinical data regarding breed, sex, body weight, and final diagnosis were recorded for each dog by a second-year European College of Veterinary Imaging (A.S.) and the ECVDI-certified veterinary radiologist (A.C.).

For the first part of the study, CT images of dogs where the presumed PLN was reported were retrieved from the PACS and analyzed using freestanding workstations (OsiriX v5.8.5 64-bit) by the ECVDI-certified veterinary radiologist (A.C.). The shape of the presumed PLN was assessed, and the maximum diameter was measured for all dogs. The pre- and postcontrast mean attenuation values (measured in Hounsfield Units—HU) of the presumed PLN were assessed by drawing a round region of interest in the center of the structure; particular care was taken to avoid the surrounding mediastinal fat, the caudal vena cava, or other vascular structures. For comparative purposes, the pre- and postcontrast mean attenuation values (HU) of one of the sternal lymph nodes (SLN) were also recorded for each dog. The difference in pre- and postcontrast mean attenuation (HU) between the presumed PLNs and the SLNs was recorded for each dog. In addition, the presence of concomitant lymphadenopathy of the sternal, cranial mediastinal, tracheobronchial, axillary, superficial cervical, and cranial abdominal lymph nodes was also recorded. Lymphadenopathy was assessed subjectively based on increased size of the lymph nodes, abnormal shape, and/or contrast enhancement.

For the second part of the study (prevalence study) CT and MRI images were retrieved from the PACS and analyzed using a freestanding workstation (eUnity, Mach7, South Burlington, VT) by two ECVDI-certified veterinary radiologists (A.C. for CTs and V.F.L. for MRIs). For CT studies, the postcontrast series were evaluated to assess the visualization of the presumed PLN. All transverse T1w and T2w images of the thoracolumbar studies were evaluated to identify if the region of the presumed PLN was included in the field of view. If so, images were further evaluated to assess the visualization of presumed PLN. In addition, US examinations of 10 dogs (randomly included based on the daily caseload) were prospectively performed in order to assess the visibility of the region of the presumed PLN. Technical parameters for ultrasound studies are provided in Table 1.

TABLE 1 CT, MRI, and US parameters used in the study.

Institution	Imaging modality	No. of cases	Imaging equipment	Technical parameters	Contrast media
Ghent University	CT	13 (+1 postmortem)	320-row MDCT unit, Canon Aquilion One, Toshiba Medical Systems	Helical modality, 120 kVp, 200 mAs, image matrix 512 × 512, 0.5 mm slice thickness	Iohexol 370 mgI/mL, 2 mL/kg dosage
Queen Mother Hospital	CT	777	320-row MDCT unit, Canon Aquilion One; Toshiba Medical Systems	Helical modality, 120 kVp, 100–200 mAs, image matrix 512 × 512, 2–3 mm slice thickness, 1.5 mm reconstruction interval	Iohexol 300 mgI/mL, 2 mL/kg dosage
Queen Mother Hospital	MR	276	1.5 Tesla MRI unit, Intera, Philips Medical Systems, Eindhoven	FSE T2-weighted (TR 3000–3700 ms; TE 83–120 ms), T1-weighted (TR 400–620 ms; TE 8–15 ms). slice thickness 2–5 mm with an interslice gap of 3.3–5.3 mm	0.1 mmol/kg gadopentetate dimeglumine
Queen Mother Hospital	US	10	RS80A (Samsung Medison)	Microconvex (4–9 MHz) and linear (3–12 MHz) transducers	NA

3 | RESULTS

3.1 | Phase I study

3.1.1 | Clinical findings

A total of 13 cases in which the presumed PLN was identified and reported at CT examination were retrieved. Median age of the dogs included was 7.5 (range 2–11.5) years, and median weight was 36 (range 16–83) kg. Most of the included dogs were females (9/13, 69%), and the remainder 4 of 13 (31%) were males. Thirteen different breeds were represented (one dog each): Barbet, Golden Retriever, English Springer Spaniel, Nova Scotia Duck Tolling Retriever, Labradoodle, Rottweiler, Dogue de Bordeaux, White Swiss Shepherd, Border Collie, Boerboel, Kooikerhondje, Kangal Shepherd Dog, and crossbreed dog. All dogs included in this first part of the study underwent CT examination as part of the staging protocol for metastasis. Four dogs were diagnosed with multicentric lymphoma, three with hepatic neoplasia (one carcinoma, one hemangiosarcoma, and one hepatic T-cell lymphoma), two with histiocytic sarcoma, one with pancreatic carcinoma, one with gastric adenocarcinoma, one with mesothelioma, and one with rib chondrosarcoma.

3.1.2 | CT findings

Computed tomographic technical parameters are summarized in Table 1. A soft tissue, enhancing structure was detected at the level of the plica vena cava, just cranial to the diaphragm, located immediately ventral and lateral to the right side of the caudal vena cava, surrounded by fat tissue. The exact location in all three planes is shown in Figure 1. This structure, presumed to correspond to the PLN, was constantly detected in the same position and showed comparable CT characteristics in all dogs (Figure 2). Other anatomical structures are normally present in dogs at this level, including the right phrenic nerve and right cranial phrenic vein, sometimes visible at CT examination (Figure 3).

The presumed PLN was rounded in 7 of 13 (54%) dogs, ovoid in 5 of 13 (39%), and bilobed in one (7%). The median of the maximum diameter of the presumed PLN was 6 mm (3.5–12 mm). The median of the precontrast mean attenuation values of the presumed PLN was 28 HU (12–44 HU), while postcontrast was 64 HU (40–89 HU). Median differences in the mean attenuation values between the presumed PLN and SLN were 5 HU for precontrast images and 7 HU for postcontrast images. In all 13 dogs included, at least one thoracic or abdominal lymph center was also considered abnormal at CT examination. Eleven out of 13 (85%) dogs presented with SLN enlargement and 9 of 13 (69%) with abdominal lymphadenopathy; in 6 of 13 (46%) dogs the CrMLNs, in 5 of 13 (38%) the axillary or cervical superficial, and in 4 of 13 (31%) the TBLNs were enlarged.

3.1.3 | Postmortem evaluation and anatomical description

One dog, Cane Corso, male castrated of 4 years old, was euthanized at xxx for causes unrelated to the study (recurrent intestinal obstruction and intussusception). A CT examination of thorax and abdomen was performed 24 h postmortem, using the same parameters described above. The CT examination revealed the presence of a presumed PLN with a diameter of approximately 3 mm (Figure 4A). The dog underwent anatomical dissection of the thorax, and an accumulation of fat tissue was macroscopically visible in the described location (Figure 4B).

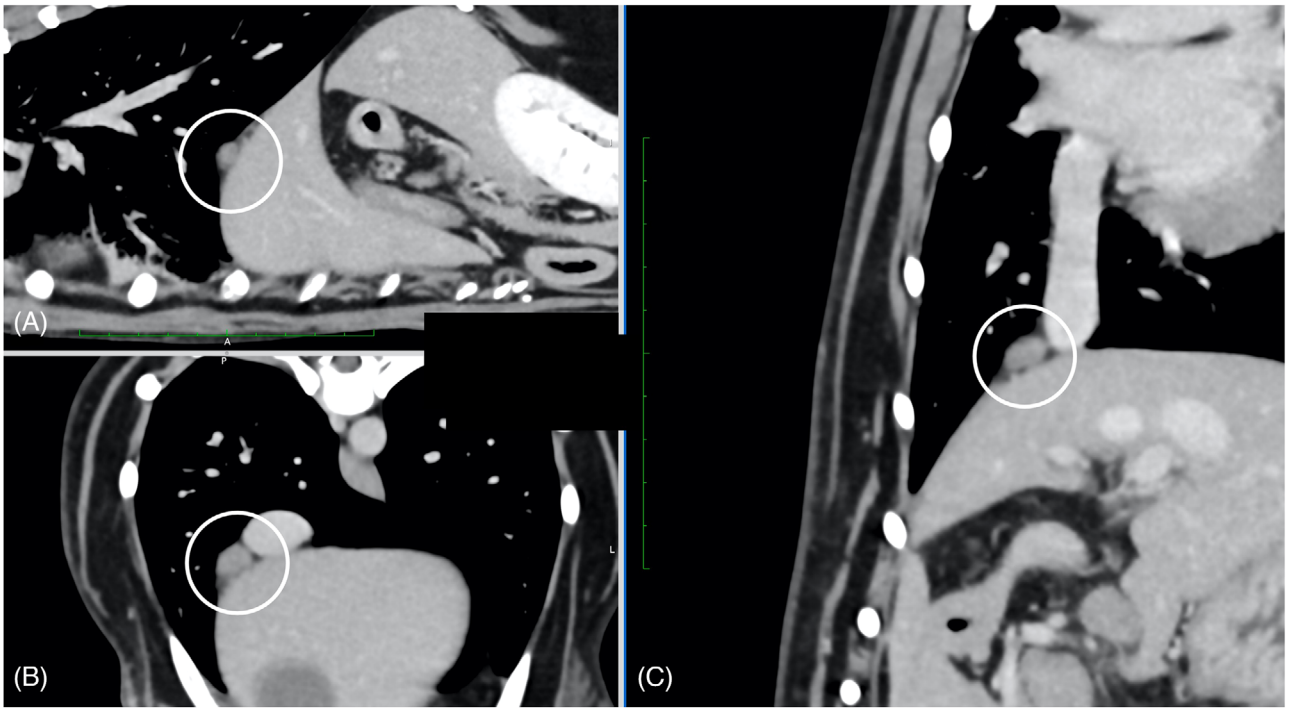

FIGURE 1 Postcontrast CT multiplanar reformations (MPRs) of the caudal thorax of a dog diagnosed with lymphoma. Note the localization of the phrenic lymph node (circled) in the sagittal (A), transverse (B), and dorsal (C) planes. [Color figure can be viewed at wileyonlinelibrary.com]

The tissue was excised, and histological examination was performed, revealing the presence of a small amount of well-vascularized lymphoid tissue within the fat, of the same dimensions as reported at postmortem CT, organized as follicles/aggregates of lymphocytes, with abundance of macrophages (Figure 4C). Despite the lack of classic organization typical of a true lymph node, this was considered normal lymphatic tissue.

3.2 | Phase 2 study

3.2.1 | Prevalence of presumed PLN in CT studies

In the one-year period selected, 800 dogs underwent CT examination (at least one precontrast and one postcontrast series) of the thorax and/or abdomen for different reasons. Nine studies were excluded as the CT was performed in lateral recumbency, and 14 dogs were excluded as the area of interest was not assessable due to the presence of an adjacent severe pneumopathy or thoracic mass.

A total of 777 CTs were reviewed, and the presumed PLN was visible in 29 (3,7%) cases. Of these, 11 of 29 (38%) were females and 18 of 29 (62%) were males; median bodyweight was 30 (9.5–56.5) kg. Most of these dogs were crossbreed (9/29–31%), 7 of 29 were Labrador Retrievers (24%), 3 of 29 were Cocker Spaniels (10%), and 1 each (3%) Border Collies, American Staffordshire Terriers, Cane Corso, German Shepherd, Golden Retriever, Husky, Jack Russell Terrier, Nova Scotia Duck-Tolling Retriever, Rottweiler, and Weimaraner. In 748 dogs the presumed PLN was not identified. Of these, 308 were females (41%) and 440 were males (59%), median bodyweight was 18.5 (8–79) kg, 70 were Labrador Retrievers (9%) and 35 were Cocker Spaniels (5%). Of the 29 cases with the presumed PLN visualized, 20 of 29 (69%) presented with neoplastic process, 6 of 29 (21%) with inflammatory condition, 2 of 29 (7%) with immune-mediated hemolytic anemia, and one (3%) with a congenital anomaly (arterioportal malformation). The diagnosis and details regarding other lymph nodes in these dogs are summarized in Table 2. In two cases more than one CT of the region was available for review, and the presumed PLN was visible in both CTs. Interestingly, the size of the presumed PLN was in both cases different at the two time points: in one dog, the second CT was acquired after treatment was initiated for diagnosed hepatic abscess, and the presumed PLN was smaller in the follow-up CT (Figure 5). In the other dog, the presumed PLN was smaller in the first CT (gastrointestinal foreign body) and larger in the second CT, performed after the dog developed signs of liver failure secondary to suspected histiocytic sarcoma.

3.2.2 | MRI findings

A total of 276 MRIs of the thoracolumbar spine were reviewed. All dogs underwent MRI examinations of the thoracolumbar spine for neurological conditions. In 27 of these, at least one T2w and one T1w transverse sequence including the anatomical region of presumed PLN were available, 12 with also postcontrast T1w transverse sequence. A small (2.5 mm), rounded structure, hypointense in T1w and T2w sequences, was detected within the fat only in one case, a female pug presented with constrictive myelopathy (Figure 6). This dog underwent

FIGURE 2 Postcontrast transverse CT images (A, B) and dorsal reconstructions (C, D) of the phrenic lymph node (circled) in two dogs: one (A, C) diagnosed with hepatic T-cell lymphoma and the other (B, D) with histiocytic sarcoma.

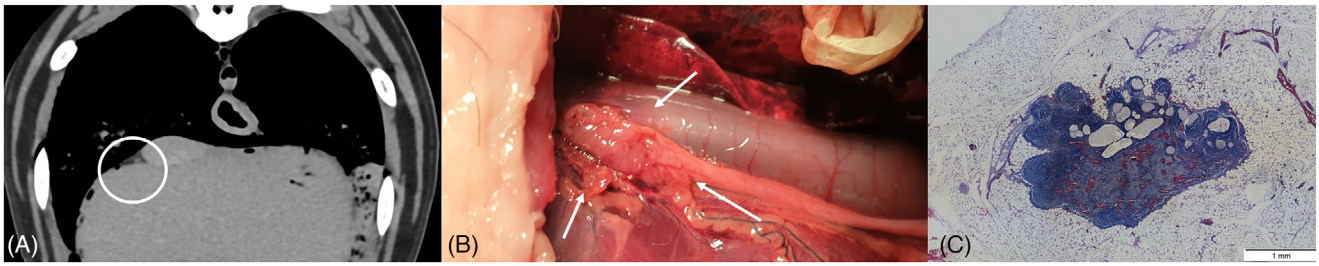

FIGURE 3 Transverse CT image (A) performed postmortem in a Cane Corso dog, showing a small phrenic lymph node (circled). (B), postmortem image of the same dog, right lateral approach at the level of the 8th intercostal space (cranial is on the right of the image). (C), histological examination, hematoxylin and eosin stain, the bar corresponds to 1 mm. Some well-vascularized lymphoid tissue, organized as follicles/aggregates of lymphocytes, is visible within the fat. [Color figure can be viewed at wileyonlinelibrary.com]

nonenhanced CT examination for the vertebral column the same day, and in the expected region a small soft tissue structure was also recognized. Unfortunately, no postcontrast or fat-suppressed images were available in this case.

3.2.3 | Ultrasound findings

A US approach was attempted in order to visualize the region of the plica vena cava in 10 dogs; both an intercostal and a subxiphoid

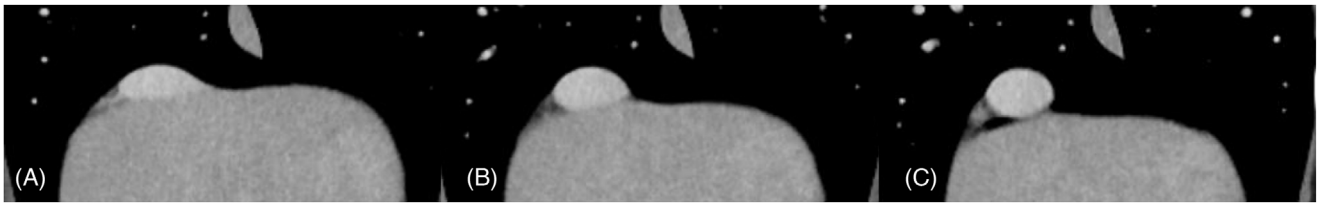

FIGURE 4 Close-up of the region of plica vena cava, transverse postcontrast CT images of a dog diagnosed with hepatic lymphoma, from cranial to caudal: (A), a contrast-enhanced vessel is entering the caudal vena cava from its right side, consistent with the right cranial phrenic vein; (B), a thin, nonenhancing, structure is running close to the caudal vena cava on its right lateral aspect, consistent with right phrenic nerve; (C), a rounded, well-defined, contrast-enhanced structure is visible within the fat, consistent with phrenic lymph node.

TABLE 2 Final diagnoses of dogs with presumed PLN detected in CT (second phase of the study) and concomitant enlarged lymph nodes.

Disease group (*n*)	Thoracic	Abdominal	Systemic	Other	Other LNs enlarged
Neoplastic (19)	Total: 4 2 lung masses (carcinoma) 1 HBT 1 mediastinal ly	Total: 7 3 hepatic masses (1 HCC, 1 HS, 1 ND) 1 adrenal pheo 1 cecal GIST 2 splenic HSA	Total: 7 4 ly 1 HS 1 MCT 1 ND (hepatic, splenic, and lung masses)	Total: 1 1 mammary gland carcinoma	Yes: 13 (7 generalized, 3 hepatics, 1 sternal, 1 all thoracic, 1 inguinal) No: 6
Inflammatory (7)	Total: 1 Migrating grass seed (pleuritis, pneumonia)	Total: 6 1 hepatic abscess 1 pancreatitis 1 bacterial nephritis 1 septic peritonitis 1 colitis and pancreatitis 1 bacterial cystitis	–	–	Yes: 3 (1 generalized, 1 all thoracic, 1 jejunal and colic) No: 4
IMHA (2)	–	–	–	–	Yes: 1 (all thoracic) No: 1
Congenital (1)	–	Hepatic arterioportal malformation	–	–	Yes: young patient

Abbreviations: GIST, gastrointestinal stromal tumor; HBT, heart base tumor; HCC, hepatocellular carcinoma, HSA, hemangiosarcoma; HS, histyocytic sarcoma; IMHA, immune-mediated hemolytic anemia; MCT, mast cell tumor; ND, no final diagnosis; ly, lymphoma; pheo, pheochromocytoma.

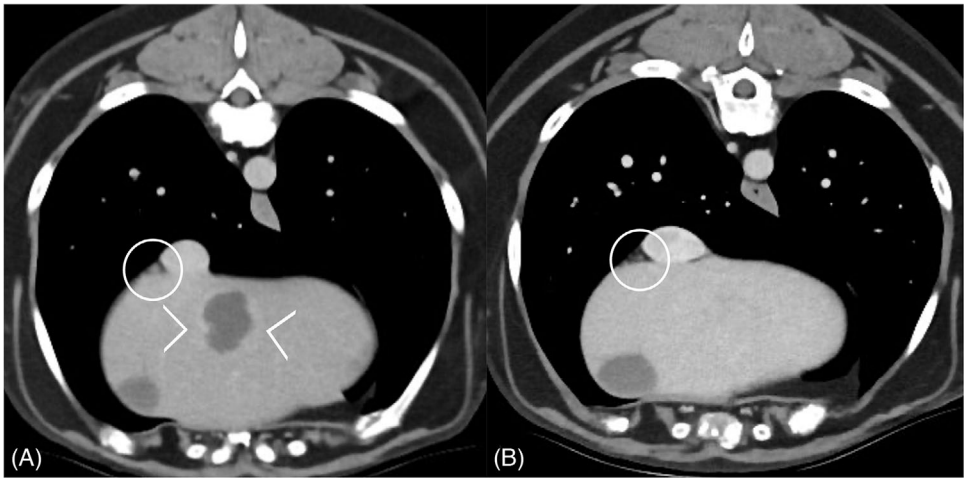

FIGURE 5 Postcontrast transverse CT images of the thorax of one dog diagnosed with a hepatic abscess at two different time points: (A) at the time of diagnosis, and (B) follow up 6 weeks after treatment. Note the difference in size of the phrenic lymph node (circled) in the two studies; the hepatic abscess (between arrowheads) is not visible anymore in the follow-up exam, and the phrenic lymph node is notably reduced in size.

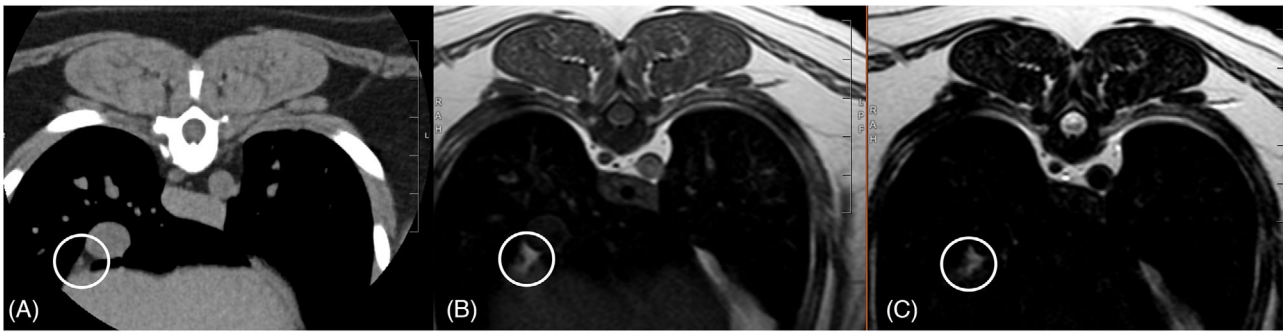

FIGURE 6 Transverse CT (A), and MR images, T1w (B) and T2w (C) images of the thorax of a pug, diagnosed with constrictive myelopathy, showing the different appearance of the phrenic lymph nodes (circled) in the two modalities: soft tissue attenuating in CT images, T1w and T2w hypointense in MRI when compared with the surrounding fat (T1w and T2w hyperintense), that helps in its visualization. [Color figure can be viewed at wileyonlinelibrary.com]

windows were used. The dogs were scanned under sedation, using both a subcostal abdominal approach and a right intercostal approach. For the subcostal approach, the probe was placed in a sagittal plane close to the midline and pointing towards the right, to visualize the cranial margin of the liver against the diaphragm and the caudal vena cava in a longitudinal view. Next, the vessel was followed until it crossed the diaphragm, and the region was assessed using slight displacements of the probe on the lateral plane. For the right intercostal approach, the probe was placed on the lateral aspect between one of the last intercostal spaces (depending on the dog's anatomy) in order to visualize the diaphragm and the caudal vena cava, then slightly rotated to obtain a longitudinal view. The thoracic portion of the caudal vena cava and the region of the presumed PLN were not easily assessed with US, due to artifacts created by the aerated lungs. In one dog, a pulmonary mass was present in the region and in another dog moderate pleural effusion was present, therefore the thoracic portion of the caudal vena cava was followed more cranially than in other subjects. Only in one of the dogs (the subject with pleural effusion) a lymph node-like structure was detected, of the same size as the presumed PLN visualized at CT examination (Figure 7).

4 | DISCUSSION

The intentions of the present, two-part, study were to describe the diagnostic imaging and anatomic characteristics of presumed phrenic lymph nodes (presumed PLN) in a large sample of dogs. Based on our review of the literature, these characteristics have not been previously described. In the first phase of our study, the presumed PLN was detected in CT examinations for 13 dogs that underwent CT examination for staging of neoplastic disease. In these cases, the presumed PLN appeared rounded or ovoid in shape (bilobed only in one case), with a median diameter of 6 mm. Observers commented that the size of the presumed PLN was large enough to be easily detectable with a standard CT protocol used for the examination of thorax of dogs for staging purposes. Observers noted that it was possible that, in these dogs, the presumed PLN was easily visualized because it was potentially enlarged. The median of the pre- and postcontrast mean attenuation values of the presumed PLN were very comparable when compared with the pre- and postcontrast values of the SLN of the same dog. The histology performed on one dog that died for causes unrelated to the study confirmed the presence of lymphatic tissue in this location. In this case, in which histology was available, despite the soft tissue structure detected at postmortem CT corresponding to lymphatic tissue, the latter lacked classical organization proper of other lymph nodes. It can be hypothesized that this tissue could correspond to hemal nodes, small nodules most commonly found in ruminants, and reported in horses, primates, and some canids, or aggregated lymphoid nodules, present in different locations throughout the organism, such as tonsils, Peyer's patches, and respiratory, ocular, genitourinary system.[8]

The CT characteristics, together with the histological findings and the visualization of this structure in patients with thoracic and/or abdominal or generalized lymphadenomegaly, support the theory of the lymphatic origin of this structure. The location is the same as described in other species as "phrenic lymph node",[3,6] therefore this is the nomenclature proposed for dogs as well.

The presumed PLN is located on the cranial surface of the diaphragm, close to the vena cava foramen.[3] The thoracic part of the caudal vena cava extends from the foramen until the right atrium, and it is located in a pleural fold called plica vena cava. Within the plica vena cava, the right phrenic nerve terminates its course to innervate the diaphragm[1,9]; the right cranial phrenic veins begin in the ventral part of the diaphragm, and empties into the caudal vena cava, usually through a small trunk, on the thoracic side of the vena cava foramen.[9] In some dogs, these structures are visible in CT examinations, and should not be confused with a nonenlarged presumed PLN.

In the second phase of the study, the prevalence of the presumed PLN was assessed in a relatively large canine population. The included dogs presented with several thoracic, abdominal, or generalized diseases. Due to the retrospective nature of the study, no healthy dog underwent CT examination for the visualization of the presumed PLN. In most of the included dogs, the presumed PLN was not visualized on CT examination, with a prevalence of 3.7%. Multiple lymph nodes are inconstant in dogs, and therefore authors propose that the PLN is

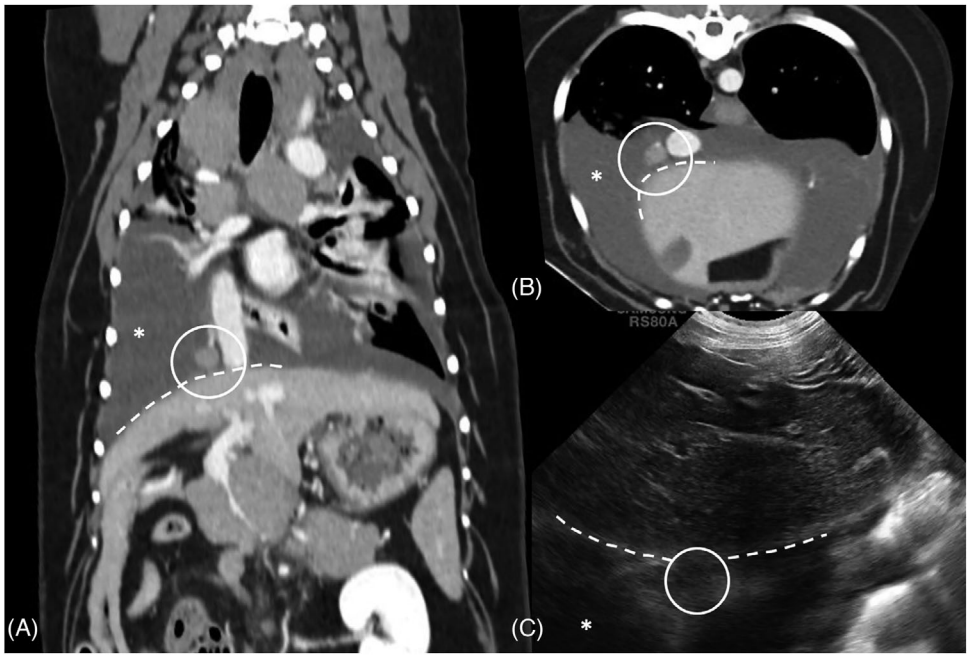

FIGURE 7 Postcontrast CT dorsal (A) and transverse (B) images of the phrenic lymph node (circled) in a dog diagnosed with lymphoma, compared with the US image of the same region of the same dog, showing a rounded structure (circled) cranial to the diaphragm (dotted in all images). The area is assessable with the US as this dog presented with pleural effusion (asterisk).

possibly present only in a small part of the canine population. Another hypothesis is that the PLN in a normal condition is very small, and possibly not detectable at CT examination. Furthermore, the body weight of the group of dogs in which the presumed PLN was visualized in CT was higher than the bodyweight of those in which it was not visualized, also suggesting that the size could play a role in the detection of this structure. The size of the normal presumed PLN and the inconsistent presence among the canine population are possibly responsible for the current lack of reports describing this structure in dogs.

Labrador Retrievers appeared to be overrepresented in the population with the visible presumed PLN, being 24% of the total, while in the overall population, only 9% of the dogs were Labrador Retrievers. Comparably, 10% of dogs with visible presumed PLN were Cocker Spaniels while being only 5% of the total population. This result could suggest a breed-specific anatomical variation, but further anatomical studies in these canine breeds are necessary to evaluate this hypothesis.

When considering all included dogs where the presumed PLN was visible, most of them were diagnosed with neoplasia, either thoracic, abdominal, or systemic. The presence of other LNs enlarged in most of these dogs suggests the fact that the presumed PLN was also enlarged in these dogs (as reference values for normality are lacking) and, therefore more visible.

The detection of possibly enlarged PLN in dogs with neoplasia located both in the thorax, in the abdomen, or both, suggests a complex or multiple drainage of this lymphatic tissue. In bovine species, the PLN receives afferents from the diaphragm and the mediastinum, and the efferent duct(s) drain to the caudal mediastinal lymph nodes.[6] The PLN is part of the caudal mediastinal lymph center: in carnivores, afferent lymphatic ducts for these LNs come from the caudal mediastinum, esophagus, pericardium, and diaphragm, and in ruminants also from liver, spleen, and peritoneum.[3] Further studies are needed to assess the lymphatic afferent and efferent ducts present in dogs, in order to determine which organs are drained by this lymphatic tissue and to assess the clinical importance of its enlargement in particular when staging for neoplasia.

Due to the anatomic localization of this structure, its visualization with imaging techniques other than CT could be difficult. The US visualization is impaired by the presence of aerated lungs in the surroundings of the structure, and the abdominal approach can sometimes be technically challenging due to the depth of the structure. Visualization of the PLN is potentially possible with the US technique in small-medium size dogs when the aerated lung against the diaphragm is replaced by tissue or fluid. Other cross-sectional modalities, such as MRI, could be potentially useful. In our study, the presumed PLN was visible only in one case. Nevertheless, due to the retrospective nature of the study, the protocol used was set to maximize the quality of the images on the spinal cord, and no thoracic-specific protocols were used. Further studies would be needed to compare the different imaging modalities.

This study presents some limitations: given the retrospective nature of the study, all dogs included underwent CT examination for clinical purposes, therefore all dogs in which the presumed PLN was visualized had thoracic and/or abdominal disease, in most of the cases of neoplastic nature. Given the fact that no size ranges are to date available for this LN, it was not possible to assess if the presumed PLNs were normal or enlarged. Further studies including normal dogs would be needed in order to determine the normal size of this LN in dogs. Furthermore, the histological examination has been carried out only on one dog that died of causes unrelated to the study. Unfortunately, due to its localization,

the sampling of PLN in vivo (either with US- or CT-guided technique) has not been attempted in other dogs, as the procedure was considered invasive and not justified by the clinical relevance for each case.

In conclusion, the present study describes clinical, CT, MRI, US, anatomic, and prevalence findings for a presumed PLN in a sample of prospectively and retrospectively recruited dogs. Most dogs were presented for imaging as part of neoplastic staging, therefore it remains unknown whether these presumed PLN were visible because they were enlarged. Future research such as postmortem analysis in a larger sample of dogs and studies in healthy dogs are indicated to better understand the characteristics, drainage patterns, and clinical relevance of the presumed PLN in dogs.

LIST OF AUTHOR CONTRIBUTIONS

Category 1

(a) Conception and design: Cordella
(b) Acquisition of data: Skarbek, Germonpré, Fouriez-Lablée
(c) Analysis and interpretation of data: Cordella, Stock, Cornillie, Saunders

Category 2

(a) Drafting the article: Cordella
(b) Revising article for intellectual content: Stock, Saunders, Cornillie, Fouriez-Lablée, Skarbek, Germonpré

Category 3

(a) Final approval of the completed article: Cordella, Stock, Saunders, Cornillie, Fouriez-Lablée, Skarbek, Germonpré

Category 4

(a) Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved: Cordella, Stock, Saunders, Cornillie, Fouriez-Lablée, Skarbek, Germonpré

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

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