**CLINICAL, COMPUTED TOMOGRAPHIC AND ULTRASONOGRAPHIC FEATURES OF CANINE AND FELINE PLEURAL AND PERITONEAL CARCINOMATOSIS AND SARCOMATOSIS**

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**Study design**: Retrospective, multicenter, descriptive study.

**Conflict of interest**

None of the authors have a conflict of interest regarding this study.

**Presentation and publication disclosure**

Findings of this study have not been presented as an oral presentation or published as an abstract.

**EQUATOR network disclosure**

An EQUATOR network checklist was not used in this study.

**Abstract**

Carcinomatosis and sarcomatosis describe the widespread dissemination of metastatic neoplastic cells throughout the body. Studies describing their imaging and clinical features in veterinary patients are limited. The objective of this retrospective, multicenter, cross-sectional study is to describe the clinical, ultrasonographic and computed tomographic features of pleural and peritoneal carcinomatosis and sarcomatosis in dogs and cats to aid detection and differentiation of these lesions. Medical records and computed tomographic and ultrasonographic images were reviewed. Although a large degree of overlap was observed between the imaging features and clinical signs of canine and feline carcinomatosis and sarcomatosis, some distinguishing features were observed. Dogs were significantly more likely to present with abdominal pain compared to cats (P=0.022), whereas cats more commonly presented with inappetence (P=0.019). Dogs with sarcomatosis had a significantly heavier bodyweight than dogs with carcinomatosis (P=0.005), largely due to a higher prevalence of splenic hemangiosarcoma in this patient cohort. Peritoneal effusion was more frequently observed in dogs with carcinomatosis compared to dogs with sarcomatosis (P=0.021).

Imaging and clinical features observed in this study may help to distinguish sarcomatosis and carcinomatosis lesions. Due to the large degree of overlap observed, cytological or histopathological analysis is recommended for definitive diagnosis.

**Introduction**

Carcinomatosis is defined as the widespread dissemination of neoplastic cells of epithelial origin throughout the body1,2. Sarcomatosis describes a similar spread of mesenchymal tumors3. Carcinomatosis and sarcomatosis affecting the peritoneal4,5 pleural6,7, and cerebrospinal cavities8,9 have been reported in dogs and cats. Presence of carcinomatosis or sarcomatosis is generally associated with a poor prognosis2 and has limited therapeutic options, including intracavitary or combination chemotherapy, which have little success10–12. Accurate detection of carcinomatosis and sarcomatosis is therefore essential due to the associated impact on case management and prognosis.

The imaging features of pleural and peritoneal carcinomatosis and sarcomatosis have been documented in association with various primary tumors in dogs and cats in small case-series and individual case reports4-7,12,15. The radiographic appearance of peritoneal carcinomatosis in dogs and cats typically includes a generalised loss of serosal detail, alongside diffuse, patchy, and poorly defined soft tissue lesions throughout the abdomen15. Ultrasonographically, lesions in cats have been described as nodular, poorly defined, hypoechoic masses communicating between the visceral and parietal peritoneal layers5. However, these imaging features are largely non-specific. For example, in dogs, computed tomographic (CT) features of pleural neoplasia and pleuritis can frequently overlap16–19.

Furthermore, recent advances in CT and ultrasonographic image quality and resolution may enable improved detection of these lesions14. Knowledge of the CT and ultrasonographic features of these conditions is required to further characterize these lesions in order to yield further information with regard to patient prognosis2.

Larger cohort studies characterizing the CT and ultrasonographic appearance of pleural or peritoneal carcinomatosis or sarcomatosis in dogs and cats are lacking. The aim of this retrospective, multicenter study was to characterize and compare the clinical, ultrasonographic and computed tomographic appearance of pleural and peritoneal carcinomatosis and sarcomatosis in dogs and cats to aid detection and differentiation of these lesions. We hypothesize that 1) Due to the broad range of tumor types with associated carcinomatosis or sarcomatosis, there would be no significant association between patient signalment of clinical findings when comparing sarcomatosis and carcinomatosis, 2) because of species characteristics, dogs and cats will show different clinical presentation, and 3) Significant differences in imaging features of sarcomatosis and carcinomatosis could aid discrimination between these lesions.

**Materials and methods**

In this retrospective, cross-sectional, descriptive study the databases of the University of Liverpool’s Small Animal Teaching Hospital and Willows Veterinary Centre and Referral Service were searched for dogs and cats with carcinomatosis or sarcomatosis between January 2013 and October 2018. Keywords used included ‘carcinomatosis’, ‘sarcomatosis’, ‘peritoneal nodule’ or ‘pleural nodule’. Ethical approval for this study was granted by the University of Liverpool’s Veterinary Research and Ethics Committee.

Dogs and cats were included in the study if they had: an ultrasonographic or CT study documenting the presence of a primary tumor, with synchronous pleural or peritoneal nodules suggestive of carcinomatosis or sarcomatosis, alongside at least two of the following three criteria; 1) cytological or histopathological confirmation of the primary tumor, 2) cytological or histopathological confirmation of a sarcomatosis or carcinomatosis nodule, or 3) cytological confirmation of a corresponding neoplastic effusion. All sampling was performed at the time of imaging examination. All samples were examined by a clinical pathologist or a pathologist at the time of sampling. Decisions for subject inclusion were made by a veterinary radiology resident (PW) and an ECVDI boarded veterinary radiologist (JM)

Medical records were searched, and information regarding patient signalment, bodyweight, clinical presentation, results of hematology and biochemistry, and outcome were recorded by an ECVDI veterinary radiology resident (PW). As blood samples were analyzed at multiple laboratories, abnormal values outside of the individual laboratories reference ranges were recorded.

Static ultrasonographic images and CT images were reviewed by an ECVDI board-certified veterinary radiologist (JM) and an ECVDI veterinary radiology resident (PW) as a consensus, in one sitting. Reviewers were aware of the final diagnosis at the time of viewing. As previously described, nodules were defined as discrete, sessile or plaque-like lesions extending along any pleural or peritoneal surface16. On both modalities, recorded imaging features of peritoneal or pleural nodules included the number of nodules (single or multiple), distribution of nodules (visceral/parietal), proximity to the primary tumor (close to and/or remote), maximum nodule diameter (cm), margination (good/poor), and presence or absence of mineralization, cavitation, and pleural or peritoneal thickening. On CT, the attenuation pattern (homogeneous/heterogeneous) and attenuation values (HU) pre- and post-contrast were recorded by region of interest (ROI) placement around an entire nodule, or, if poorly defined, the largest area of affected tissue. The degree of nodule contrast enhancement was recorded as the increase in Hounsfield units (HU), and graded as (1) no significant enhancement (<15HU increase); (2) significant enhancement (≥15HU-<25HU increase); or (3) substantial enhancement (≥25HU increase) as previously described20. The contrast enhancement pattern was recorded as rim-like, homogeneous or heterogeneous. Nodule echogenicity (hyperechoic/hypoechoic relative to the splenic parenchyma) and echotexture (heterogeneous/homogeneous) were recorded from ultrasonographic images.

For both modalities, presence of peritoneal or pleural fluid was recorded, and the volume of the effusion was subjectively graded as mild (1), moderate (2) and severe (3).

The maximum height (cm) of lymph nodes were compared to standardized CT and ultrasonographic reference values21–25. The maximum height of the most enlarged lymph node and its location was recorded from CT images. The location of the primary tumor was documented. Where present, metastasis to visceral organs including the liver and spleen were recorded on both modalities, alongside other metastases seen on CT images.

Data was entered into a spreadsheet (Microsoft Excel; Microsoft Corporation, Redmond, WA) and summary statistics were generated. Statistics were performed by a double-certified ECVS specialist in Small Animal Surgery and RCVS specialist in Small Animal Oncology (S.J.B). Continuous variables were expressed as median and range. Comparative statistical analysis was carried out using Graph Pad Prism 7.00 (GraphPad Software, La Jolla, CA) using Chi-squared or Fisher’s exact test for categorical variables and Mann-Whitney U test for continuous variables. Significance was set at P<0.05.

**Results**

*Population*

Thirty-one patients (21 dogs and 10 cats) met the inclusion criteria. Carcinomatosis was confirmed in 14 dogs and 10 cats, and sarcomatosis was confirmed in 7 dogs. Information regarding patient signalment and primary tumor type are summarized in Tables 1a and 1b. Of the 14 canine carcinomatosis cases, the median age at presentation was 10 years (range 2.6-14.3 years) and 6/14 (42.9%) were neutered females, 4/14 (28.6%) neutered males, 3/14 entire males (21.4%), and one (7.1%) was an entire female. Breeds included Staffordshire bull Terriers (4), Labrador retrievers (3), Boxer (2), cross breed (1), Shih tzu (1), Lhasa apso (1) cocker spaniel (1), miniature schnauzer (1). Of the seven canine sarcomatosis cases, the median age at presentation was 10.9 years (range 8.1-13.2 years), 5/7 (71.4%) were neutered males, and 2/7 (14.2%) were neutered females. Breeds included Labrador retrievers (3), cross breed (3), and German shepherd (1).

Dogs with sarcomatosis were significantly heavier (median bodyweight 36.8kg, range 21.4-43.7kg) than dogs with carcinomatosis (median bodyweight 16.5kg, range 5.7-33.7kg) (P=0.005).

Of the 10 cats the median age at presentation was 10.7 years (range 2.7-16.3 years) with 4/10 (40.0%) neutered females, and 6/10 (60.0%) neutered males. The median bodyweight of cats at presentation was 4.4 kg (range 2.4-7.9 kg). Breeds included domestic shorthair (5), Bengal (2), ragdoll (1), Maine coon (1) and British shorthair (1).

*Clinical presentation*

Presenting complaints in dogs included lethargy 7/21 (33.3%), abdominal pain 7/21 (33.3%), inappetence 6/21 (28.6%), vomiting 5/21 (23.8%), weight loss 4/21 (19.0%), abdominal distension 3/21 (14.3%), diarrhea 2/21 (9.5%), tachypnea 2/21 (9.5%), melena 2/21 (9.5%) with hematuria, collapse, cough, and dyspnea each noted in one animal.

Presenting complaints in cats included inappetence 7/10 (70.0%), abdominal distension 4/10 (40.0%), lethargy 3/10 (30.0%), weight loss 3/10 (30.0%) with hematochezia, vomiting, hematemesis and diarrhea each noted in one animal.

Dogs were significantly more likely to present with abdominal pain (7/21) compared to cats (0/7) (P=0.022), whereas cats (7/10) were more likely to present with inappetence than dogs (6/21) (P=0.019).

*Clinical pathology*

In total, 19 dogs underwent hematology and biochemistry. Hematology showed anemia 6/19 (31.6%), lymphopenia 4/19 (21.1%), thrombocytosis 4/19 (21.1%), thrombocytopenia 3/19 (15.7%), leukocytosis 3/19 (15.8%), neutrophilia 3/19 (15.8%), and leukopenia 1/19 (5.3%). Biochemistry showed hypochloremia 4/14 (28.6 %), elevated ALP 4/18 (22.2%), elevated ALT 3/18 (16.7%), elevated serum urea 3/16 (18.8%), hypercholesterolemia 3/17 (17.6%), hyperkalemia 3/15 (20.0%), elevated creatinine 2/14 (14.3%), hypoproteinemia 2/18 (11.1%), and one (7.1%) of each hyperphosphatemia, hyponatremia and hyperbilirubinemia. Urinalysis was performed in 6 dogs: 2/6 (33.3%) had mild proteinuria, and one of each (16.7%) had isosthenuria and hematuria. No significant difference in hematological or biochemical abnormalities was found between carcinomatosis or sarcomatosis groups. Seven underwent hematology and biochemistry. Hematology revealed neutrophilia 4/7 (57.1%), 2/7 (57.1%) leukocytosis, and one of each (14.3%), anemia, thrombocytopenia, and thrombocytosis. Biochemistry revealed hyponatremia 3/7 (42.9%), and one of each (14.3%) hypokalemia, hypochloremia, and hyperphosphatemia. Urinalysis was not performed in any cat.

*Histopathology and cytology*

In dogs, confirmation of the primary tumor was achieved by histopathology and cytology in 11/21 (52.4%) and 10/21 (47.6%) cases, respectively. Cytological confirmation of neoplastic peritoneal and/or pleural nodules was obtained in 15/21 (71.4%) cases. Cytology of effusions confirmed neoplastic effusion in 14/21 (61.9%) cases. Nine cats (90.0%) had cytological confirmation of the primary tumor. Confirmation of carcinomatosis was obtained by cytology of neoplastic peritoneal and/or pleural nodules in 9/10 (90.0%) cats, and by cytology of neoplastic effusion in 8/10 (80.0%) cats. A modified transudate was noted in the remaining 2/10 (20.0%) cats.

Primary tumor types in dogs, further detailed in Table 1a, included 14/21 (66.7%) carcinomas, and 7/21 (33.3%) sarcomas. Four (28.6%) carcinomatosis cases demonstrated bicavitary carcinomatosis, which comprised of single cases of pulmonary, hepatocellular, renal, and jejunal carcinoma. Nine cases (64.3%) demonstrated peritoneal carcinomatosis, which comprised small intestinal adenocarcinoma 3/14 (21.4%), pancreatic carcinoma 2/14 (14.3%), and one of each of ovarian, pulmonary, thyroid, and renal carcinoma. One case (7.1%) of ectopic thyroid carcinoma demonstrated pleural carcinomatosis without peritoneal carcinomatosis.

Primary tumors in dogs with sarcomatosis included splenic hemangiosarcoma 5/7 (71.4%), 3/5 of these had a known history of splenic rupture. Further primary sarcomas included one case of scapular osteosarcoma that demonstrated pleural sarcomatosis, and one case with peritoneal sarcomatosis secondary to an abdominal wall hemangiosarcoma.

Primary tumors in all ten cats were carcinomas, all demonstrated peritoneal carcinomatosis. Primary tumors in cats comprised pancreatic adenocarcinoma 6/10 (60.0%), ileal adenocarcinoma 1/10 (10.0%), ileocecocolic adenocarcinoma 1/10 (10.0%), gall bladder carcinoma 1/10 (10.0%), and hepatocellular carcinoma 1/10 (10.0%). Findings are detailed in Table 1b.

**Imaging features**

CT was performed using either a 16-slice multidetector unit (Brightspeed, General Electric Medical Systems, Milwaukee) or an 80-slice Toshiba Aquilion Prime unit (Canon Medical System, Crawley). All patients were under sedation or general anesthesia and positioned in sternal recumbency. Images were acquired using a 0.5s rotation time, 0·625 or 1·25 mm slice collimation, 512 x 512 matrix dimensions 120 kVp and variable mAs. The reconstruction field of view depended on body size. Pre- and post-contrast images were acquired, post-contrast after intravenous injection of iodinated contrast medium [600 mg I/kg, Iopromide, (Ultravist; Bayer PLC, UK), or 600mg I/kg Iobitridol (Xenetix; Guerbet, France)] administered by pressure injector were obtained using standard soft tissue and lung algorithms, and viewed using a window and level optimized for soft tissue (window 400HU, level 50HU), or lung (window 1500HU, level -600HU). Ultrasonographic images were acquired with either a Logiq 7 (General Electric Medical System, Milwaukee) or a RS80A system (Samsung Medison, Republic of Korea) with a linear or microconvex probe and frequencies from 3-12MHz.

Fifteen patients underwent CT comprising 7 dogs and 1 cat with carcinomatosis, and 7 dogs with sarcomatosis. Twenty patients underwent ultrasonographic evaluation comprising 10 dogs and 9 cats with carcinomatosis, and one dog with sarcomatosis. Five patients (4 dogs and one cat) underwent both CT and ultrasonography. Further description of the CT and ultrasonographic imaging features are detailed in Table 2 and Table 3, and Figures 1-3.

*Canine carcinomatosis*

Peritoneal lesions were observed in the majority of canine carcinomatosis cases (11/14; 78.5%) whereas pleural lesions were present only in 4/14(28.6%). Across both CT and ultrasonographic studies, multiple pleural or peritoneal lesions were more commonly seen, 10/14(71.4%), compared to solitary lesions, 4/14(28.6%). Nodules were distributed on parietal surfaces in 10/14(71.4%) cases, and visceral surfaces in 10/14(71.4%) cases. Nodules were observed remote to the primary tumor in all cases 14/14(100.0%), and less frequently observed close to the primary tumor, 8/14(57.1%). Nodules were well-marginated in 7/14(50.0%) cases, and poorly-marginated and plaque-like in 7/14(50.0%) cases. Multifocal regions of pleural and peritoneal thickening were observed in 10/14 (71.4%) cases.

On CT the median pre-contrast attenuation values of nodules was 37.0 HU (range 25-55 HU), and median post-contrast attenuation of nodules was 72.0 HU (range 26-126 HU). The degree of contrast enhancement was graded as significant 1/7(14.3%) or substantial 5/7(85.7%) degree of contrast-enhancement, with a homogeneous 2/7 (28.5%), heterogeneous 3/7 (42.9%), or rim 1/7 (14.3%) enhancement pattern. Of the 10 cases assessed ultrasonographically, nodule echotexture was homogeneous in6/10(60.0%) and heterogeneous in 4/10(40.0%). Nodules were hypoechoic in 6/10(60.0%), hyperechoic in 1/10(10.0%) and isoechoic to the splenic parenchyma in 3/10(30.0%) (Figure 2).

*Feline carcinomatosis*

Carcinomatosis lesions were documented ultrasonographically in 9 cats, and in one cat by CT. Multiple peritoneal lesions were observed in all cats 10/10(100.0%). Pleural carcinomatosis was not documented in any cat. Of the 9 cats that underwent ultrasonography, the majority of nodules were distributed on the visceral peritoneum 8/9(88.9%), in close proximity to the primary tumor 7/9 (77.8%). Nodules were predominantly poorly defined 5/9(55.6%), and had a variable echotexture, but were largely 8/9(88.9%) hypoechoic to the abdominal viscera. Subjectively, diffuse peritoneal thickening was observed in most 8/9(88.9%) cases. In the single cat that underwent CT, multiple peritoneal nodules were diffusely distributed throughout visceral and parietal surfaces, both close and remote to the primary tumor. Nodules were variable in size, well-marginated, had a heterogeneous soft tissue attenuation, substantial enhancement (24 HU pre-contrast, 80 HU post contrast), with both cavitated and hyperattenuating mineralized foci, and a marked rim-like enhancement pattern.

*Canine sarcomatosis*

Peritoneal lesions were documented in the majority 6/7 (85.7%) of canine sarcomatosis cases that underwent CT. Poorly defined, plaque-like pleural nodules and thickening were seen in one dog with a scapular osteosarcoma. Multiple nodules were seen in all 7/7 (100.0%) cases. Nodules were distributed on the visceral surfaces in 7/7 (100.0%) cases, and the parietal surfaces in 6/7 (85.7%) cases. All 7/7 (100.0%) cases had nodules distant from the primary tumour, and 4/7 (57.1%) cases also had nodules close to the primary tumour. Peritoneal thickening was observed in 3/7 (42.9%) cases.

Sarcomatosis lesions were well-marginated in the majority of cases 5/7 (71.4%). Nodules had a variable parenchymal appearance, 4/7 (57.1%) were homogeneous, while 3/7 (42.9%) were heterogeneous. Median pre-contrast attenuation value was 32 HU (range 28-315 HU), and median post-contrast attenuation of nodules was 60 HU (range 40-315 HU). Substantial contrast enhancement with a heterogeneous pattern was observed in in the majority 5/7 (71.4%) of cases, and rim-like in one case (14.3%). Heterogeneous mineralization of nodules without significant contrast enhancement was seen in one case (Figure 3). Ultrasonography was performed in addition to CT in one dog with sarcomatosis secondary to splenic hemangiosarcoma. This demonstrated multiple well-defined, hypoechoic, peritoneal nodules close to the primary tumor.

*Cavitary effusion, lymphadenomegaly, and further nodular lesions*

Pleural and peritoneal effusions were frequently documented in dogs with carcinomatosis. Peritoneal effusion was present in all 7/7 (100.0%), and bicavitory effusion in 3/7 (42.9%) of dogs with carcinomatosis undergoing CT. Ultrasonographically, peritoneal effusions were present in 9/10 (90.0%), and pleural effusion in 3/10 (30.0%) of carcinomatosis cases.

In cats, pleural effusion was present in 5/10 (50.0%) cases and peritoneal effusion in 5/10 (50.0%) cases. When comparing ultrasonographic features of canine and feline carcinomatosis, cats were significantly less likely to have an associated peritoneal effusion compared to dogs (P=0.043).

A small volume peritoneal effusion was seen in 2/7(28.6%) dogs with sarcomatosis. Pleural effusion was documented in one dog (14.3%) with a scapular osteosarcoma. Of the canine patients undergoing CT, carcinomatosis lesions were significantly more likely to have an associated peritoneal effusion compared to sarcomatosis lesions (P=0.021). No further significant findings in relation to the imaging findings and final diagnosis were established.

Lymphadenomegaly was documented in 7/14(50.0%) dogs with carcinomatosis, 3/10(30.0%) cats with carcinomatosis, and 6/7(85.7%) dogs with sarcomatosis. Lymph node cytology or histopathology was not available for these patients. This data is summarized in Tables 2 and 3.

Of the dogs with carcinomatosis, 3/14(21.4%) had hepatic nodules, 2/14(14.3%) had splenic nodules, and 1/14(7.1%) had pulmonary nodules. Hepatic nodules were documented in 1/9(11.1%) cat with carcinomatosis. Of the dogs with sarcomatosis, 4/7(57.1%) had pulmonary nodules, 3/7(42.9%) had hepatic nodules, and 1/7(14.3%) had splenic nodules. Cytology or histopathology was not available for these lesions. This data is summarized in Tables 2 and 3.

*Outcome*

Of the 21 dogs, 9/21(42.9%) dogs were euthanized immediately after diagnosis. Twelve dogs underwent treatment, including palliative care 6/21(28.6%), chemotherapy 4/21(19.0%) or chemotherapy with surgical removal of the primary tumor in 2/21(9.5%) cases. Eight cases (47.6%) were lost to follow up. The median survival time of the remaining four dogs was 195 days (range 30 days – 420 days).

Of the 10 cats, 7/10 (70.0%) of cats were euthanized immediately after diagnosis. Two (20.0%) cats were lost to follow up, and one cat was euthanized after 90 days of chemotherapy.

**Discussion**

Carcinomatosis and sarcomatosis describe the widespread distribution of malignant epithelial and mesenchymal cells throughout the body1. These lesions are commonly associated with a poor prognosis, but are relatively infrequently reported in veterinary oncology. This is the first study describing and comparing the computed tomographic and ultrasonographic features of carcinomatosis and sarcomatosis in dogs. Contrary to our first two hypotheses, significant distinguishing features were observed in this patient cohort: dogs with sarcomatosis weighed significantly more than those with carcinomatosis, and dogs were more likely to present with abdominal pain compared to cats. In support of our last hypothesis, peritoneal effusion was an imaging feature more characteristic of dogs with carcinomatosis compared to dogs with sarcomatosis. Characteristic clinical and imaging features have not yet been reported in veterinary patients with carcinomatosis or sarcomatosis.

A large degree of overlap was observed between the CT appearance of canine carcinomatosis and sarcomatosis. Sarcomatosis was more frequently observed as well defined nodules with a heterogeneous contrast enhancement compared to carcinomatosis nodules which were more frequently poorly defined with a homogeneous contrast enhancement, although there was no significant difference between the groups. A similar differentiation between carcinomatosis and sarcomatosis has been described in human patients13. Ill defined, plaque-like omental lesions, “omental cakes” or “stellate-like” mesentery are frequently reported in human carcinomatosis cases, resulting from fibrotic and neoplastic infiltration of the omental fat and perivascular structures, respectively 26,27. Plaque-like pleural lesions have been described in dogs with pleural carcinomatosis16. Conversely, sarcomatosis lesions are frequently described as smoothly marginated, nodular lesions 3,13. Due to their highly vascular nature, sarcomatosis lesions often demonstrate a strong, heterogeneous contrast enhancement in human patients13, as was observed in this study. Awareness of the varied appearance of these neoplastic lesions may help to avoid lesion mis-diagnosis, which could profoundly affect patient prognosis2.

In this study, the ultrasonographic features of canine and feline carcinomatosis lesions were most frequently described as multiple, predominantly heterogeneous, hypoechoic nodules of variable margination dispersed throughout the visceral or parietal peritoneum and pleura. This is supported by the ultrasonographic features previously documented in cats where multiple, hypoechoic, ovoid shaped nodules throughout the connecting peritoneum were described5.

Peritoneal effusion was frequently seen in cases of carcinomatosis in dogs. Presence of pleural or peritoneal effusion in cats with carcinomatosis was more variable in this study compared to previous studies5,28. Presence of effusion is common in human patients with carcinomatosis, but is infrequently seen with sarcomatosis, and tends to occur in smaller volumes29. Peritoneal and pleural neoplasia can cause malignant effusion by impairment of lymphatic drainage, or overwhelming of Starling’s capillary forces30. Increased fluid production can result from increased capillary surface area due to neoangiogenesis, fluid leakage due to permeable neovascular capillaries, alongside oncotic pressure gradients created by highly proteinaceous effusions30. Presence of effusion can facilitate further dissemination of tumor cells. Dissemination of malignant cells occurs through one of three pathways: direct seeding onto body cavities or surfaces; lymphatic spread; and hematogenous spread2. Peritoneal effusion was absent in many canine sarcomatosis cases in this study, and sarcomatosis was frequently observed in the presence of a primary splenic hemangiosarcoma. Early metastasis to the liver, lung and peritoneum is often seen with splenic hemangiosarcoma31. Only 3 dogs in our study had a known history of splenic rupture at presentation, suggesting that tumor spread was more often achieved by hematogenous or lymphatic spread, or contiguous extension along adjacent membranes3. However, subclinical rupture with subsequent reabsorption of peritoneal fluid should still be considered, especially since dogs that present with significant hemoabdomen have often had episodes of milder, poorly defined ill-health prior to this.

Concurrent lymphadenomegaly was not uncommonly observed in both canine and feline patients with sarcomatosis and carcinomatosis. Similarly, pulmonary, hepatic and splenic nodules were seen in a small number of patients in each disease category. No significant difference was established between the presence of carcinomatosis and sarcomatosis and the prevalence of lymphadenomegaly, or parenchymal nodules. Due to the retrospective nature of the study, results from histopathological or cytological analysis was not available, and therefore, inflammatory and hyperplastic etiologies such as reactive lymphadenitis and nodular hyperplasia must also be considered32. That said, dissemination via hematogenous and lymphatic routes are common forms of tumor metastasis1. Lymphadenomegaly has been documented in feline lymphomatosis and carcinomatosis cases5, 33. In human patients, it is more frequently associated with lymphomatosis compared to sarcomatosis or carcinomatosis3. Such comparison is beyond the scope of this study but may warrant further investigation.

Patient body weight was associated with the types of tumor dissemination, with sarcomatosis being significantly associated with a higher patient body weight. This is unsurprising since splenic hemangiosarcoma accounted for the majority of canine sarcomatosis cases in this study and splenic hemangiosarcoma is more common in large breed dogs34. Splenic hemangiosarcoma is much less common in cats, occurring in 0.5% cats examined at necropsy35 which may explain the absence of feline sarcomatosis in our study. Pleural sarcomatosis secondary to scapular osteosarcoma is rare and this case was published in the veterinary literature as a case report36.

The majority of feline cases were diagnosed with pancreatic adenocarcinoma. Pancreatic adenocarcinoma, small intestinal adenocarcinoma, and hepatocellular carcinoma have been previously associated with carcinomatosis in cats5. Pancreatic adenocarcinoma is a rare, aggressive tumor of the exocrine pancreatic tissue, and accounts for <0.5% of feline neoplasias34,37. The prevalence of these tumors in our study reflects their high metastatic rate, and these tumors commonly metastasize to the liver, lymph nodes, lung, and peritoneum38.

In this study, intestinal adenocarcinoma was the most common primary tumor with associated carcinomatosis in dogs 4/14 (28.6%). Canine small intestinal adenocarcinoma most frequently metastasizes to regional lymph nodes, however, peritoneal carcinomatosis may also occur39,40. Gastrointestinal carcinoma is commonly associated with carcinomatosis in humans, as is ovarian adenocarcinoma41. Ovarian adenocarcinoma with carcinomatosis was observed in one case in our study, which had similar imaging features, such as cavitation, to those previously reported42. The small number of entire female patients in our cohort may be responsible for the low prevalence of ovarian tumors in dogs and cats in comparison to humans. Ovarian cancer is the seventh most commonly diagnosed cancer in women43, with 70% prevalence of peritoneal carcinomatosis at the time of diagnosis44. It is likely that routine ovariectomy or ovariohysterectomy in cats and dogs is responsible for this contrast in disease prevalence45.

In this patient cohort, canine carcinomatosis patients were significantly more likely to present with abdominal pain in comparison to cats, which more commonly presented with a history of inappetence. This is largely unsurprising, given that abdominal pain is relatively commonplace in dogs with solid abdominal tumors46, whereas cats often present with non-specific signs of malaise including behavioral changes and inappetence47. Both refractory abdominal pain and cancer cachexia-anorexia are well documented in human patients with peritoneal carcinomatosis48,49.

Our study has several limitations. Firstly, due to its retrospective nature, the diagnostic tests such as imaging protocol and sampling were not standardized. As a result, not all cases had histopathological confirmation, and in a small number of cases, the diagnosis was based upon cytological analysis of neoplastic effusion and primary tumor alone. In human patients, cytology is generally considered specific for diagnosis of neoplastic effusion50, and some studies demonstrate a high correlation between cytological analysis of the effusion and histopathology of the primary tumor51. Secondly, the small sample size prevents robust statistical analysis to aid clear differentiation between the imaging features of the respective sarcomatosis and carcinomatosis patient groups. Another limitation was the fact that the ultrasonographic technical parameters such as transducer type and transducer frequency were not recorded for each individual patient. Although imaging characteristics of lesions may vary depending on the technical parameters and ultrasound probe, these were optimized for each patient and are likely representative of every day clinical situations in practice. Lastly comparison of imaging features of sarcomatosis and carcinomatosis with further peritoneal or pleural pathology, such as inflammatory or infectious etiology, was beyond the objective of our study. Studies with a larger patient cohort and variable etiology are required to further assess possible associations between imaging features and final diagnosis.

**Conclusion**

This study demonstrates some differences between sarcomatosis and carcinomatosis in dogs and cats. Dogs were more likely to present with abdominal pain whereas cats were more likely to present with inappetence. In dogs, a higher patient bodyweight was significantly associated with sarcomatosis, whereas peritoneal effusion was significantly associated with carcinomatosis. However, due to the overlap between these conditions, cytological or histopathological analysis is required for a definitive diagnosis of sarcomatosis and carcinomatosis.

**List of author contributions**

**Category 1**

1. Conception and design: Mortier, Weston, Finotello
2. Acquisition of data: Weston, Mortier
3. Analysis and interpretation of data: Weston, Mortier, Baines

**Category 2**

1. Drafting the article: Weston, Mortier, Baines, Finotello
2. Revising the article for intellectual content: Weston, Mortier, Baines, Finotello

**Category 3**

1. Final approval of completed article: Weston, Mortier, Baines, Finotello

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|  |  |  |
| --- | --- | --- |
| **Variable** | **Carcinomatosis (n=14)** | **Sarcomatosis (n=7)** |
| Age (years) | Median 10.0 (range 2.6 -14.3) | Median 10.9 (range 8.1-13.2) |
| Weight (Kg) | Median 16.5 (range 5.7-33.7) | Median 36.8 (range 8.1-13.2) |
| Sex | Neutered female (n=6), Neutered male (n=4), Female entire (n=1), Male entire (n=3) | Neutered female (n=2), Neutered male (n=5) |
| Primary tumor | Small intestinal adenocarcinoma (n= 4),  Renal carcinoma (n=2),  Pancreatic carcinoma (n=2),  Pulmonary adenocarcinoma (n=2),  Thyroid carcinoma (n=2),  Hepatocellular carcinoma (n=1),  Ovarian adenocarcinoma (n=1) | Splenic hemangiosarcoma (n=5),  Soft tissue hemangiosarcoma (n=1)  Scapular osteosarcoma (n=1) |

Table 1a) Patient characteristics and primary tumors in dogs with carcinomatosis and sarcomatosis

Table 1b) Patient characteristics and primary tumors in cats with carcinomatosis

|  |  |
| --- | --- |
| **Variable** | **Carcinomatosis (n=10)** |
| Age (years) | Median 10.7 (range 2.7-16.3) |
| Weight (Kg) | Median 4.4 (range 2.4-7.9) |
| Sex | Neutered Female (n=4), Neutered Male (n=6) |
| Primary tumor | Pancreatic carcinoma (n=6)  Cholangiocellular carcinoma (n=1)  Biliary carcinoma (n=1)  Ileal carcinoma (n=1)  ICCJ carcinoma (n=1) |

Table 2: Computed Tomographic features of carcinomatosis and sarcomatosis in dogs

|  |  |  |
| --- | --- | --- |
| Variable | Carcinomatosis | Sarcomatosis |
| Number of cases | 7 | 7 | |
| Pleural nodules | 3/ 7 | 1/7 | |
| Single | 2/7 | 0/7 | |
| Multiple | 1/7 | 1/7 | |
| Peritoneal nodules | 6/7 | 6/7 | |
| Single | 1/7 | 0/7 | |
| Multiple | 5/5 | 3/7 | |
| Parietal | 7/7 | 6/7 | |
| Visceral | 6/7 | 7/7 | |
| Remote from primary tumor | 7/7 | 7/7 | |
| Local to primary tumor | 6/7 | 4/7 | |
| Median max nodule diameter (cm) | 1.8 (range 1.4-6.0) | 1.8 (range 1.1-3.5) | |
| Well-marginated | 5/7 | 5/7 | |
| Poorly-marginated | 2/7 | 3/7 | |
| Median pre-contrast attenuation (HU) | 37 (range 25-55) | 32 (range 28-315) | |
| Median post-contrast attenuation value (HU) | 72 (range 26-126) | 60 (range 40-315) | |
| Non-enhancing | 1/7 | 1/7 | |
| Enhancing | 6/7 | 6/7 | |
| No contrast enhancement (<15) | 1/7 | 1/7 | |
| Significant enhancement (≥15-<25HU) | 1/7 | 1/7 | |
| Substantial enhancement (≥25HU) | 5/7 | 5/7 | |
| Homogeneous | 2/7 | 0/7 | |
| Heterogeneous | 3/7 | 5/7 | |
| Rim enhancing | 1/7 | 1/7 | |
| Cavitation | 0 | 0 | |
| Mineralization | 0 | 1/7 | |
| Peritoneal effusion | \*7/7 | \*2/7 | |
| Pleural effusion | \*3/7 | \*1/7 | |
| Bicavitatory effusion | \*3/7 | \*0 | |
| Mild volume | 5/7 | 2/7 | |
| Moderate volume | 2/7 | 1/7 | |
| Severe volume | 0 | 0 | |
| Pleural thickening | 2/7 | 1/7 | |
| Peritoneal thickening | 4/7 | 3/7 | |
| Thoracic lymphadenomegaly | 3/7 | 4/7 | |
| Abdominal lymphadenomegaly | 1/7 | 1/7 | |
| Cervical lymphadenomegaly | 1/7 | 1/7 | |
| Median short axis (cm) | 1.5 (range 1.3 -3.0) | 1.3 (range 0.8-2.7) | |
| Pulmonary nodules | 1/7 | 4/7 | |
| Hepatic nodules | 1/7 | 3/7 | |
| Splenic nodules | 2/7 | 1/7 | |

*\* Statistically significant results*

Table 3: Ultrasonographic features of carcinomatosis in cats and dogs

|  |  |  |
| --- | --- | --- |
| Variable | Dogs | Cats |
| Number of cases | 10 | 9 |
| Pleural nodules | 2/10 | 0 |
| Single | 0 | 0 |
| Multiple | 2/10 | 0 |
| Peritoneal nodules | 9/10 | 9/9 |
| Single | 6/10 | 4/9 |
| Multiple | 3/10 | 5/9 |
| Parietal | 3/10 | 5/9 |
| Visceral | 7/10 | 8/9 |
| Remote from primary tumor | 9/10 | 4/9 |
| Local to primary tumor | 3/10 | 7/9 |
| Median max nodule diameter (cm) | 3.3 (range 0.5-7.0) | 1.0 (range 0.5-3.0) |
| Well-marginated | 5/10 | 4/9 |
| Poorly-marginated | 5/10 | 5/9 |
| Hypoechoic | 6/10 | 8/9 |
| Hyperechoic | 1/10 | 1/9 |
| Mixed | 3/10 | 0 |
| Homogeneous | 6/10 | 4/9 |
| Heterogeneous | 4/10 | 5/9 |
| Cavitation | 0 | 1/9 |
| Mineralization | 0 | 0 |
| Peritoneal effusion | 9/10 | 4/9 |
| Pleural effusion | 3/10 | 5/9 |
| Bicavitatory effusion | 2/10 | 0 |
| Pericardial effusion | 1/10 | 0 |
| Anechoic | 6/10 | 9/9 |
| Echogenic/ cellular | 4/10 | 0 |
| Pleural thickening | 1/10 | 0 |
| Peritoneal thickening | 5/10 | 8/9 |
| Thoracic lymphadenomegaly | 0 | 0 |
| Abdominal lymphadenomegaly | 3/10 | 3/9 |
| Pulmonary nodules | 0 | 0 |
| Hepatic nodules | 3/10 | 1/9 |
| Splenic nodules | 2/10 | 0 |

Figure 1) Transverse post-contrast CT images demonstrating A) peritoneal carcinomatosis and B) peritoneal sarcomatosis in dogs. A) Multiple rim-enhancing nodules (white arrow) and peritoneal effusion (30HU) (white arrowheads) in a dog with renal carcinoma (asterisk). B) Multiple well-defined peritoneal nodules with heterogeneous contrast enhancement (black arrows) in the absence of peritoneal effusion in a dog with splenic hemangiosarcoma. All patients were scanned in sternal recumbency. Images were acquired with a 0.5s rotation time, 1mm slice collimation, 120kVp and 150mAs. Both images are displayed in a transverse plane, soft tissue kernel, window level 40HU, window width 400HU.

Figure 2) Some examples of peritoneal carcinomatosis (A-C), and sarcomatosis (D) nodules identified on abdominal ultrasonography. A) and B) Well-defined nodules (white arrows) with variable echogenicity, associated with parietal peritoneal thickening (black arrow) and mild peritoneal effusion (asterisk) in two cats with pancreatic carcinoma cytologically confirmed carcinomatosis. (C) Multiple, well-defined, homogeneously hypoechoic nodules within the mesenteric fat (black arrowhead) in a dog with unilateral renal carcinoma. (D) Multiple coalescing nodules with a heterogeneously hyperechoic echotexture (white arrowheads) in a dog with splenic hemangiosarcoma. Images are acquired in longitudinal (A&B) and transverse (C&D) planes, with the following probes: A&B) GE 12MHz Linear Array, C) GE 11MHz Microconvex, and D) GE 8MHz Microconvex.

Figure 3) Transverse CT images demonstrating A) Pleural carcinomatosis and B) pleural sarcomatosis in dogs. A) Multiple, well-defined, homogeneously enhancing pleural nodules (white arrow) with pleural effusion (white arrowheads) in a dog with ectopic thyroid carcinoma. B) Multiple, poorly defined, plaque-like, hyperattenuating (mineralized) nodules are present throughout the parietal and visceral pleura (black arrows), accompanied by pleural effusion (16HU) (black arrowheads), in a dog with a scapular osteosarcoma. All patients were scanned in sternal recumbency. Image A is acquired post-contrast, and image B pre-contrast. Both images are displayed in a transverse plane, soft tissue kernel, window level 40HU, window width 400HU.