A better understanding of the CT features of different forms of canine and feline adipose tumors would be valuable for improving patient management and treatment. The purpose of this retrospective, cross-sectional study was to describe and compare the CT features of pathologically confirmed lipomas, infiltrative lipomas, and liposarcomas in a sample of canine and feline patients. A total of 50 animals (46 dogs, four cats) and a total of 60 lesions (23 lipomas, 20 infiltrative lipomas, and 17 liposarcomas) were included in the study. Lipomas appeared as round to oval-shaped (n = 21), well-marginated (n = 20) fat-attenuating lesions. Infiltrative lipomas appeared as homogeneous, fat-attenuating masses but, unlike lipomas, they were most commonly characterized by an irregular shape (75%; P < 0.001), and linear components, hyperattenuating relative to the surrounding fat (100%; P < 0.05). Liposarcomas were represented exclusively by heterogeneous lesions with soft tissue attenuating components with a multinodular appearance (76.5%; P < 0.05). Regional lymphadenopathy (n = 10) and amorphous mineralization (n = 4) were also observed in association with liposarcomas. Computed tomography can provide useful information regarding disease location, extent, and involvement of the adjacent structures. Tumor definition and shape were the most useful parameters to differentiate between lipomas and infiltrative lipomas. The presence of a heterogeneous mass, with a multinodular soft tissue component and associated regional lymphadenopathy and mineralization, were features favoring a diagnosis of liposarcoma.

Key words: CT, canine, feline, infiltrative lipoma, lipoma, liposarcoma.

Introduction

The current World Health Organization (WHO) classification of mesenchymal skin and soft tissue tumors of domestic animals recognizes three benign forms of tumors of the adipose tissue, represented by lipoma, infiltrative lipoma and angiolipoma, and one malignant form, represented by liposarcoma. Lipomas are tumors characterized by well-differentiated adipocytes that are common in the dog, with a reported incidence rate of 5.1% of all diagnosed canine neoplasms, while they are far less common in other species. Lipomas are defined as infiltrative when they show a more aggressive biological behavior by invading adjacent structures, most commonly muscle and fasciae. Angiolipoma is another uncommon variant of lipoma characterized by the presence of small, well-differentiated blood vessels interspersed in mature adipose tissue that can be further subclassified as infiltrative or noninfiltrative. Liposarcoma, the rare malignant counterpart of lipoma, is histologically characterized by lipoblasts with variable grade of pleomorphism. Liposarcomas have been further classified into subtypes based on cellular morphology, however the different histological appearances do not correspond to differences in biological behavior in domestic animals. Although liposarcomas generally show a low metastatic potential, they are characterized by local invasion and high recurrence rate.

While the majority of lipomas are asymptomatic and do not require surgical intervention, aggressive treatment may be necessary for the local control of infiltrative lipomas and liposarcomas. Therefore, a correct diagnosis is essential for prognosis and therapy planning. Infiltrative lipomas cannot be readily distinguished from simple lipomas in fine

From the Small Animal Clinical Sciences, University of Florida College of Veterinary Medicine, Gainesville, FL 32610 (Spoldi), Royal (Dick) School of Veterinary Studies, Easter Bush Veterinary Centre, University of Edinburgh, Roslin, Midlothian, Scotland, UK (Schwarz), the Department of Veterinary Medical Sciences, University of Bologna, Ozzano Emilia, Bologna, Italy (Sabattini), Universita degli Studi di Teramo Facolta di Medicina Veterinaria, Teramo, Abruzzo, Italy (Vignoli), Centro Oncologico Veterinario, Sasso Marconi, Italy (Cancedda), and Clinica Veterinaria dell’Orologio, Sasso Marconi, Bologna, Italy (Rossi).


Portions of this study were presented at the 2013 ECVDI and EAVDI Annual Meeting, Cascais, Portugal.

Address correspondence and reprint requests to Elisa Spoldi, at the above address. E-mail: espoldi@ufl.edu

Received February 14, 2016; accepted for publication September 26, 2016.

doi: 10.1111/vru.12445

This is an open access article under the terms of the Creative Commons Attribution License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited.
needle aspirates or small biopsy specimens. Computed tomography is currently used to better delineate these tumors, evaluate their actual extension and assess their relationship with the adjacent anatomic structures, allowing for accurate treatment planning.

The CT and MRI appearance of fat-containing tumors has previously been described in humans. Both modalities have been proven to be useful in identifying and characterizing adipose masses. In veterinary medicine there are a few reports describing adipose tumors, but there is only limited information available on their CT features. Moreover, a comparison between benign and malignant fatty masses based on CT characteristics in a larger group of animals has not been reported. Diagnostic imaging would be a valuable and noninvasive procedure to discriminate between the different neoplastic forms and assess their growth pattern before treatment planning. The aim of this study was to describe and compare CT features of histologically confirmed lipomas, infiltrative lipomas, and liposarcomas in dogs and cats.

Material and Methods

The study was a retrospective, cross-sectional design. Patients were selected from two board-certified veterinary radiologist (T.S., F.R.) on the basis of having helical CT evaluation and a confirmed histological diagnosis of lipoma, infiltrative lipoma, or liposarcoma. Cases were retrieved from the electronic database of the Clinica Veterinaria dell’Orologio and the Royal (Dick) School of Veterinary Studies, University of Edinburgh, and chosen from clinical databases from January 2005 through June 2015. Images were acquired using one of the following three different CT scanners: helical single-slice CT unit (ProSpeed, GE, Milwaukee), helical 4-slice CT unit (Somatom Volume Zoom, Siemens, Germany) and helical 16-slice CT unit (BrightSpeed, GE, Milwaukee). All CT studies were performed under general anesthesia. To ensure the greatest consistency in evaluation of imaging features, the images were retrospectively reviewed and reevaluated in a randomized order by the primary author (E.S.) and one board-certified veterinary radiologist (F.R.), who were unaware of the final diagnosis at the time of the image review. Images measurements were made in triplicate by each reviewer and final assessment was reached by means of consensus. Images were reviewed following determination of the computed tomographic characteristics by using image analysis freeware (OsiriX v.4.1.2 32-bit, Pixmeo Sàrl, Geneva, Switzerland). Display settings were adjusted as needed for optimal evaluation of the images.

CT images were reviewed and assessed for the following criteria:

1. Volume of the mass was measured by the rotational ellipse method: the largest tumor diameter was measured in the three orthogonal planes on CT images and volume was calculated as the product of the three measurements times $\pi / 6$.
2. Shape of the mass: defined as round to oval or irregular (for all the lesions that were neither round nor oval in shape).
3. Tumor definition: margins were classified on the postcontrast series as well-defined (presence of a distinct border to surrounding tissues), poorly defined (absence of a distinct border to surrounding tissues), or a combination of well-defined and poorly defined regions.
4. Pre- and postcontrast homogeneity and attenuation characteristics of the lesion were evaluated subjectively and by measuring Hounsfield Unit (HU) values. Overall lesion attenuation was calculated by placing different regions of interest (ROIs) on pre- and postcontrast series. The mean HU values were recorded for the different series.
5. Prevalence of a fat or a soft tissue component was evaluated based on the HU values.
6. Presence of intrallesional areas that are hyperattenuating compared to fat (defined as hyperattenuating components).
7. Type of hyperattenuating component classified as linear (presence of hyperattenuating septa) or as nodular-globular-mass (presence of irregular conglomerate areas).
8. Presence of minimal attenuating areas within the lesion.
9. Presence of regional lymphadenopathy (round, enlarged, and/or heterogeneously contrast enhancing lymph nodes). Normal lymph nodes are oval in shape, smoothly marginated with a uniform appearance and are soft tissue attenuating.
10. Evidence of potential metastatic lesions (round, enlarged, irregularly marginated and/or heterogeneous, heterogeneously contrast enhancing lymph nodes or other nodules/masses distant from the primary lesion).

None of the masses underwent cytoreductive surgery or incisional biopsy prior to imaging. Definitive diagnoses were based on histopathological examination of surgical or postmortem specimens, according to the WHO criteria. The samples were not available for review or for mapping correlation with the CT images.

Data were analyzed with commercial software programs (SPSS Statistics v. 19, IBM, Somers, NY, and Prism v. 5.0, GraphPad, San Diego, CA) by one of the authors (SS, DVM, PhD in animal pathology and biotechnology). When appropriate, data sets were tested for normality by using the D’Agostino and Pearson omnibus normality test. Values were expressed as mean ± standard deviation for normal distribution, or as median with a range for nonnormal distribution. Differences in the
demographic and CT parameters between lipomas and liposarcomas and between infiltrative and noninfiltrative lipomas were evaluated with Mann–Whitney U test (continuous variables) and Chi Square/Fisher’s exact test (categorical variables). Binary logistic regression model was performed to estimate which study variables best-predicted tumor type. For all analyses, \( P \) values of \( \leq 0.05 \) were considered significant.

### Results

A total of 50 patients met the inclusion criteria (\( n = 46 \) dogs; \( n = 4 \) cats). None of the total number of patients with a helical CT evaluation and a confirmed histological diagnosis of lipoma, infiltrative lipoma or liposarcoma were excluded from the data analysis. Signalment characteristics of animals for each tumor type are summarized in Table 1. Eight dogs had two lesions and one dog had three lesions, for a total of 60 lesions. Definitive diagnoses included 23 lipomas (15 dogs and three cats), 20 infiltrative lipomas (17 dogs and one cat), and 17 liposarcomas (15 dogs). Only one dog had both a lipoma and an infiltrative lipoma. None of the cases were diagnosed as angiolipoma or infiltrative angiolipoma. Ten tumors were intracavitary (thorax or abdomen) and included four lipomas, four infiltrative lipomas, and two liposarcomas. The extracavitary neoplasms included four lesions within the head-neck region (two lipomas, one infiltrative lipoma, and one liposarcoma); 14 lesions located in the thoracic or pelvic limbs (five lipomas, eight infiltrative lipomas, and one liposarcoma); and 32 lesions located within the trunk (12 lipomas, seven infiltrative lipomas, and 13 liposarcomas).

Helical CT scans of the whole body (\( n = 34 \)) or of the area of interest (\( n = 16 \)) were acquired before and after intravenous administration of a bolus of water-soluble contrast medium (Ioversol 300 mgI/ml Optiray, Covidiem, Segrate, Italy; Iopramide 370 mgI/ml Ultravist 370, Bayer, Germany) at a dose of 600 or 740 mg Iodine/kg with the use of a power injector or manual injection. Only precontrast images were available for five lesions and only post-contrast images were available for three other lesions. Tube voltage was consistent at 120 kVp, adaptive tube current ranged from 0.5 and 1.5 s, slice thickness varied from 1 to 7 mm, image interval ranged from 0.625 to 7 mm, helical collimator pitch from 0.625 to 1.75, display field of view from 242 to 354 mm-based on patient size, body part imaged, and

### Table 1. Summary of Signalment for Each Tumor Type Group (Lipoma, Infiltrative Lipoma, and Liposarcoma)

<table>
<thead>
<tr>
<th>Species, breed</th>
<th>Lipoma ((n = 18))</th>
<th>Infiltrative lipoma ((n = 18))</th>
<th>Liposarcoma ((n = 15))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dogs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labrador retriever</td>
<td>15</td>
<td>17</td>
<td>15</td>
</tr>
<tr>
<td>Weimaraner</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Other breeds</td>
<td>4*</td>
<td>5\†</td>
<td>6\‡</td>
</tr>
<tr>
<td>Mongrel</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Cats</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Persian</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Domestic shorthair</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>3 (1 castrated)</td>
<td>11 (3 castrated)</td>
<td>12 (1 castrated)</td>
</tr>
<tr>
<td>Female</td>
<td>15 (3 spayed)</td>
<td>7 (1 spayed)</td>
<td>3 (0 spayed)</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median (range)</td>
<td>11 years (1–13)</td>
<td>8.8 years (3–15)</td>
<td>10.5 years (2–14)</td>
</tr>
</tbody>
</table>

Numbers indicate number of patients.

\*Other breeds include a single patient representing each of the following breeds: English Setter, Border Collie, Doberman Pinscher, Bernese Mountain Dog.

\†Other breeds include a single patient representing each of the following breeds: Chihuahua, English Springer Spaniel, Shih Tzu, Dachshund, Siberian Husky.

\‡Other breeds include a single patient representing each of the following breeds: Samoyed, West Highland White Terrier, Rottweiler, German Shepherd Dog, Doberman Pinscher, Bearded Collie.

### Table 2. CT Features within Benign Adipose Masses

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Lipoma ((n = 23))</th>
<th>Infiltrative lipoma ((n = 20))</th>
<th>Significance ((P) value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume median</td>
<td>115.7 cm³</td>
<td>157.9 cm³</td>
<td>0.342</td>
</tr>
<tr>
<td>(Range)</td>
<td>(1.6–1457.0)</td>
<td>(0.1–5073.7)</td>
<td></td>
</tr>
<tr>
<td>Shape</td>
<td></td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>Oral/round</td>
<td>21 (91.3%)</td>
<td>5 (25%)</td>
<td></td>
</tr>
<tr>
<td>Irregular</td>
<td>2 (8.7%)</td>
<td>15 (75%)</td>
<td></td>
</tr>
<tr>
<td>Margins</td>
<td></td>
<td>0.005</td>
<td></td>
</tr>
<tr>
<td>Well-defined</td>
<td>20 (87%)</td>
<td>9 (45%)</td>
<td></td>
</tr>
<tr>
<td>Mixed</td>
<td>3 (13%)</td>
<td>8 (40%)</td>
<td></td>
</tr>
<tr>
<td>Poorly-defined</td>
<td>0 (0%)</td>
<td>3 (15%)</td>
<td></td>
</tr>
<tr>
<td>Attenuation</td>
<td></td>
<td>0.6</td>
<td></td>
</tr>
<tr>
<td>Homogeneous</td>
<td>18 (78.3%)</td>
<td>4 (20%)</td>
<td></td>
</tr>
<tr>
<td>Heterogeneous</td>
<td>5 (21.7%)</td>
<td>4 (20%)</td>
<td></td>
</tr>
<tr>
<td>Precontrast attenuation</td>
<td></td>
<td>0.8</td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>−120.0 HU</td>
<td>−113.0 HU</td>
<td>0.7</td>
</tr>
<tr>
<td>(Range)</td>
<td>(−130.0 to −6.0)</td>
<td>(−134.0 to −23.0)</td>
<td></td>
</tr>
<tr>
<td>Postcontrast attenuation</td>
<td></td>
<td>0.7</td>
<td></td>
</tr>
<tr>
<td>Median</td>
<td>−113.5 HU</td>
<td>−103.5 HU</td>
<td>0.7</td>
</tr>
<tr>
<td>(Range)</td>
<td>(−157.0–27.0)</td>
<td>(−133.0 to −18.0)</td>
<td></td>
</tr>
<tr>
<td>Prevalent component</td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Fat</td>
<td>23 (100%)</td>
<td>20 (100%)</td>
<td></td>
</tr>
<tr>
<td>Soft tissue</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td></td>
</tr>
<tr>
<td>Hyperattenuating components</td>
<td>10 (43.5%)</td>
<td>17 (85%)</td>
<td>0.01</td>
</tr>
<tr>
<td>Type of hyperattenuating component</td>
<td></td>
<td>0.04</td>
<td></td>
</tr>
<tr>
<td>Linear</td>
<td>7 (70%)</td>
<td>17 (100%)</td>
<td></td>
</tr>
<tr>
<td>Nodular/global mass</td>
<td>3 (30%)</td>
<td>0 (0%)</td>
<td></td>
</tr>
<tr>
<td>Mineralization</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>1</td>
</tr>
<tr>
<td>Regional lymphadenopathy</td>
<td>4 (17.4%)</td>
<td>5 (25%)</td>
<td>0.711</td>
</tr>
<tr>
<td>Metastatic lesions</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>1</td>
</tr>
</tbody>
</table>

Numbers indicate number of lesions.

\*Continuous variables compared by using Mann–Whitney U test, categorical variables compared by using Chi Square test/Fisher’s exact test.

\†Percentages are calculated for each group on the total number of masses showing hyperattenuating components.
Infiltrative lipomas appeared irregular in shape (n = 15, 75%), with well- (n = 9, 45%), mixed- (n = 8, 40%), or poorly-demarcated margin definition (n = 3, 15%). Masses were homogeneous (n = 16, 80%), with prevalent fat attenuation in all cases (n = 20, 100%), with a median precontrast attenuation of –113 HU (range = –134 to –23 HU) and postcontrast of –103.5 HU (range = –133 to –18 HU). In seventeen cases (85%) hyperattenuating components were seen, but were all linear in appearance (Fig. 3). Regional lymphadenopathy was present in five cases (25%). CT parameters significantly different between lipomas and infiltrative lipomas included shape (P < 0.001), margins (P = 0.005), presence and type of hyperattenuating components (P = 0.01 and P = 0.04, respectively; Table 2).

A high percentage of liposarcomas (n = 14; 82.3%) were round to oval shaped. Margins were well-defined (n = 9, 53%), mixed- (n = 6, 35.3%) or poorly-defined (n = 2, 11.7%). All the lesions were heterogeneous with hyperattenuating components, mostly represented by nodular-globular-mass-like conglomerates (n = 13, 76.5%). Median attenuation values varied from –5 HU precontrast (range = –49 to 28) to 13 HU postcontrast (range = –48 to 61). In four cases amorphous mineralized areas were observed. Two lesions determined osteolysis of the adjacent skeletal structures (Fig. 4). Regional lymphadenopathy was observed...
in 10 cases (58.8%). A suspected metastatic lesion was seen in one case (Fig. 5). Computed tomographic features significantly different between benign (lipoma/infiltrative lipoma) and malignant forms were pre- and postcontrast homogeneity ($P < 0.001$), attenuation characteristics ($P < 0.001$), prevalent component ($P < 0.001$); presence and type of hyperattenuating components ($P < 0.001$ and $P = 0.003$, respectively), mineralization ($P = 0.005$), and regional lymphadenopathy ($P = 0.007$; Table 3). On logistic regression, presence of a heterogeneous lesion, with a prevailing soft tissue component showing an irregular conglomerate appearance, together with the presence of mineralization and regional lymphadenopathy were features with statistically significant odds ratio favoring a diagnosis of a malignant form (Table 4). Presence of well-defined lesions without any evidence of hyperattenuating component within the mass, and presence of an irregularly shaped mass are features with statistically significant odds ratio favoring a diagnosis of lipoma and infiltrating lipoma, respectively (Table 4).

**Discussion**

This retrospective study described CT features of adipose masses that warrant a higher suspicion for infiltration and malignancy. In the current study, none of the masses underwent cytoreductive surgery or incisional biopsy prior to imaging and all adipose masses showed complete or partial fat attenuation. The majority of the benign tumors in this study appeared as a homogenous mass while liposarcomas were all represented by heterogenous masses with a large component of nonadipose tissue, generally characterized by a more nodular appearance, consistent with the literature. Nevertheless, as previously reported, a high percentage of the benign forms identified in this study showed a heterogeneous appearance, with presence of hyperattenuation components within. The exact cause of these characteristics remains unknown because the pathologic samples were not available for review or for mapping correlation with the CT images. According to the literature and the pathologic reports available, the authors propose that these regions most likely represented areas of...
Recognizing lipoma were the presence of a well-defined mass without associated hyperattenuating components. In general, the fat attenuating lesions did not show contrast-medium enhancement, except for some peripheral areas in those masses characterized by a fibrous capsule or perilesional inflammation, consistent with previous reported data. Evidence of bone involvement has been reported in patients with infiltrative lipomas. In this study, only three cases of liposarcomas showed an involvement of skeletal structures adjacent to the neoplastic lesion.

There were several limitations in this study. Firstly, this was a retrospective study, so no standardized protocols were established and only precontrast studies were available for five lesions and only postcontrast studies were available for three lesions. Also, there were a limited number of cases. In particular, the number of feline patients to feline masses was extremely small. Only the excised large lipomas causing clinical abnormalities for either compression or location were included in the study since the availability of the histopathology represented one of the inclusion criteria. The entire spectrum of adipose masses was not represented in our sample. In fact we did not have any cases of angiolipoma or infiltrating angiolipoma. The absence of cytologic confirmation and characterization of the regional lymphadenopathy and potential metastatic lesion was another limitation of the current study. Also, as previously mentioned, the pathological specimens were not available for review, thus a mapping correlation between the CT and the histopathological images was not possible.

In conclusion, findings supported the use of CT as a modality for assessing adipose tumor location, shape, extension, and relationship with the adjacent anatomic structures in dogs and cats. Although some CT features were shared by the different groups of fat-containing tumors, the present study identified several statistically significant features such as attenuation characteristics, margins, shape, and presence of regional lymphadenopathy, that are helpful to distinguish between adipose masses. Nevertheless, histopathology will be required to obtain a definitive diagnosis. Additional prospective studies comparing CT findings and gross pathological lesion patterns are needed to further characterize CT features of malignancy for fat-containing tumors.

**LIST OF AUTHOR CONTRIBUTIONS**

**Category 1**

(a) Conception and Design
Elisa Spoldi, Tobias Schwarz, Silvia Sabattini, Federica Rossi

(b) Acquisition of Data
Elisa Spoldi, Tobias Schwarz, Massimo Vignoli, Simona Cancedda, Federica Rossi
FIG. 5. Transverse contrast-enhanced image at the level of the stomach (A) in an 8-year-old intact female German Shepherd diagnosed with a liposarcoma. There is a multifocal to coalescing, predominantly heterogeneously fat attenuating mass with irregular nodular soft tissue component (white arrowhead) within the peritoneal cavity. There is a large amount of gravity-dependent abdominal fluid (white arrows). WW = 400, WL = 40.

Transverse contrast enhanced image in the same patient diagnosed with an intrabdominal liposarcoma (B). The sternal lymph node (white asterisk) is severely enlarged with rounded, lobulated margins, and heterogeneous contrast enhancement. WW = 400, WL = 40.
REFERENCES


