GENERAL DIAGNOSTIC IMAGING IN SMALL ANIMAL ONCOLOGY
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INTRODUCTION
Radiographs and ultrasonography are in integral part of cancer diagnosis and staging in small animals. This lecture will discuss their use in thoracic, abdominal, and musculoskeletal imaging with regards to certain cancers.

THORAX
Thoracic radiographs are routinely performed for cancer diagnosis and staging. One of the most common uses for thoracic radiographs is to evaluate for metastatic neoplasia, particularly pulmonary metastasis. Radiographs can also identify thoracic masses, as well as sequela to neoplastic processes, such as pleural effusion. Obtaining well-positioned three-view thoracic radiographs (right lateral, left lateral, and ventrodorsal projections), instead of a single lateral projection or two view thoracic radiographs will help with lesion detection, as some lesions will only be seen in one view, and with identifying the lesion location and extent. Pulmonary nodules, thoracic lymphadenopathy, and sometimes even thoracic mass (pulmonary, mediastinal, heart base, etc.) can be missed on radiographs. Thoracic computed tomography (CT) is superior to radiographs for lesion identification. Thoracic CT can be used to evaluate for metastatic neoplasia (e.g. pulmonary nodules, lymphadenopathy), to find lesions otherwise not appreciable with radiographs, to determine lesion location and extent, and for surgical planning. Ultrasonography can be used for lesion sampling or to evaluate intrathoracic masses and the pleural space as long as the structure of interest is not surrounded by aerated lung; air in the lungs will obscure evaluation of everything deeper than the surface of the lungs. Thoracic MRI is not as routinely performed because any motion, including respiratory and cardiac motion, results in significant artifacts. In this section, we will briefly discuss radiographic primary and metastatic pulmonary neoplasia, histiocytic sarcoma, lymphoma, and carcinomatosis.

Metastatic pulmonary nodules have to reach a certain size to be recognized on a radiograph. In a well inflated lung and an area without too many superimposed structures, nodules measuring 4-5 mm can be detected. In general, pulmonary nodules have to be on the order of at least 3-5 mm diameter to be recognized and differentiated from end-on vessels. Smaller nodules are only visible if a large number are present, leading to summation of the single small opacities. The areas where nodules can best be detected are the periphery of the lungs (larger than peripheral vessels) and the portion of the lung superimposed on (summation) the cardiac silhouette and the diaphragm. Two orthogonal views, two lateral views, or ideally 3 thoracic views, are important, as a partial collapse of the pulmonary parenchyma in dependent portions of the thorax will obscure pulmonary nodules.

Common pitfalls in the diagnosis of pulmonary nodules are end-on vessels, the presence of heterotopic bone (also called pulmonary osteomas), skin nodules, and nipples.
- End-on vessels can be recognized by their position close to a bronchus and adjacent to an equivalent sized vessel seen in long axis giving the appearance of a “tail.” End-on vessels are also relatively opaque as they are cylindrical in shape compared with a round metastatic nodule. They are smaller in the periphery of the lung and never larger than the vessels nearby.
- “Pulmonary osteomas” are small (1-4 mm) areas of osseous metaplasia within the interstitium just beneath the visceral pleura. They can be differentiated from metastatic nodules because they are smaller, relatively opaque, and well defined, usually several to many and of uniform size.
- Skin nodules, nipples, and ectoparasites (e.g. engorged ticks) can mimic pulmonary nodules, and can best be recognized based on their very sharp outline and position. If in doubt, the animal should be palpated and thoracic wall structures should be marked (metal “nipple markers” or some barium placed on the lesion) and thoracic films repeated.

Larger masses in the lungs may represent primary pulmonary neoplasms or other types of neoplasia, such as histiocytic sarcoma in dogs or lymphoma in cats. When present, air bronchograms within the mass help to identify the lesion origin as pulmonary. Primary pulmonary neoplasia in dogs and cats are usually a type of carcinoma. In
dogs, these are typically a large soft-tissue mass. In cats, pulmonary carcinomas can present as a large mass, a cavity less well-defined mass, or more diffuse disease (mixed lung pattern with bronchoalveolar carcinoma) as opposed to a solitary mass. Cavitated or mineralized areas within the mass may be evident in dogs or cats, but may be more common in cats. The affected lung lobe may lose volume, appearing somewhat smaller or resulting in an ipsilateral mediastinal shift, particularly if the mass is hilar in location. Bronchial compression or invasion may be present. Pulmonary carcinomas have a propensity for the caudal lung lobes, although they can occur in any lung lobes. Metastasis to the tracheobronchial lymph nodes may be present, but is often not radiographically appreciated. **Histiocytic sarcoma** in dogs can produce pulmonary masses and occurs most often in the ventral lung field, particularly the right middle lobe. With histiocytic sarcoma, there may be a single large mass or few masses/nodules. Lymphadenopathy, including sternal, cranial mediastinal, and tracheobronchial lymphadenopathy, may also be identified on radiographs. **Lymphoma** in cats may also produce a pulmonary mass or nodules. In dogs with lymphoma, thoracic lymphadenopathy may be present and is more common than pulmonary infiltrates. When present, pulmonary lymphoma more often produces an interstitial pattern – an unstructured interstitial pattern or a reticulonodular interstitial pattern.

When pleural effusion is present in conjunction with a pulmonary mass, pleural carcinomatosis may be present. **Pleural carcinomatosis** may occur secondary to primary pulmonary carcinomas or other neoplasms. Pleural effusion is present. The pleural and pulmonary margins may be undulating due to the presence of pleural thickening or nodules. Sometimes larger nodules or masses also may be seen along the ventral thorax, between the sternum and heart, on lateral projections.

**ABDOMEN**

Abdominal radiographs are frequently obtained as a screening tool to detect abdominal masses and can also be used to stage malignancies. Unless an abdominal mass is quite large, it may be easily missed on abdominal radiographs. Variation in species, breed and conformation, body condition, gastrointestinal contents, and radiographic projection may affect visualization of normal abdominal structures and abnormalities. Abdominal ultrasonography is an excellent screening and staging tool for abdominal disease, but is highly operator and equipment dependent. For example, an experienced sonographer with modern equipment can routinely identify the adrenal glands and normal lymph nodes which typically measure a few millimeters thick in dogs and cats. Gas, gastrointestinal contents, and mineralization inhibit evaluation of adjacent abdominal viscera. In addition to detecting lesions, ultrasonography is an excellent tool for facilitating lesion sampling. Ultrasound-guided fine-needle aspirates are a relatively less invasive procedure. Most dogs and cats require sedation to facilitate safe tissue sampling. Depending on the lesion location, appearance, size, and vascularity, ultrasound-guided tru-cut biopsies can also be considered; sedation or anesthesia is necessary to facilitate safe tissue biopsies. Abdominal CT and MRI are excellent complimentary imaging modalities for the abdomen and allow better visualization of lesions, lesion extent, and involvement of regional structures, such as vascular invasion of adrenal tumors or vertebral involvement of retroperitoneal masses. In this section, we will briefly discuss abdominal masses, including splenic, hepatic, gastrointestinal, and prostatic masses, and metastasis.

Identification of a space-occupying lesion, such as a mass or organomegaly, is assisted by describing its location and its “**mass effect**” - how the other abdominal structures are displaced by the mass. There may also be regional loss of detail from the space-occupying effect of the mass, as it displaces and silhouettes with adjacent structures. You may be able to visual the mass, but sometimes you are only able to see a mass effect (organ displacement, something seems to be taking up space in a region) rather than identifying a discrete mass. Depending on the anatomic region of the mass and its resulting mass effect, different organs can be prioritized. It’s all about anatomy and location. (And of course the other roentgen signs – opacity, margin, etc. – help as well). Use of special projections (i.e. opposite lateral view, oblique projections, projections with compression applied to the abdomen), contrast studies, and alternate imaging modalities (CT, MRI, and especially ultrasound) can assist in identification of a lesion. Even with ultrasound, the organ of origin can sometimes be difficult to delineate, particularly with large masses. It can sometimes be difficult to discern if the mass is adjacent to and abutting a structure versus arising from it. Anatomic landmarks, including vascular anatomy, can aid in identification of structures. The margins of the mass should be closely evaluated to identify a region adjacent to more normal parenchyma; sometimes larger vessels from the parent organ can be seen entering the mass.
Splenic and hepatic masses are two of the more commonly occurring large masses. On radiographs, splenic masses are typically mid abdominal masses. Portions of normal spleen may still be appreciable depending on where the mass arises along the spleen. Hepatic masses may cause caudal displacement of the portions of the stomach and may be seen protruding along the hepatic contour; however, even large hepatic masses may be missed on radiographs. Some hepatic masses are pedunculated, extending caudal to the stomach on a stalk of hepatic tissue. Pedunculated hepatic masses may radiographically look like splenic masses, being located just caudal to the stomach in the mid abdomen. With ultrasound, splenic and hepatic nodules and masses can be readily visualized. The vascular pattern can aid in differentiating a splenic vs hepatic origin. Splenic vessels can be seen extending into the parenchyma at multiple locations along the hilus, then branch, with the larger branches coursing roughly parallel to the spleen; whereas, hepatic vessels extend from the porta hepatitis and taper towards the periphery. The sonographic appearance of masses on ultrasound may help in prioritizing of differential diagnoses; however, the appearances are not specific and sampling (aspirates or biopsies) is required for diagnosis. For example, hemangiosarcomas and hematomas tend to have large “cavitary” areas of echogenic fluid, instead of being composed of solid tissue. (In general aspiration of cavitary masses is not recommended as there is increased risk of hemorrhage.) Hepatocellular carcinomas and adenomas may contain cyst-like regions. Splenic histiocytic sarcoma may produce numerous heterogeneously hypoechoic nodules and masses which efface the splenic architecture. Lymphoma may produce numerous small hypoechoic splenic nodules creating a “Swiss cheese” appearance.

Gastrointestinal masses, such as from lymphoma or a carcinoma, are often not radiographically visible. Gastric masses may be seen on survey radiographs if they are outlined by gas in the lumen, and may appear as focal mural thickening which may protrude into the lumen (depends on the amount of gas in the stomach, amount and presence of other gastric contents, patient positioning as gastric contents shift with patient position, and the size and location of the mass). Small intestinal masses may be seen on radiographs as a tubular, rounded, or lobular soft-tissue opaque structures and may have gas within them. Large intestinal masses may appear similar to small intestinal masses or may be seen as eccentric thickening along the colonic wall if gas or fecal material are present in the lumen. Ultrasound is capable of detecting changes to the intestinal wall, nodules, masses, and sequela such as an obstruction or perforation. If a gastrointestinal mass results in an obstruction, it may produce a “gravel sign” on radiographs. A gravel sign indicates a chronic partial obstruction. With a chronic partial obstruction, fluid material can pass but particulate material cannot. Particulate material accumulates just orad to the obstruction and is seen on radiographs as an accumulation of small mineralized fragments. If the mass results in perforation, poor regional serosal detail (due to free fluid and regional inflammation) and pneumoperitoneum may be detected on radiographs. Free air in the peritoneal space produces small bubbles or in large amounts may “highlight” or “outline” adjacent structures resulting in enhanced serosal detail - increased subject contrast. Pneumoperitoneum is often easiest to detect in the cranial abdomen (the least dependent aspect of the abdomen), particularly adjacent to the diaphragm or between liver lobes. Changes can be quite subtle unless there is a large volume of free air. To help with visualization of a small volume pneumoperitoneum, a horizontal beam projection can be obtained, either VD projection with the animal in left lateral recumbency or a lateral view with the patient in dorsal recumbency. A gas-fluid interface (“gas cap” or “fluid line”) can be seen with horizontal beam projection (i.e. looking at the side of a glass of water), but not with vertical beam projections (gas and fluid are superimposed; looking into a glass of water from the directly above it). Ultrasound is also capable of detecting a pneumoperitoneum; however, the changes may be subtle or difficult to differentiate from intestinal loops in the periphery of the abdomen.

Prostatic carcinomas are a relatively common type of neoplasm identified in dogs. In a neutered male dog prostatic carcinoma is the primary differential diagnosis for a radiographically visible prostate or for the presence of prostatic mineralization. When intrapelvic, the prostate itself may not be seen. Dorsal displacement of the colon or rectum and compression/narrowing of fecal material, may suggest that prostatomegaly is present. With ultrasound, the normal canine prostate in intact male dogs is relatively hyperechoic and has a bilobed appearance. In normal neutered male dogs, the prostate is small and relatively hypoechoic. With prostatic neoplasia, the prostatic echotexture is more heterogeneous; nodules, a mass, cavitations, and mineralization may be appreciated. The prostate gland may or may not be enlarged, and enlargement may be symmetric or asymmetric. Extension into the bladder may be evaluated. Metastasis to the sublumbar lymph nodes may be evident on ultrasound. The nodes may be more rounded, hypoechoic, heterogeneous, and surrounded by hyperechoic fat. Areas of cavitation may be present within the nodes. On radiographs, sublumbar lymph nodes produce and dorsally broad-based retroperitoneal mass at the level of approximately L5 and L6. Ventral displacement and compression of the adjacent colon may be
present. Metastasis to osseous structures (or the lungs) may also be present and appreciated with radiographs, but not during a routine abdominal ultrasound study. An irregular periosteal reaction may be seen along the ventral aspects of the caudal lumbar vertebrae in the region of the sublumbar lymph nodes. Areas of moth eaten lysis in the pelvis, vertebrae, or long bones also occur. Infiltration into the vertebral canal and secondary spinal cord or nerve root compression may result in neurologic deficits; these changes are not detectable with radiographs (MRI would be recommended).

For cancer staging, the abdomen is evaluated for local extension, for regional lymphadenopathy, and for nodules or masses in visceral structures or along the peritoneum (carcinomatosis). Metastatic lesions are more readily detected with ultrasound than with radiographs. On radiography, enlarged lymph nodes may be obscured due to superimposition of regional structures. Enlargement of the sublumbar lymph nodes may be more readily identifiable due to relatively less superimposed structures in this region. If markedly enlarged, the jejunal lymph nodes (also known as the mesenteric lymph nodes) might produce an ill-defined mass-effect in the mid abdomen – fewer small intestinal segments will be appreciated in the mid abdomen due to displacement from the lymph nodes. With ultrasonography abnormal lymph nodes, either reactive or neoplastic nodes, can be detected and may be rounded, hypoechoic, heterogeneous, enlarged, and/or surrounded by hyperechoic fat. Hepatic and splenic nodules are commonly identified with ultrasound, but not with radiographs. With radiographs hepatic and splenic nodules may create an undulating or “lumpy” organ contour where the nodules bulge from the parenchyma; visualization of this appearance depends on the nodules being large enough, on the location of the nodules in the parenchyma, and on the affected contour being tangential to the radiographic beam. Nodules in the liver and spleen are a common nonspecific ultrasonographic finding in aged canine and feline patients. These may represent benign processes, such as nodular hyperplasia, or may be neoplastic. Depending on the depth and location, nodules may be aspirated using ultrasound-guidance to aid in differentiating benign and malignant lesions; sedation is often needed to facilitate safe tissue sampling. Aspiration of small nodules and masses close to vasculature (such as the aorta, vena cava, mesenteric vessels, or intraparenchymal vessels) can be attempted with caution and should only be done in sedated patients. With carcinomatosis, in addition to peritoneal fluid, ultrasound may detect small nodules or masses along the parietal or visceral peritoneum and within the mesentery. Radiographically, a dog or cat with carcinomatosis may have poor serosal detail with or without mottling (ground-glass appearance).

MUSCULOSKELETAL STRUCTURES
With regard to osseous lesions, radiographs may help to determine if a lesion is aggressive or non-aggressive. Patterns of lysis, cortical lysis, lesion margins, zone of transition, and the pattern of periosteal reaction can assist with assessing the aggressiveness of a lesion (Table 1). Orthogonal radiographs should ideally be obtained. Sedation is often needed for straight position of skeletal radiographs. Straight radiographs and multiple views are particularly important when evaluating the axial skeleton. Lesions affecting the axial skeleton are particularly challenging to identify on radiographs or may not be radiographically detectable. In addition to the more classic aggressive appearances, vertebral lesions may sometimes alternatively appear predominantly sclerotic. Although radiographs may be used for screening purposes, MRI and CT may be necessary to detect a lesion, are useful to evaluate the location and extent of a lesion, and may aid in surgical planning. For evaluation of the spinal column, MRI is generally preferable over CT. Ultrasound may be used for guided-aspirates of osseous lesions if cortical disruption is present.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Non-Aggressive</th>
<th>Aggressive lesions</th>
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<tr>
<td>Lysis</td>
<td>No lysis or Geographic lysis</td>
<td>Presence of lysis (geographic, moth eaten, or permeative patterns)</td>
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<tr>
<td>Cortical destruction</td>
<td>None or Expansile cortical thinning (e.g. bone cyst)</td>
<td>+/- Cortical lysis</td>
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<tr>
<td>Margins</td>
<td>Well-defined</td>
<td>Poorly-defined</td>
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<tr>
<td>Transition from lytic to normal bone</td>
<td>Short transition zone</td>
<td>Longer transition zone</td>
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<tr>
<td>Periosteal reaction</td>
<td>Smooth</td>
<td>Irregular, Sunburst, Amorphous</td>
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Lesion location (bone affected, region of bone affected) and distribution (monostotic, polyostotic) assist with prioritization of differential diagnoses. Primary osseous neoplasms of the long bones (i.e. osteosarcoma) are typically centered at the metaphysis and monostotic, not extending into adjacent bones. Metastatic lesions in long bones tend to have a diaphyseal location due to hematogenous spread by the nutrient vessels and may be polyostotic.

With pathologic fractures, the fracture margins may be ill-defined, rounded, and there may be regional lysis. Aggressive changes may be subtle. The contrary is also possible. Within an aggressive lesion, a secondary pathologic fracture may be subtle; changes may include disruption or a step along the cortices or shortening/compaction of the bone.

FURTHER READING