Thoracic computed tomography in dogs with neoplasia

Thoracale computertomografie bij honden met neoplasie

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ABSTRACT

Computer tomography has been described for the detection and characterization of different thoracic neoplastic diseases in dogs, both primary and metastatic. Its use and availability in veterinary medicine are rapidly increasing in the clinical setting, particularly in referral practices. Due to the cross-sectional nature of this modality, CT is particularly useful in the assessment of complex anatomical regions, such as the thoracic cavity. In this review, the most common applications of thoracic CT for the diagnosis and staging of different neoplastic processes in dogs are highlighted.

SAMENVATTING

Computertomografie (CT) wordt beschreven voor de detectie en karakterisering van verschillende thoracale neoplastische ziekten, zowel primaire als gemetastaseerde. Het gebruik van CT neemt snel toe in de klinische setting in de diergeneeskunde en is steeds meer beschikbaar, met name in verwijzingspraktijken. Vanwege de dwarsdoorsnede van deze modaliteit is CT bijzonder nuttig voor de beoordeling van complexe anatomische regio's, zoals de thoracale holte. In dit overzichtsartikel worden de meest voorkomende toepassingen van thoracale CT belicht voor de diagnose en stadiëring van verschillende neoplastische processen bij honden.

INTRODUCTION

Computed tomography (CT) is nowadays widely used in veterinary medicine to assess thoracic diseases in dogs and cats. Thoracic radiographs can still be considered the first-line modality, but the main limitation includes the two-dimensional superimposition of a three-dimensional volume of information. It has been shown that CT leads to a more accurate assessment of thoracic pathologies, providing cross-sectional anatomic information that can aid in anatomic localization and evaluation of the extent of the disease (Prather, 2005).

In a recent study by Ruby et al. (2020), the limitations of conventional radiography for the differentiation of mediastinal and pulmonary masses in dogs and cats were highlighted. Furthermore, in several studies, the performances of radiography and CT in the detection of pulmonary nodules have been compared (Nemanic et al., 2006; Eberle et al., 2010; Otoni et al., 2010; Alexander et al., 2012; Armbrust et al., 2012). CT has proven to be superior to thoracic radiographics in the detection of pulmonary nodules (Nemanic et al., 2006; Eberle et al., 2010; Alexander et al., 2012) and is more sensitive than radiography, particularly in large-breed to giant-breed dogs (Armbrust et al., 2012). In addition, excellent interobserver diagnostic accuracy and agreement have been reported with CT (Alexander et al., 2012).

CT TECHNIQUE FOR THORACIC IMAGING IN DOGS

Dogs undergoing thoracic computed tomography are usually under sedation or general anesthesia, and

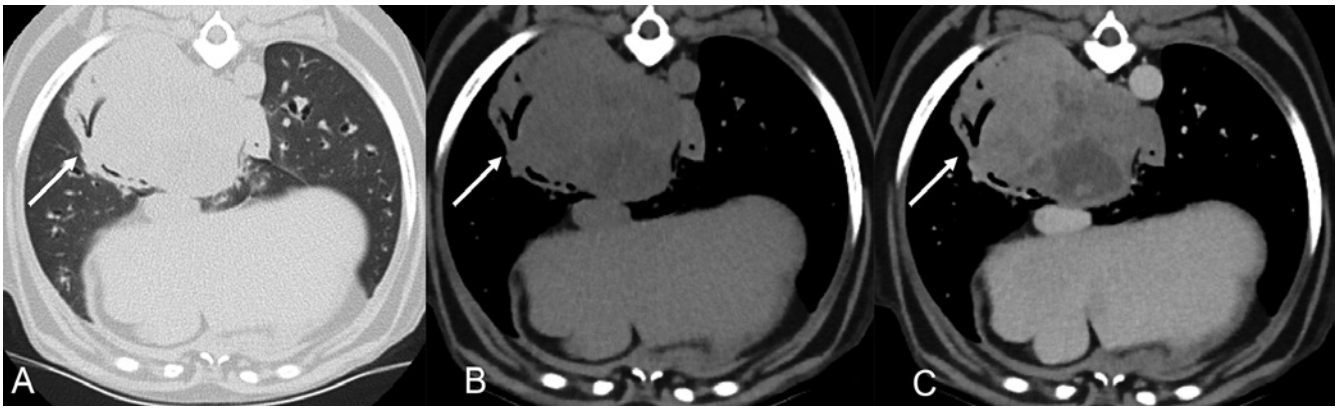

Figure 1. Transverse images of the caudal thorax of a dog with pulmonary adenocarcinoma. A. Lung window; B. Pre-contrast soft tissue window and C. Post-contrast soft-tissue window. There is a large mass at the dorsal aspect of the right caudal lung lobe, causing compression and displacement of the bronchus (arrow); the mass is well circumscribed and has heterogeneous contrast enhancement.

it is advised to maintain them in sternal recumbency as lung atelectasis develops rapidly and may affect image quality (Bertolini et al., 2011). In a recent study by Hunt et al. (2021), CT images obtained in dogs under sedation showed a lower percentage of poorly aerated lung than CT images obtained in anesthetized dogs; in the same study, the use of sedation protocols has been described. Nevertheless, the use of general anesthesia allows the acquisition of the images during a phase of apnea, limiting the motion artifacts related to the respiration, and therefore increasing the quality and the clinical usefulness of the CT study.

For thoracic CT, the acquisition of high resolution data is recommended for the morphological assessment of thoracic diseases in dogs, as in human medicine. With advanced multi-detector CT scanners (with 16 or more rows), the acquisition of thoracic images can be performed with narrow, near-isotropic collimation and a narrow reconstruction interval, to allow the visualization of datasets in any spatial plane. A complete evaluation of the thoracic structures in dogs requires pre- and post-contrast series. In particular, contrast-enhanced series are useful for the assessment of extrapulmonary structures (Schwarz et al., 2011; Bertolini, et al. 2011).

Different display parameters, especially window width (WW) and window level (WL), are used in order to interpret thoracic CT data. For lung evaluation, the following parameters are commonly used: 1500-2000 HU WW, -500 HU WL, while for mediastinal structures, the WW is usually set at 400 HU and WL at +40 HU (Petite et al., 2011; Schwarz et al., 2011).

CT OF THE LUNGS

Primary pulmonary neoplasia

Bronchoalveolar carcinoma is the most common primary lung tumor in dogs. Other tumor types include acinar or papillary adenocarcinoma, squamous cell carcinoma, anaplastic carcinoma and rarely, primary sarcoma (McNeil et al., 1997).

Canine primary lung tumors, in particular carcinoma, are typically seen radiographically as a well-circumscribed soft-tissue solitary mass, while lobar consolidation and diffuse forms of primary lung tumors are less commonly observed (Miles et al., 1988). CT characteristics of primary lung tumors have been previously described in the veterinary literature. They appear to be bronchocentric in origin, with the bronchi typically narrowed, displaced and often obstructed by the tumor (Marolf et al., 2011). Most solitary tumors are well circumscribed, with the presence of internal air bronchograms, and have mild to moderate heterogeneous contrast enhancement (Marolf et al., 2011). Associated findings include the presence of pulmonary metastases, mineralization within the mass and tracheobronchial lymphadenopathy (Marolf et al., 2011). These characteristics particularly apply to pulmonary carcinomas (Figure 1).

The most common CT findings in dogs with thoracic histiocytic sarcoma have been described in a retrospective study by Tsai et al. (2012) (Figure 2). The presence of intrathoracic lymphadenopathy and pulmonary masses are the most common features of this disease, and in particular right middle lung lobe masses are significantly more common than masses in any other lung lobe (Tsai et al., 2012). At CT examination, the majority of histiocytic sarcomas are mildly to moderately enhancing, heterogeneous, poorly marginated and bronchocentric (Tsai et al., 2012).

Although being solid in most of the cases, pulmonary adenocarcinoma in dogs, can also present as a cavitary pulmonary mass on CT (Figure 3). Common features include lesions in the caudal lung lobes, lobular and spiculated lesion margins, presence of air bronchograms within the mass and heterogeneous contrast enhancement (Parry et al., 2021). In a recent study by Bello et al. (2021), transformation of cystic airspace lesions in pulmonary carcinoma has been described in two dogs, and the monitoring of cystic airspace le-

sions with thoracic CT has been recommended.

CT features of rounded atelectasis in dogs and cats have been recently described (Fukuda et al., 2022; Tran et al., 2023). Rounded atelectasis is a focal lung collapse that appears as a round mass-like lesion in the periphery of the lung and can be misdiagnosed as neoplasia. Patients with rounded atelectasis commonly have a history of pleural effusion and abnormal pleura, and CT features (i. e. broad-based, homogeneous lesions, located in the subpleural gravity-dependent regions of the lung) can help in the differentiation from primary neoplasia in patients with concurrent inflammatory pleural disease (Fukuda et al., 2022; Tran et al., 2023).

Pulmonary metastases

As already described, CT is considered superior to conventional radiography in the detection of pulmonary nodules in dogs (Nemanic et al., 2006; Eberle et al., 2010; Otoni et al., 2010; Alexander et al., 2012; Armbrust et al., 2012) (Figure 4). In particular, the use of thoracic CT has been described as a fundamental diagnostic tool in the staging of different types of neoplasia, including appendicular osteosarcoma (Eberle et al., 2010), mammary tumors (Otoni et al., 2010), anal sac adenocarcinoma (Sutton et al., 2022).

In a study by Lamb et al. (2019), the prevalence of pulmonary nodules in dogs with malignant neoplasia were estimated; the results indicated that dogs with hemangiosarcoma had most commonly pulmonary metastases at CT, dogs with mast cell tumor were infrequently affected, and none of the dogs with squamous cell carcinoma had pulmonary metastases (Lamb et al., 2019). The detection of a single pulmonary nodule at CT examination has to be carefully interpreted as metastatic in origin, as it can potentially be unassociated with the presence of neoplasia (Lamb et al., 2019).

CT OF THE PLEURAL SPACE

Thoracic CT can be used in dogs with pleural effusion to detect the underlying cause. Several studies have aimed to identify CT features that could be used to distinguish malignant pleural neoplasia from pleuritis (Watton et al., 2017; Reetz et al., 2018). Although there is a considerable overlap, dogs with malignant pleural effusions are older than dogs with pleuritis; on CT, they frequently show more severe pleural thickening and tend to have costal pleural and pulmonary masses (Watton et al., 2017; Reetz et al., 2018).

CT characteristics of pleural space masses and nodules have been described in patients with neoplasia (mesothelioma and carcinoma) and less frequently in dogs with benign diseases (pleuritis, pyothorax) (Reetz et al., 2012). Dogs with pleural masses commonly present with pleural effusion, and post-contrast

Figure 2. Dorsal reconstruction of the post-contrast images of the thorax of a dog diagnosed with a histiocytic sarcoma. An irregular, heterogeneous pulmonary mass is noticed in the left cranial lung lobe (between arrowheads) together with markedly enlarged middle tracheobronchial lymph node (arrow).

Figure 3. Transverse image of the caudal thorax of a dog with pulmonary adenocarcinoma, showing a large mass in the left caudal lung lobe, characterized by the presence of an intraparenchymal gas-filled lesion (cavitary mass).

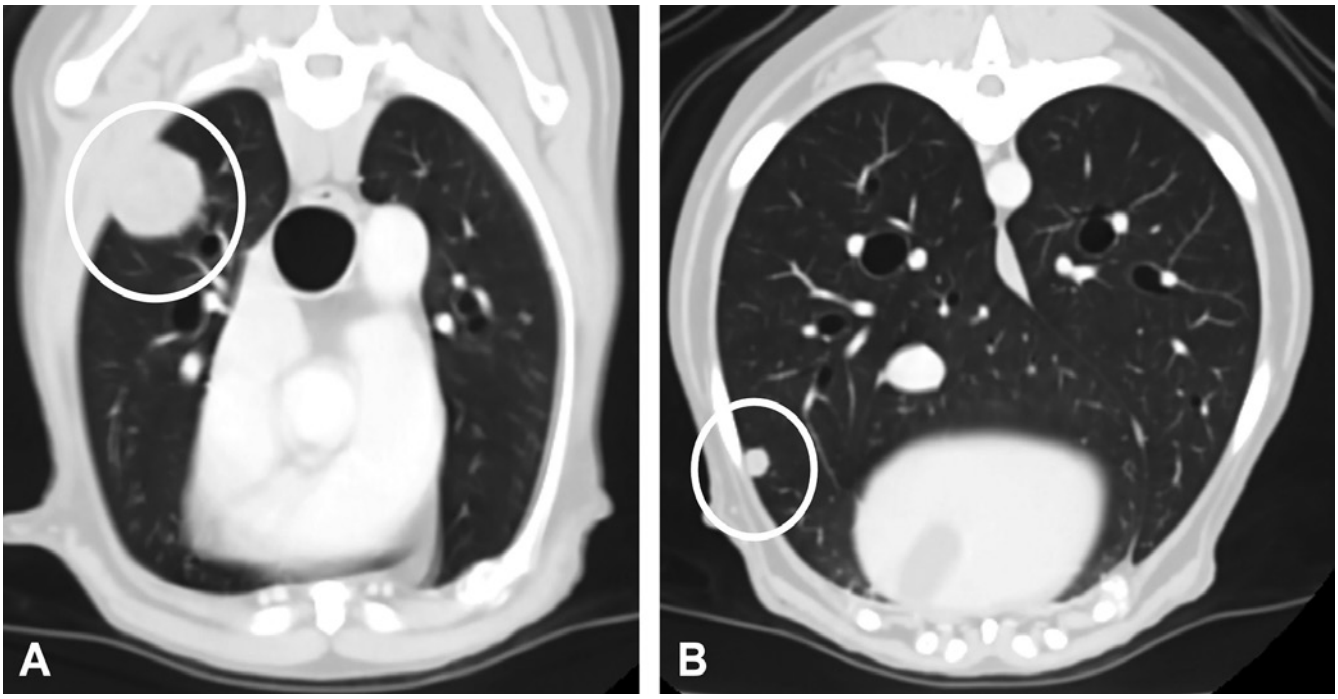

Figure 4. Two transverse images of the lungs of the same dog diagnosed with a mammary carcinoma. Two rounded, well-defined, pulmonary nodules (between circles) of different size are seen in two different lung lobes (A. right cranial and B. right caudal lobes).

CT is helpful in delineating the lesions from the effusion (Reetz et al., 2012). Furthermore, CT has proven to be important as guidance for further diagnostic procedures, such as thoracoscopy and exploratory thoracotomy (Reetz et al., 2012).

The widespread dissemination of metastatic neoplastic cells in the peritoneal and pleural space has been described in dogs both in case of carcinoma (carcinomatosis) and sarcoma (sarcomatosis). In a recent study by Wenston et al. (2021), well-defined nodules with a heterogeneous contrast enhancement were more suggestive of sarcomatosis, while carcinomatosis nodules are poorly defined, with a homogeneous contrast enhancement (Wenston et al., 2021).

Mesothelioma is a rare tumor affecting the epithelial lining of a coelomic cavity. CT characteristics in dogs have been rarely described and include pleural effusion and multiple areas of soft tissue thickening along the body wall with concomitant areas of subpleural thickening (Echandi et al., 2007).

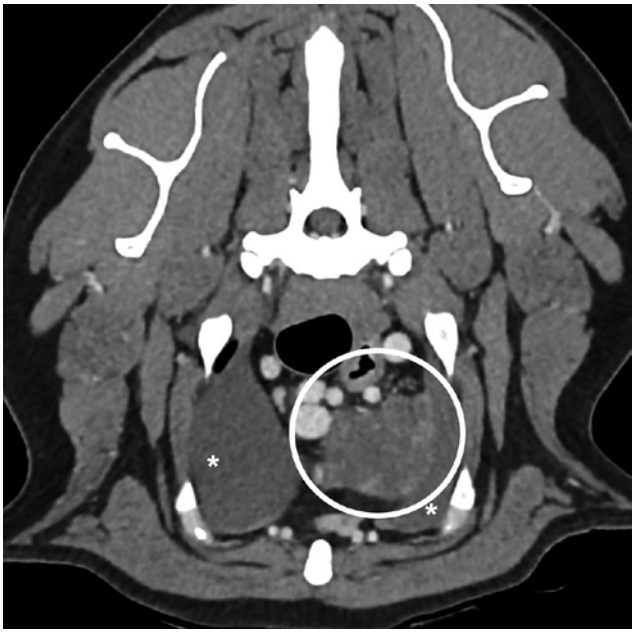

Figure 5. Transverse CT image of the post-contrast series of the cranial mediastinum of a dog diagnosed with thymoma. Well-defined, irregular, heterogeneous cranial mediastinal mass (between circle) associated with bilateral pleural effusion (asterisks).

CT OF THE MEDIASTINUM

Mediastinal masses

Mediastinal masses are relatively common in dogs. Malignancies include lymphoma, thymoma, neurogenic tumor, paraspinal tumor, ectopic thyroid or parathyroid tumor, and heart-base tumors. CT is useful in the presurgical staging of cranial mediastinal masses in dogs (Yoon et al., 2004). Thymoma is the second most common cranial mediastinal mass in dogs (Figure 5); CT features of this neoplasm have been recently described. Thymoma can be small and well-circumscribed or large and invasive, and it is usually heterogeneously contrast enhancing. Larger tumors are more likely to have cystic appearance and can be associated with vascular invasion and recurrence after surgical resection (von Staede et al., 2019).

Cranial mediastinal lymphomas and thymomas

can be difficult to differentiate, both clinically and radiographically. Some CT features have been described in order to distinguish these two tumor types: thymic epithelial neoplasms tend to occur in older dogs and are more heterogeneous, whereas mediastinal lymphomas appear to be homogeneous and more likely to envelop the cranial vena cava (Reeve et al., 2019).

Thoracic lymphadenopathy

Different lymph nodes are visible at CT examination in dogs: sternal, cranial mediastinal and tracheobronchial lymph nodes are typically assessed for metastatic disease in case of thoracic neoplasia (Kayanuma et al., 2020). Tracheobronchial lymphadenopathy can be present in dogs with primary lung tumors and is better detected at CT examination than by thoracic radiography (Paoloni et al., 2006). A significantly lower survival time has been described in dogs with high-grade lung tumors and metastases to tracheobronchial lymph nodes (Paoloni et al., 2006). A maximum tracheobronchial lymph node diameter greater than 12 mm is suggestive for metastatic disease, as well as heterogenous or ring pattern of contrast enhancement (Ballegeer et al., 2010).

The sternal lymph nodes are important in the staging of both thoracic and abdominal neoplasia, as well as mammary gland complex neoplasia (Iwasaki et al., 2018). Sternal lymphadenopathy has been frequently detected in dogs with multicentric lymphoma, splenic hemangiosarcoma and histiocytic sarcoma, and in a multitude of different neoplasia (Smith et al., 2012) (Figure 6). Enlargement of the sternal lymph node is however not restricted to (primary or metastatic) neoplasia but can be associated with infectious or inflammatory processes. In a recent study by Iwasaki et al. (2018), it has been shown that the sternal lymph node-to-second sternebra ratio is significantly higher in metastatic than in reactive lymph nodes.

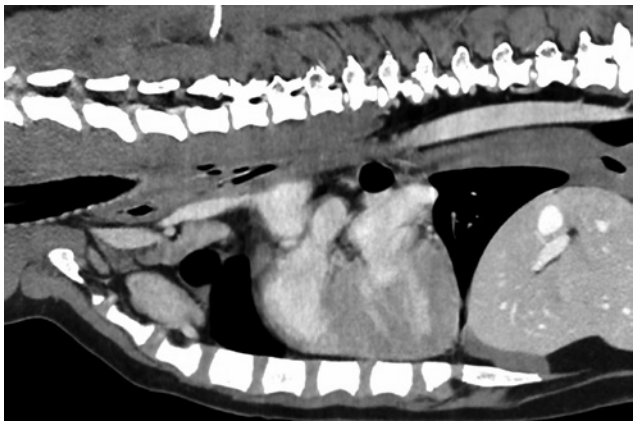

Figure 6. Sagittal reconstruction of the thorax of a dog with markedly enlarged sternal lymph node, seen as a well-defined soft tissue attenuating, contrast-enhancing structure dorsal to the second-third sternebrae. This dog was diagnosed with lymphoma.

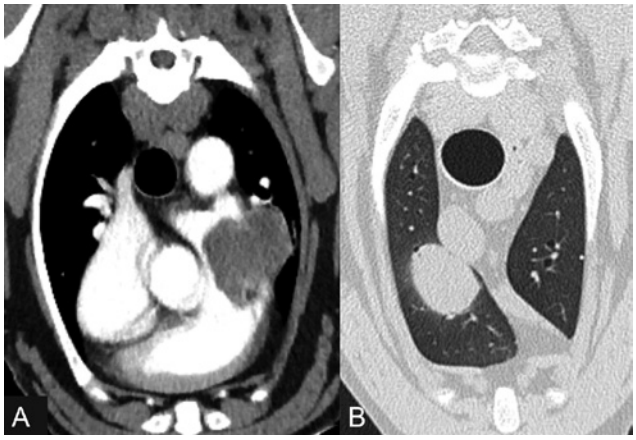

Figure 7. Two transverse images of A. the heart and B. the cranial lungs of the same dog. The CT examination is useful in identifying and characterizing the cardiac lesion, and at the same time, it permits to identify pulmonary metastasis.

Cardiac and muscular neoplasia

Pericardial effusion is a cardiac condition that results in the accumulation of fluid within the pericardium and can be secondary to cardiac neoplasia. The most common types of cardiac neoplasia in dogs are hemangiosarcoma, chemodectoma and mesothelioma. CT is a useful modality in the clinical setting, and its use is recommended in dogs with cardiac neoplasia as it allows a more comprehensive staging of the thorax and abdomen with a single study (Scollan et al., 2015). The use of CT increases the detection of pulmonary metastases, helps in the definition of tumor location, and allows to assess neoplastic lesions in the abdominal cavity with only one modality and scan (Scollan et al., 2015) (Figure 7).

Muscular metastases, including cardiac, may occur in dogs with different tumors. Whole body CT enables visualization of muscular metastatic lesions and is therefore recommended for the staging of oncologic patients (Vignoli et al., 2013). In a study by Carloni et al. (2019), hemangiosarcomas in dogs have been shown to have a high prevalence of muscular metastases; CT has been described as the best available imaging modality for the staging of these patients (Carloni et al., 2019).

POSSIBLE FURTHER APPLICATIONS

Thoracic CT is widely used in veterinary medicine for the evaluation of thoracic structures in dogs with thoracic and non-thoracic neoplasia. The structures most commonly assessed are lungs, pleural space and mediastinum. Despite some minor disadvantages, such as the relatively high cost (when compared to e.g. radiography) and the need for sedation/general

anesthesia, this modality is superior to other imaging modalities due to its intrinsic characteristics. CT examination could be used for the characterization of other thoracic structures, as described in human medicine: CT can be a useful tool in the detection and characterization of tumors of the thoracic wall (Nam et al., 2011) or can help in the evaluation of primary and metastatic processes of less studied mediastinal organs, such as thymus (other than thymoma), trachea, esophagus, nerves and vessels (Takahashi et al., 2010; Jia et al., 2022; Zhang et al., 2023).

CONCLUSION

The use of thoracic CT in dogs is recommended both for the characterization of primary neoplasia, such as pulmonary or mediastinal, and for the detection of (distant) metastases in case of (non-)thoracic neoplasia.

REFERENCES

Alexander K, Joly H, Blond L, D'Anjou MA, Nadeau ME, Olive J, Beauchamp G (2012). A comparison of computed tomography, computed radiography, and film-screen radiography for the detection of canine pulmonary nodules. *Veterinary Radiology and Ultrasound 53*, 258-265.

Armbrust L, Biller DS, Bamford A, Chun R, Garrett LD, Sanderson MW (2012). Comparison of three-view thoracic radiography and computed tomography for detection of pulmonary nodules in dogs with neoplasia. *Journal of American Veterinary Medical Association 240*, 1088-1094.

Ballegeer EA, Adams WM, Dubielzig RR, Paoloni MC, Klauer JM, Keuler NS (2010). Computed tomography characteristics of canine tracheobronchial lymph node metastasis. *Veterinary Radiology and Ultrasound 51*, 397-403.

Bello AM, Anselmi C, Frau M, Berman KG, Novellas R, Espada Y, Longley MJ, Dhumeaux MP (2022). Pulmonary carcinoma associated with cystic airspaces in two dogs. *Journal of Small Animal Practice 63*, 486-449.

Bertolini G, Prokop M. (2011). Multidetector-row computed tomography: technical basics and preliminary clinical applications in small animals. *Veterinary Journal 189,* 15-26.

Carloni A, Terragni R, Morselli-Labate AM, Paninarova M, Graham J, Valenti P, Alberti M, Albarello G, Millanta F, Vignoli M (2019). Prevalence, distribution, and clinical characteristics of hemangiosarcoma-associated skeletal muscle metastases in 61 dogs: A whole body computed tomographic study. *Journal of Veterinary Internal Medicine 33*, 812-819.

Eberle N, Fork M, von Babo V, Nolte I, Simon D (2011). Comparison of examination of thoracic radiographs and thoracic computed tomography in dogs with appendicular osteosarcoma. *Veterinary and Comparative Oncology 9*, 131-140.

Echandi RL, Morandi F, Newman SJ, Holford A (2007). Imaging diagnosis - canine thoracic mesothelioma. *Veterinary Radiology and Ultrasound 48*, 243-245.

Fukuda S, Reetz JA, Hamamoto K, Griffin L, Schaffer PA (2022). Diagnostic imaging and histopathologic features of rounded atelectasis in four cats and one dog: A descriptive case series study. *Veterinary Radiology and Ultrasound 64,* 411-419.

Hunt TD, Wallack ST (2021). Minimal atelectasis and poorly aerated lung on thoracic CT images of normal dogs acquired under sedation. *Veterinary Radiology and Ultrasound 62*, 647-656.

Iwasaki R, Murakami M, Kawabe M, Heishima K, Sakai H, Mori T (2018). Metastatic diagnosis of canine sternal lymph nodes using computed tomography characteristics: A retrospective cross-sectional study. *Veterinary and Comparative Oncology 16*, 140-147.

Jia Y, Zhang Q, Li E, Zhang Z, Chen Z (2022). Submucosal oesophageal squamous cell carcinoma with lymph node metastasis: a case report and literature review. *BMC Gastroenterology 22,* 97. https://doi.org/10.1186/s12876-022-02169-1.

Kayanuma H, Yamada K, Maruo T, Kanai E (2020). Computed tomography of thoracic lymph nodes in 100 dogs with no abnormalities in the dominated area. *Journal of Veterinary Medical Science 82,* 279-285.

Lamb CR, Whitlock J, Foster-Yeow ATL (2019). Prevalence of pulmonary nodules in dogs with malignant neoplasia as determined by CT. *Veterinary Radiology and Ultrasound* 60, 300-305.

Marolf AJ, Gibbons DS, Podell BK, Park RD (2011). Computed tomographic appearance of primary lung tumors in dogs. *Veterinary Radiology and Ultrasound 52*, 168-172.

McNeil EA, Ogilvie GK, Powers BE (1997). Evaluation of prognostic factors for dogs with primary lung tumors: 67 cases (1985–1992). *Journal of American Veterinary Medical Association 211*, 1422-1427.

Miles KG. (1988). A review of primary lung tumors in the dog and cat. *Veterinary Radiology and Ultrasound 29*, 122-128.

Nam SJ, Kim S, Lim BJ, Yoon C-S, Kim TH, Suh J-S, Ha DH, Kwon JW, Yoon YC, Chung HW, Sung MS, Choi YS, Cha JG (2011). Imaging of primary chest wall tumors with radiologic-pathologic correlation. *Radiographics 31*, 749-770.

Nemanic S, London CA, Wisner ER (2006). Comparison of thoracic radiographs and single breath-hold helical CT for detection of pulmonary nodules in dogs with metastatic neoplasia. *Journal of Veterinary Internal Medicine 20*, 508-515.

Otoni CC, Rahal SC, Vulcano LC (2010). Survey radiography and computerized tomography imaging of the thorax in female dogs with mammary tumors. *Acta Veterinaria Scandinavica 52*, 20-29.

Paoloni MC, Adams WM, Dubielzig RR, Kurzman I, Vail DM, Hardie RJ (2006). Comparison of results of computed tomography and radiology with histopathologic findings in tracheobronchial lymph nodes in dogs with primary lung tumors: 14 cases (1999–2002). *Journal of American Veterinary Medical Association 228*, 1718-1722.

Parry M, Selmic LE, Lumbrezer-Johnson S, Lapsley J, Wavreille VA, Hostnic E (2021). Computed tomographic characteristics of cavitary pulmonary adenocarcinoma in 3 dogs and 2 cats. *Canadian Veterinary Journal* 62, 719-724.

Petite A, Kirberger R (2011). Mediastinum. In: Schwarz and Saunders (editors). *Veterinary Computed Tomography*.

John Wiley & Sons Ltd., pp. 249-260.
Prather AB, Berry CR, Thrall DE (2005). Use of radiography in combination with computed tomography for the assessment of noncardiac thoracic disease in the dog and cat. *Veterinary Radiology and Ultrasound 46*, 114-121.
Reetz JA, Suran JN, Zwingenberger AL, Stefanovski D (2019). Nodules and masses are associated with malignant pleural effusion in dogs and cats but many other intrathoracic CT features are poor predictors of the effusion type. *Veterinary Radiology and Ultrasound 60*, 289-299.
Reetz JA, Buza EL, Krick EL (2012). CT features of pleural masses and nodules. *Veterinary Radiology and Ultrasound 53*, 121-127.
Reeve EJ, Mapletoft EK, Schiborra F, Maddox TW, Lamb CR, Warren-Smith CMR (2020). Mediastinal lymphoma in dogs is homogeneous compared to thymic epithelial neoplasia and is more likely to envelop the cranial vena cava in CT images. *Veterinary Radiology and Ultrasound 61*, 25-32.
Ruby J, Secrest S, Sharma A (2020). Radiographic differentiation of mediastinal versus pulmonary masses in dogs and cats can be challenging. *Veterinary Radiology and Ultrasound 61*, 385-393.
Schwarz T, Johnson V (2011). Lungs and Bronchi. In: Schwarz and Saunders (editors). *Veterinary Computed Tomography*. John Wiley & Sons Ltd. Pp 261-278.
Scollan KF, Bottorff B, Stieger-Vanegas S, Nemanic S, Sisson D (2015). Use of multidetector Computed Tomography in the assessment of dogs with pericardial effusion. *Journal of Veterinary Internal Medicine 29*, 79-87.
Smith K, O'Brien R. (2012). Radiographic characterization of enlarged sternal lymph nodes in 71 dogs and 13 cats. *Journal of American Animal Hospital Association 48*, 176-181.
Sutton DR, Hernon T, Hezzell MJ, Meakin LB, Gould SM, Bradley KJ, Major AC (2022). Computed tomographic staging of dogs with anal sac adenocarcinoma. *Journal of Small Animal Practice 63*, 27-33.
Takahashi K, Al-Janabi NJ (2010). Computed tomography and magnetic resonance imaging of mediastinal tumors. *Journal of Magnetic Resonance Imaging 32*, 1325-1339.
Tran DTH, Donovan TA, Daverio H, Le Roux AB (2023). CT features of rounded atelectasis in chronic inflammatory pleural effusions in cats and dogs. *Veterinary Radiology and Ultrasound 64,* 420-428.
Tsai S, Sutherland-Smith J, Burgess K, Ruthazer R, Sato A (2012). Imaging characteristics of intrathoracic histiocytic sarcoma in dogs. *Veterinary Radiology and Ultrasound 53*, 21-27.
Vignoli M, Terragni R, Rossi F, Fruhauf L, Bacci B, Ressel L, Capitani O, Marconato L (2013). Whole body computed tomographic characteristics of skeletal and cardiac muscular metastatic neoplasia in dogs and cats. *Veterinary Radiology and Ultrasound 54*, 223-230.
von Stade L, Randall EK, Rao S, Marolf AJ (2019). CT imaging features of canine thymomas. *Veterinary Radiology and Ultrasound 60*, 659-667.
Watton TC, Lara-Garcia A, Lamb CR (2017). Can malignant and inflammatory pleural effusions in dogs be distinguished using computed tomography? *Veterinary Radiology and Ultrasound 58*, 535-541.
Weston PJ, Baines SJ, Finotello R, Mortier JR (2021). Clinical, CT, and ultrasonographic features of canine and feline pleural and peritoneal carcinomatosis and sarcomatosis. *Veterinary Radiology and Ultrasound 62,* 331-341.
Yoon J, Feeney DA, Cronk DE, Anderson KL, Ziegler LE (2004). Computed tomographic evaluation of canine and feline mediastinal masses in 14 patients. *Veterinary Radiology and Ultrasound 45*, 542-546.
Zhang M, Shi H, Tu X, Li W, Wei Z (2023). Resection of a schwannoma originating from vagus nerve in the right superior mediastinum. *Journal of Cardiothoracic Surgery 18, 69* https://doi.org/10.1186/s13019-023-02177-6.