TITLE: Can malignant and inflammatory pleural effusions in dogs be distinguished using computed tomography

AUTHORS: Thom C. Watton, Ana Lara-Garcia, Christopher R. Lamb

JOURNAL TITLE: Veterinary Radiology & Ultrasound

PUBLISHER: Wiley

PUBLICATION DATE: 16 July 2017 (online)

DOI: 10.1111/vru.12534

Can malignant and inflammatory pleural effusions in dogs be distinguished using computed tomography?

Thom C. Watton, Ana Lara-Garcia, Christopher R. Lamb

Department of Clinical Sciences and Services, The Royal Veterinary College, University of London

Address correspondence to: C. R. Lamb, Department of Clinical Sciences and Services, The Royal Veterinary College, Hawkshead Lane, North Mymms, Hertfordshire AL9 7TA, UK.

Tel: 01707-666234

Email: clamb@rvc.ac.uk

Key words: computed tomography, chylothorax, dog, mesothelioma, pleural disease, pyothorax

Running head: CT of pleural effusions

Funding Sources: The authors received no financial support for the research, authorship or publication of this article.

Abstract

Computed tomography (CT) is the primary imaging modality used to investigate human patients with suspected malignant or inflammatory pleural effusion, but there is a lack of information about the clinical use of this test in dogs. In order to identify CT signs that could be used to distinguish pleural malignant neoplasia from pleuritis, a retrospective case-control study was done based on dogs that had pleural effusion, pre- and post-contrast thoracic CT images, and cytological or histopathological diagnosis of malignant or inflammatory pleural effusion. There were 20 dogs with malignant pleural effusion (13 mesothelioma, 6 carcinoma; 1 lymphoma), and 32 dogs with pleuritis (18 pyothorax; 14 chylothorax). Compared to dogs with pleuritis, dogs with malignant pleural effusions were significantly older (median 8.5 years versus 4.9 years, p=0.001), more frequently had CT signs of pleural thickening (65% versus 34%, p= 0.05), tended to have thickening of the parietal pleura only (45% versus 3%, p=0.002) and had more marked pleural thickening (median 3mm versus 0mm, p=0.03). CT signs of thoracic wall invasion were observed only in dogs with malignant pleural effusions (p= 0.05). There were no significant differences in pleural fluid volume, distribution or attenuation, degree of pleural contrast accumulation, amount of pannus, or prevalence of mediastinal adenopathy. Although there was considerable overlap in findings in dogs with malignant pleural effusion and pleuritis, marked thickening affecting the parietal pleural alone and signs of thoracic wall invasion on CT support diagnosis of pleural malignant neoplasia, and may help prioritize further diagnostic testing.

Introduction

Pleural fluid accumulation may occur as a result of several different pathologic mechanisms that determine the nature of the fluid.[1] Inspection of pleural fluid is the basis for tentative diagnosis in many instances[2]; however, pleural fluid containing blood, moderate protein and non-specific cellular content can occur with neoplasia, inflammatory or idiopathic conditions[3,4], and fluid analysis alone may be insufficient for diagnosis. Although low in prevalence, the neoplasms that most frequently cause pleural effusion in dogs by direct seeding and invasion of the pleura are mesothelioma and carcinoma. Mesothelioma, a primary malignant neoplasm of the pleura[5-7], pericardium[8-10] or peritoneum[10-12], can be particularly difficult to diagnose on routine cytologic preparations because malignant mesothelial cells may appear similar to the reactive mesothelial cells seen with inflammatory pleural conditions.[1,6,13,14] Carcinoma metastasis to the pleura can also be difficult to diagnose cytologically and may require immunocytochemical analysis of the effusion or histopathology.[15] Metastasis to the pleura could occur with any type of carcinoma, but in the dog this condition is mainly associated with primary epithelial lung tumors, mammary carcinoma, prostatic carcinoma and transitional cell carcinoma of the urinary bladder.[16] Dogs with pleural carcinoma (or sarcoma) usually have a primary tumor elsewhere, the detection of which aids diagnosis of the pleural effusion.

Diagnostic imaging is indicated for patients with pleural effusion of unknown cause. Depending on clinical signs, ultrasonography and/or radiography may be performed first and may enable detection of various well-recognized predisposing causes of pleural effusion, such as thoracic masses, lung lobe torsion, pericardial disease, and cardiac failure. When echocardiography and radiography are negative or findings are non-specific,

computed tomography (CT) is indicated to examine the thorax in more detail.[17] CT is the primary imaging modality used for humans with suspected pleural neoplasia.[18-21] There have been numerous studies of the CT features of pleural mesothelioma and other pleural malignancies in humans.[18-24] CT features that support a diagnosis of pleural malignant neoplasia rather than pleuritis include pleural thickening >1cm, nodular thickening, interlobar distribution of thickening, and thoracic volume contraction.[18-26]

There have been fewer reports of imaging findings in dogs with malignant neoplasia affecting primarily the pleura. The radiographic signs primarily represent pleural or pericardial fluid accumulation, although pleural masses due to mesothelioma may be visible in radiographs made after fluid drainage.[6] Few reports describe use of CT to examine the pleura in dogs. Multifocal, irregular thickening of the parietal pleura on CT was illustrated in a report of a dog with pleural mesothelioma.[27] Pleural thickening in CT images was also reported in 8/12 (67%) dogs[28] and 3/10 (30%) dogs[29] with pyothorax, but was not described in detail. A more recent study[30] described the CT findings in 7 dogs with various pleural conditions including primary and metastatic neoplasia and pleuritis. Masses and nodular lesions affecting the pleura were observed in 5/7 (71%) dogs, but there was no apparent association between the morphologic features of pleural lesions and the specific diagnosis.[30] Even on gross inspection, pleural masses due to mesothelioma may resemble granulation tissue.[10] For patients in which pleural masses are suspected but not visualized clearly or imaging findings are non-specific, thoracoscopy or thoracotomy for pleural biopsy is indicated.

The aim of the present study was to compare the results of CT in a larger series of dogs with pleural effusion secondary to pleural malignant neoplasia or pleuritis in order to identify signs that could be used to distinguish these conditions.

Materials and Methods

Ethical approval was granted by the Clinical Research Ethical Review Board at the Royal Veterinary College. For this retrospective case-control study, medical records from the Queen Mother Hospital for Animals (QMHA) in the period 2010-2016 were searched by one observer (TCW) for dogs that had pleural effusion, pre- and post-contrast thoracic CT images, and cytologic or histopathologic diagnosis of pleural effusion secondary to pleural malignant neoplasia or pleuritis. For the purposes of this study, pleuritis included pyothorax and chylothorax. Although chylothorax has various primary causes, the effect of chyle on the pleura is inflammatory.[31] Dogs with primary neoplasia affecting non-pleural thoracic structures were not included. Dogs in which a migrating thoracic foreign body was visible in CT images were also not included.

Diagnosis of malignant pleural neoplasia was based on compatible cytologic, histologic and/or immunohistochemical findings. Criteria for pleural malignant neoplasia were characteristic cellular morphology on cytologic[16] or histologic preparations and, when diagnosis was uncertain, immunocytochemistry or immunohistochemistry for vimentin and cytokeratin.[15] Diagnosis of pyothorax was based on cytologic evidence of suppurative bacterial infection of pleural fluid with or without positive culture. Diagnosis of chylothorax was based on finding small lymphocytes to be the most numerous cell type and elevated

pleural fluid triglyceride concentration (>2.84mmol/L). In all instances, diagnosis by a board-certified veterinary clinical pathologist was required for inclusion in the study.

As part of the inclusion criteria, all CT images were acquired using the same multi-slice scanner (MX8000 IDT, Phillips Best, the Netherlands), and transverse images were reviewed using a DICOM viewer (OsiriX version 7.01). Studies lacking pre- and post-contrast series obtained with optimal settings for soft tissue examination were excluded. For the purposes of this study, optimal settings were helical acquisition, slice thickness up to 3mm, medium frequency ('soft tissue') reconstruction algorithm, and with post-contrast CT images acquired 60 seconds after the start of intravenous injection of 2ml/kg of iohexol 300mg/ml (Omnipaque 300, GE Healthcare, Oslo, Norway). Studies with evidence of excessive motion blur were also excluded.

All CT studies were reviewed by a single board-certified radiologist (CRL) without knowledge of signalment, clinical history or diagnosis. In cases where multiple CT studies had been done, only the first CT study with evidence of pleural effusion was selected for review. CT images were reviewed using soft tissue (width 320 HU; level 80 HU) and lung (width 1500 HU; level -500 HU) windows with reference to several subjective and objective criteria. The presence of pericardial, pleural or mediastinal fluid, the distribution of pleural fluid (symmetrical or asymmetrical), presence of pleural thickening, presence of pannus, mediastinal lymphadenopathy, and evidence of thoracic wall invasion were recorded. Pleural fluid average attenuation measurements (Hounsfield units, HU) were made using a single circular region of interest placed on the largest visible collection of pleural fluid in pre-contrast images. Pleural thickening was defined as a hyperdense line at the border of pleural fluid collections in post-contrast CT images, and was classified by site (visceral,

parietal or both) and morphology (diffuse, lobar, nodular, mass-like and/or calcified). Attenuation measurements using a point region of interest and a thickness measurement (mm) were recorded at the site of maximal pleural thickening where applicable. The term pannus refers to fibrovascular tissue within the pleural cavity that tends to form sheets and exhibits enhancement following intravenous contrast administration. Subjective assessment of pleural fluid volume, amount of pannus, and degree of mediastinal lymphadenopathy were recorded using an ordinal scale (0, none; 1, slight; 2, marked). Diagnosis of thoracic wall invasion was based on observing thickening of intercostal muscles, loss of intermuscular fat planes, streaking of intercostal or sub-cutaneous fat, periosteal reaction on ribs or sternebrae and/or lysis of ribs or sternebrae.

Data were analyzed using a commercial statistical software package (SPSS 22, IBM). Fisher's exact test was used to test differences in categorical data, and Mann-Whitney tests were utilized to test differences in continuous data between dogs that had pleural malignant neoplasia or pleuritis. Differences with $p<0.05$ were considered significant. Binomial 95% confidence intervals (CI) for estimates of likelihood ratios were determined using the statistical calculator provided by the Centre for Evidence Based Medicine (http://ktclearinghouse.ca/cebm/practise/ca/calculators/statscalc).

Results

Fifty-two dogs satisfied all criteria for inclusion in the study. There were 24 females (14 neutered) and 28 males (18 neutered) representing 22 different pedigree dog breeds plus 6 crossbred dogs. Twenty dogs had pleural malignant neoplasia (13 mesothelioma, 6 metastatic carcinoma, 1 lymphoma) and 32 had pleuritis (18 pyothorax, 14 chylothorax).

Diagnosis of mesothelioma was based on histology in 8 dogs, immunohistochemistry in one, immunocytochemistry in one and cytology in 3 dogs. Diagnosis of carcinoma or lymphoma was based on cytology in each instance. Median age of dogs that had pleural malignant neoplasia was 8.5 years (range 4.0-12.8 years) compared to 4.9 years (range 1.3-13.0 years) for dogs with pleuritis (p=0.001).

Results of CT are summarized in Table 1. Pleural thickening was the sign most frequently observed in dogs with malignant pleural effusion (figure 1) whereas enlarged mediastinal lymph nodes was the sign most frequently observed in dogs with pleuritis. Dogs with malignant pleural effusion more frequently had CT signs of pleural thickening (65% versus 34%, p= 0.03), tended to have thickening of the parietal pleura only (65% versus 13%, p=0.01) and had more marked pleural thickening (median 3mm versus 0mm, p=0.01). CT signs of thoracic wall invasion were observed only in dogs with malignant pleural effusions (p=0.05) (figure 2). Likelihood ratios for pleural malignant neoplasia for categorical CT signs of significance or borderline significance were: pleural thickening 1.9 (95% CI 1.1-3.0); parietal pleural thickening only 5.2 (95% CI 2.0-13.7); and thoracic wall invasion 11.0 (95% CI 0.6-202.4). The likelihood ratio for visceral pleural thickening as a signs of pleuritis was 3.1 (95% CI 0.8-12.8). The criterion pleural thickening >1cm was not significantly associated with pleural malignant neoplasia. There were also no significant differences in pleural fluid volume, distribution or attenuation, degree of pleural contrast accumulation, amount of pannus (figure 3) or prevalence of mediastinal adenopathy or pulmonary nodules. Cause of pulmonary nodules in dogs with pleuritis was not determined: none had signs of malignant neoplasia affecting non-thoracic structures, but none were examined pathologically.

Discussion

In this study there was marked overlap in the CT signs observed in dogs with malignant pleural effusion and dogs with pleuritis. As reported in humans[18-26], pleural thickening may be observed in patients with either malignant effusion or pleuritis, hence although CT is indicated as an aid to differential diagnosis of pleural effusion, it appears to be inaccurate. In the dogs in the present series, the most discriminating CT sign (i.e. that with the highest likelihood ratio for pleural malignancy) was thoracic wall invasion; however, this was observed in only 15% dogs with mesothelioma, which suggests it is not a sensitive sign, and was of borderline statistical significance because of the wide confidence interval associated with small number of affected dogs. Parietal pleural thickening in the absence of visceral pleural thickening also appears to be a useful discriminating sign. This was observed in 45% dogs with malignant pleural effusion and only 3% dogs with pleuritis. Conversely, visceral pleural thickening was observed in 10% dogs with malignant pleural effusion and 31% dogs with pleuritis, although this difference was not significant. Malignant pleural effusion was associated with a greater median pleural thickening that pleuritis, but there were no significant differences in the prevalence of nodular thickening or calcified pleural lesions. Foci of calcification or ossification in mesotheliomas has been reported infrequently in dogs[8], hence the potential diagnostic value of this sign appears to be limited.

The normal pleura of humans is too thin to be visible in CT images.[20] On the basis of unpublished observations in a limited number of dogs with pleural transudates, we believe the same is true in dogs; therefore, observing a hyperdense line in post-contrast CT images at the border of a pleural fluid collection was considered to be evidence of pleural thickening even if the line was too thin for accurate measurement of thickness or

attenuation value. Visceral pleural thickening is most clearly visible in animals that also have pneumothorax (usually because of pleural drain placement).

The mechanisms that promote pleural effusion are similar in animals with neoplastic and inflammatory pleural conditions, including increased permeability of the pleural microvasculature and impaired lymphatic drainage from the pleural cavity because of tumor or fibrosis obstructing lymphatic vessels.[1,20] The presence of a thoracostomy tube can also induce pleural effusion, with potential for secondary infection when tubes have been in placed more than a few days.[32]

Markedly asymmetrical (including unilateral) distribution of pleural fluid was observed in the present study only in dogs with pleuritis, and has been noted in an earlier study of dogs with pyothorax.[28] This finding could reflect restricted flow of pleural fluid by increased viscosity and/or obstruction of normal routes by fibrin 'peel' that coats the pleura. Organization of fibrin peel with ingrowth of capillaries and fibroblasts occurs within 7 days of the onset of pleuritis.[20] Pannus is a term used for fibrovascular tissue that occurs in inflammatory conditions that tends to form sheets over structures, such as the cornea.[33] This term is also applicable to the sheet- or mass-like tissue that replaces fibrin peel in dogs with inflammatory or reactive pleural effusion.[34] In CT images, pannus may be distinguished from fibrin peel because it enhances after intravenous contrast administration, and distinguished from true pleural thickening when it occupies the pleural cavity with minimal contact with the pleural surfaces; however, without detailed imaging-pathologic correlation, it is possible that some masses due to pleural neoplasia in this series could have been misinterpreted as pannus, and vice versa, particularly when pannus is thick and/or in broad contact with the pleura. Compared to CT, ultrasonography may be advantageous in

distinguishing these entities because real-time imaging displaying motion of sheet-like tissue would support diagnosis of pannus; however, sessile, immobile pleural masses may remain difficult to diagnose on the basis of their imaging features alone.

Diagnosis of malignant pleural effusion is most challenging in patients in which no primary neoplasm can be found elsewhere in the body. Whereas most dogs with pleural carcinoma will have a primary neoplasm in the lung or abdomen, no other primary neoplasm will be found in dogs with mesothelioma, hence mesothelioma is the more challenging diagnosis. In the present study, only 3 dogs with mesothelioma were diagnosed on the basis of cytology alone; most required immunological testing or histology. When mesothelioma is suspected there is a need for detailed examination of the pleura. The importance of the present study is that it provides new information about use of CT to examine the pleura, which should help address this clinical problem.

To minimize bias, and to replicate the indication for detailed imaging examination of the pleura, we did not include dogs in this study whose CT images contained signs that strongly suggested either neoplasia or inflammatory conditions, such as intrathoracic masses or foreign material. Presence of a pulmonary mass, for example, could bias an observer towards an assumption of malignant pleural effusion, and to overemphasize related findings such as adenopathy or pleural thickening. The occurrence of pulmonary nodules in a similar proportion of dogs with malignant effusion and dogs with pleuritis emphasizes the non-specific nature of that finding.

The main limitation of the present study is the small number of dogs included. This mainly reflects the difficulty collecting larger numbers of dogs with primary pleural neoplasia, but is problematic because it means that our estimates of the prevalence of various CT features

241 will be imprecise, which limits the statistical power of the tests done to compare the
242 neoplastic and pleuritis groups.

243 Neoplastic processes resulting in pleural effusion can present a significant diagnostic
244 challenge and have been associated historically with a poor prognosis.[6,7,13] Recent advances
245 in malignant effusion management with pleural ports and intracavitary chemotherapy
246 appear to provide an improved prognosis.[35,36] Definite diagnosis of mesothelioma
247 sometimes requires pleural biopsy via thoracoscopy or thoracotomy. Invasive procedures
248 such as these may not be favored by veterinarians or owners in the absence of supportive
249 imaging findings. On the basis of the present study, it may be concluded that CT signs of
250 marked thickening affecting the parietal pleural alone and signs of thoracic wall invasion
251 support diagnosis of pleural malignant neoplasia whereas visceral pleural thickening
252 supports a diagnosis of pleuritis. These results may help prioritize further diagnostic testing
253 of dogs with pleural effusion.

254

255 **List of Author Contributions**

256 Category 1

257 (a) Conception and Design

258 Author name(s) Thom C. Watton, Ana Lara-Garcia, Christopher R. Lamb

259 (b) Acquisition of Data

260 Author name(s) Thom C. Watton, Ana Lara-Garcia, Christopher R. Lamb

261 (c) Analysis and Interpretation of Data

262 Author name(s) Thom C. Watton, Christopher R. Lamb

Category 2

(a) Drafting the Article

Author name(s) Thom C. Watton, Ana Lara-Garcia, Christopher R. Lamb

(b) Revising Article for Intellectual Content Author name(s) Thom C. Watton, Ana Lara-Garcia, Christopher R. Lamb

Category 3

(a) Final Approval of the Completed Article Author name(s) Thom C. Watton, Ana Lara-Garcia, Christopher R. Lamb

271 **References**

272 1. Dempsey SM, Ewing PJ. A review of the pathophysiology, classification, and analysis of
273 canine and feline cavitary effusions. J Am Anim Hosp Assoc 2011;47: 1-11.

274 2. Tyler RD, Cowell RL. Evaluation of pleural and peritoneal effusions. Vet Clin North Am-
275 Small Anim Pract 1989;19: 743-768.

276 3. Nakamura RK, Rozanski EA, Rush JE. Non-coagulopathic spontaneous hemothorax in
277 dogs. J Vet Emerg Crit Care 2008;18: 292-297.

278 4. Vogtli T, Gaschen F, VogtliBurger R, Lombard C. Hemorrhagic pericardial effusion in the
279 dog: A retrospective study of 10 cases (1989-1994) with a review of the literature.
280 Schweizer Archiv fur Tierheilkunde 1997;139: 217-224.

281 5. Dubielzig RR. Sclerosing mesothelioma in 5 dogs. J Am Anim Hosp Assoc 1979;15: 745-
282 748.

283 6. Thrall DE, Goldschmidt MH. Mesothelioma in dog - 6 case-reports. J Am Vet Radiol Soc
284 1978;19: 107-115.

285 7. Morrison WB, Trigo FJ. Clinical characterization of pleural mesothelioma in 7 dogs.
286 Compend Contin Educ Pract Vet 1984;6: 342-348.

287 8. Yamamoto S, Fukushima R, Kobayashi M, Machida N. Mixed form of pericardial
288 mesothelioma with osseous differentiation in a dog. J Comp Pathol 2013;149: 229-232.

289 9. Ceribasi S, Ozkaraca M, Ceribasi AO, Ozer H. Pericardial mesothelioma in a German
290 Shepherd dog: a case report. Vet Med 2013;58: 594-598.

291 10. Smith DA, Hill FWG. Metastatic malignant mesothelioma in a dog. J Comp Pathol
292 1989;100: 97-101.

293 11. D'Angelo AR, Di Francesco G, Quaglione GR, Marruchella G. Sclerosing peritoneal
294 mesothelioma in a dog: histopathological, histochemical and immunohistochemical
295 investigations. Vet Ital 2014;50: 301-305.

296 12. Gumber S, Fowlkes N, Cho DY. Disseminated sclerosing peritoneal mesothelioma in a
297 dog. J Vet Diagn Invest 2011;23: 1046-1050.

298 13. Mott FE. Mesothelioma: a review. Ochsner J 2012;12:70-79.

299 14. Hirsch VM, Farrow CS. A scirrhous anaplastic carcinoma in two dogs resembling
300 mesothelioma. Can Vet J 1981;22:271-276.

301 15. Przeździecki R, Sapierzyński R. Using of immunocytochemistry in differential diagnosis
302 of neoplasms of serosal cavities in dogs. Pol J Vet Sci.2014;17(1):149-59.

303 16. Rebar AH, Thopson CA. Body cavity effusions. In: RE Raskin, DJ Meyer (Eds.) Atlas of
304 canine and feline cytology. WB Saunders, Philadelphia; 2010: 185-187.

305 17. Prather AB, Berry CR, Thrall DE. Use of radiography in combination with computed
306 tomography for the assessment of noncardiac thoracic disease in the dog and cat. Vet
307 Radiol Ultrasound 2005;46:114-121.

308 18. Benamore RE, O'Doherty MJ, Entwistle JJ. Use of imaging in the management of
309 malignant pleural mesothelioma. Clin Radiol 2005;60:1237-1247.

310 19. Traill ZC, Davies RJO, Gleeson FV. Thoracic computed tomography in patients with
311 suspected malignant pleural effusions. Clin Radiol 2001;56:193-196.

312 20. Müller NL. Imaging of the pleura. Radiology 1993;186:297-309.

21. Metintas M, Ucgan I, Elbek O, Erginel S, Metintas S, Kolsuz M, et al. Computed tomography features in malignant pleural mesothelioma and other commonly seen pleural diseases. Eur J Radiol 2001;41:1-9.

22. Sahin AA, Çöplü L, Selçuk ZT, Eryilmaz M, Emri S, Akhan O, et al. Malignant pleural mesothelioma caused by environmental exposure to asbestos or erionite in rural Turkey: CT findings in 84 patients. Am J Roentgenol 1993;161:533-537.

23. Kawashima A, Libshitz HI. Malignant pleural mesothelioma: CT manifestations in 50 cases. Am J Roentgenol 1990;155:965-969.

24. Wang ZJ, Reddy GP, Gotway MB, Higgins CB, Fablons DM, Ramaswamy M, et al. Malignant mesothelioma: evaluation with CT, MR imaging, and PET. RadioGraphics 2004;24:105-119.

25. Aquino SL, Webb WR, Gushiken BJ. Pleural exudates and transudates: diagnosis with contrast-enhanced CT. Radiology 1994;192:803-808.

26. Waite RJ, Carbonneau RJ, Balikian JP, Umali CB, Pezzela AT, Nash G. Parietal pleural change in empyema: appearances at CT. Radiology 1990;175:145-150.

27. Echandi RL, Morandi F, Newman SJ, Holford A. Imaging diagnosis – Canine thoracic mesothelioma. Vet Radiol Ultrasound 2007;48:243-245.

28. Swinbourne F, Baines EA, Baines, SJ, Halfacree ZJ. Computed tomographic findings in canine pyothorax and correlation with findings at exploratory laparotomy. J Small Anim Pract 2011;52:203-208.

29. Caivano D, Birettoni F, Rishniw M, Bufalari A, De Monte V, Proni A, et al. Ultrasonographic findings and outcomes of dogs with suspected migrating intrathoracic grass awns: 43 cases (2010-2013). J Am Vet Med Assoc 2016;248: 413-421.

30. Reetz JA, Buza EL, Krick EL. CT features of pleural masses and nodules. Vet Radiol Ultrasound 2012;53:121-127.

31. Fossum TW, Evering WN, Miller MW, Forrester SD, Palmer DR, Hodges CC. Severe bilateral fibrosing pleuritis associated with chronic chylothorax in 5 cats and 2 dogs. J Am Vet Med Assoc 1992; 201:317-324.

32. Hung GC, Gaunt MC, Rubin JE, Starrak GS, Sakals SA. Quantification and characterization of pleural fluid in healthy dogs with thoracostomy tubes. Am J Vet Res 2016;77: 1387-1391.

33. Bedford PGC, Longstaffe JA. Corneal pannus (chronic superficial keratitis) in the German Shepherd dog. J Small Anim Pract 1979; 20:41-56.

34. Vansteenkiste DP, Lee KCL, Lamb CR. Computed tomographic findings in 44 dogs and 10 cats with grass seed foreign bodies. J Small Anim Pract 2014;55:579-584.

35. Charney SC, Bergman PJ, McKnight JA, Farrelly J, Novosad CA, Leibman NF, et al. Evaluation of intracavitary mitoxantrone and carboplatin for treatment of carcinomatosis, sarcomatosis and mesothelioma, with or without malignant effusions: retrospective analysis of 12 cases (1997–2002). Vet Comp Oncol 2005;3:171-181.

36. Lara-Garcia A, Kosarek C, Hosoya K, Alvarez F, Smeak D, Pozzi A, et al. Palliative management of malignant effusion with implantable vascular access ports in dogs. (abstract) Vet Comp Oncol 2008;6: 69-70.

Table 1. Computed tomographic features of malignant and inflammatory pleural effusions in 52 dogs

Computed tomographic feature	Malignant (n=20)	Inflammatory (n=32)	p-value
Pleural fluid median (range) attenuation (HU)	19 (12-32)	20 (7-45)	NS
Asymmetrical distribution of fluid	0	5 (16%)	NS
Pleural thickening	17 (85%)	14 (44%)	0.03
Parietal/visceral/both	13/1/1	4/6/4	0.01
Diffuse	6 (30%)	7 (22%)	NS
Nodular	6 (30%)	7 (22%)	NS
Median maximal thickness (mm)	3 (0-40)	0 (0-38)	0.01
Pleura >1cm thick	6 (30%)	4 (13%)	NS
Median pre-/post-C (HU)	38/98	38/77	NS
Median difference	61 (12-98)	35 (10-66)	NS
Calcification of pleura	2 (10%)	0	NS
Pannus	5 (25%)	10 (31%)	NS
Thoracic wall invasion	3 (15%)	0	0.05
Pericardial fluid	1 (5%)	1 (3%)	NS
Mediastinal fluid	2 (10%)	3 (6%)	NS
Mediastinal adenopathy	11 (55%)	21 (66%)	NS
Pulmonary nodules	5 (25%)	4 (13%)	NS

NS, not significantly different, p>0.05

Legends

Figure 1. Examples of diffuse pleural thickening. A) Slight diffuse thickening of the parietal pleura (arrowheads) in a dog with mesothelioma; B) Nodular thickening of the parietal pleura (arrowheads) in a dog with mesothelioma; C) Marked irregular thickening of the parietal and mediastinal pleura (arrowheads) in a dog with pyothorax; D) Slight diffuse thickening of the visceral pleura (arrowheads) in a dog with pyothorax. A-C soft tissue window (width 320 HU; level 80 HU); D lung window (width 1500 HU; level -500 HU).

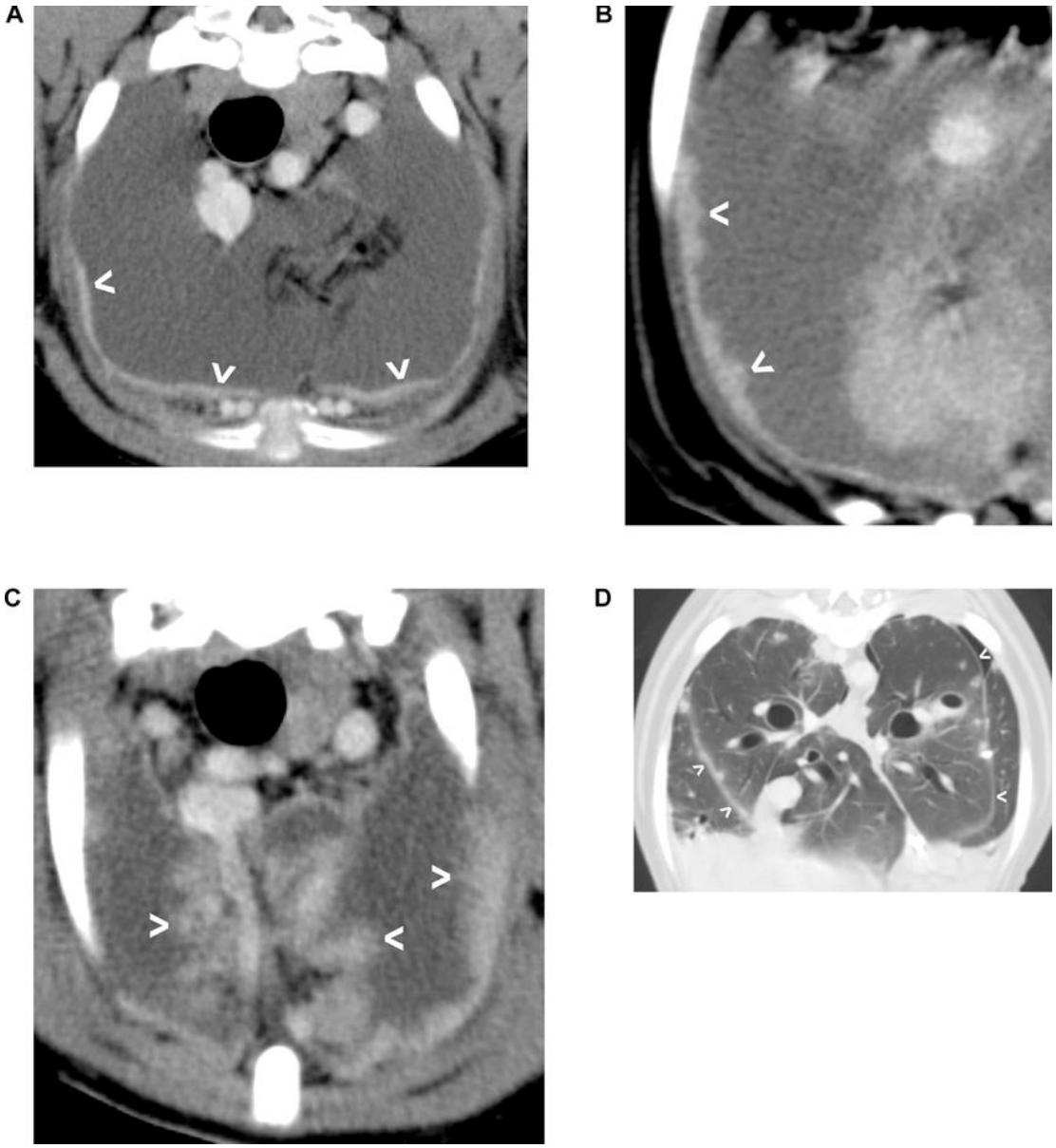

Figure 2. Examples of thoracic wall invasion by mesothelioma. A) Broad mass (*) involving parietal pleura and adjacent intercostal muscles; B) Locally invasive mass (large arrowheads) thickening the inner layer of thoracic wall (small arrowheads) and obliterating the fat plane between muscles of the thoracic wall. Both images displayed using a soft tissue window (width 320 HU; level 80 HU).

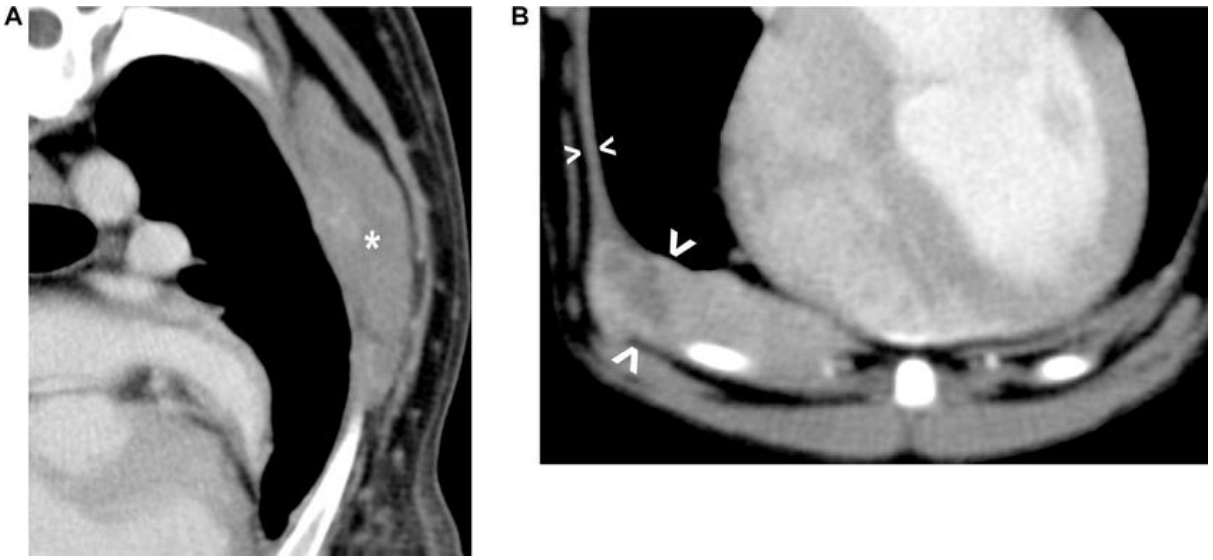

Figure 3. Examples of pannus (A and B) in dogs with pyothorax. In each instance, the morphology of pannus is a thick, folded sheet of tissue (arrowheads) that appears separate from the pleura. An enlarged sternal lymph node (*) is visible in B. Both images displayed using a soft tissue window (width 320 HU; level 80 HU).