

Imaging Techniques in the Clinical Evaluation of Oncologic Disorders

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Neoplasia almost always alters the normal spatial relationships of tissues and organs, and therefore diagnostic imaging is critical not only for the diagnosis of cancer but also for staging the patients and for following response to therapy. At present the most frequently used imaging modalities for the diagnosis of cancer are conventional radiographs and ultrasound, but magnetic resonance imaging (MRI), computed tomography (CT), and nuclear medicine are increasing in availability and usage. Even with these advances it is necessary to emphasize that the clinician still is not able to make a tissue diagnosis based on the image and that relevant clinical information as well as cytology or histopathology is necessary to make a definitive diagnosis. The use of ultrasound, CT, MRI, and nuclear medicine has not replaced conventional diagnostic radiographs but rather complements them. These newer imaging modalities have made assessing tumor margins, evaluating for metastasis, and determining the degree of invasiveness more reliable. These techniques are quite expensive but at the same time lend more information to the diagnosis, which may decrease cost and patient suffering in the long run. They may also aid in narrowing the list of differ-

ential diagnoses and prevent unnecessary surgery. The newer imaging modalities will also help to guide deep needle aspirations or biopsies as well as assist in planning open biopsies and surgical resections.

IMAGING MODALITIES

Conventional diagnostic radiography still remains a valuable diagnostic tool in the practice of veterinary oncology. Availability and cost are major advantages to the use of conventional radiographs. Radiographs provide good spatial resolution but have poor contrast discrimination between normal and neoplastic soft tissues. Invasiveness and tissue architecture cannot be assessed. One advantage to the use of conventional radiographs is their ability to cover a large area such as the abdomen or thorax in two images (lateral and ventrodorsal [VD]/dorsoventral [DV]). They can provide information regarding the size, shape, margination, opacity, position, and organ displacement more easily than other imaging modalities. Conventional radiographs are a good screening procedure and guide to further diagnostic procedures and imaging modalities.

Improved *ultrasound* technology and increased clinical applications for ultrasound have made it an important imaging modality for diagnosis and evaluation of therapeutic response in the veterinary cancer patient. The affordability and availability of ultrasound equipment have resulted in a tremendous increase in its use in veterinary practice. Ultrasound excels as an imaging modality to discriminate between cystic and solid masses, to evaluate a body cavity filled with fluid (abdominal or pleural effusion), to determine the internal architecture of an abdominal organ, or to guide fine-needle aspiration or tissue core biopsy. Ultrasound's ability to find both focal and diffuse tissue abnormalities is excellent, but definitive diagnosis still depends on cytology or histopathology.

Computed tomography is the production of tomographic images (cross-sectional slice images) using x-rays and computers. With CT scanning the recorded tissue densities have the same significance as the film densities on conventional radiographs. Compared to conventional radiographs, computed tomography has excellent contrast discrimination and the ability to separate deep structures without the superimposition of overlying tissues (e.g., it is possible to visualize the brain without the inconvenience of the surrounding skull). Soft tissues must be significantly altered by disease before changes can be visualized with conven-

tional radiographs whereas changes can be appreciated earlier and more accurately with CT. The appearance of a tumor can be compared with adjacent normal tissues to provide information on the degree of invasiveness.

Magnetic resonance imaging can be easily obtained in any plane (axial, sagittal, and coronal). The contrast between different soft tissues is superior to all other imaging modalities. Standard MRI scans also take a relatively long time (minutes rather than the seconds required in a CT); therefore body, respiratory, cardiac, and intestinal motion are potential problems. General anesthesia is required, and monitoring of patients can be difficult depending on the type of MRI unit utilized. MRI can be very expensive and availability is not as universal as CT, but benefit versus risk shows that nothing is superior for imaging of the central nervous system.

PULMONARY SCREENING

Conventional radiographs represent the most valuable and cost-effective examination for primary screening of neoplasia of the thorax. Radiographs should be taken in all patients suspected of having cancer and during treatment periods to monitor response to therapy. Taking three views of the thorax (right and left laterals as well as DV or VD) should act to increase sensitivity for finding lesions.

Pulmonary neoplastic lesions can be divided into several categories:

- Solitary or multiple well-defined nodules or masses
- Solitary or multiple ill-defined nodules or masses
- Amorphous ill-defined alveolar opacities
- Diffuse miliary (micronodular) interstitial opacities
- Diffuse interstitial opacities
- Diffuse and lobar alveolar opacities

Solitary nodules with either well- or ill-defined borders are the most characteristic findings of primary pulmonary neoplasia. Cavitation is occasionally present within primary or metastatic pulmonary nodules or masses. Primary lung tumors are most commonly found in the caudal lung lobes (right more than left). Metastatic disease from non-lung cancer is much more common than primary lung cancer in the dog and cat. Pulmonary metastases can appear as solitary, cavitory, or noncavitory interstitial masses (>4 cm diameter), interstitial nodules (2 to 4 cm diameter), or interstitial miliary masses (<2 cm diameter). The most common radiographic appearance of pulmonary metastases is multiple well-circumscribed noncavitory pulmonary masses, nodules, or miliary masses.

Computed tomography, by virtue of its cross-sectional display of anatomy and superior contrast and anatomic resolution, can differentiate pulmonary lesions from overlying normal superimposed structures. CT is clearly superior to conventional radiography in demonstrating the extent of the primary lesion, invasion of the hilum or mediastinum, body wall or pleural space involvement, and the presence of enlarged lymph nodes. Iodinated intravenous contrast can help to distinguish between vascular and nonvascular abnormalities. At present the most sensitive modality in the diagnosis and staging of pulmonary metastatic disease is CT.

SKELETAL SCREENING

A diagnosis of skeletal neoplasia can often be supported on conventional radiographs. Bone scintigraphy may be used to screen for additional lesions or to evaluate the extent of lesions diagnosed radiographically. MRI and CT are used not to obtain a diagnosis but rather to supply additional information about location and extent of the tumor. Definitive diagnosis is made based on biopsy and histopathology.

It is impossible to make a definitive diagnosis of neoplasia versus an infectious or benign bone lesion by radiographic means alone. By integrating signalment, history, and physical and laboratory examination along with the radiographic changes, a prioritized differential diagnosis can be made with a high degree of accuracy. Radiographic changes may include:

- Adjacent soft tissue swelling
- Aggressive radiographic changes (poorly demarcated long transition zone between normal and abnormal bone)
- Cortical lysis
- Periosteal reaction (amorphous or sunburst)
- Pathologic fracture

Primary bone tumors usually begin in the metaphysis and extend into the epiphysis and diaphysis secondarily. Uncommonly they may cross joints or invade adjacent bones, but this usually occurs late in the disease. Multifocal areas of increased medullary opacity (bone infarction) within the medullary cavity may be seen.

Magnetic resonance provides a highly sensitive means to document or exclude pathology. MRI is superior to all other imaging modalities for delineating the margins of a tumor with respect to adjacent normal tissues.

CENTRAL NERVOUS SYSTEM SCREENING

Evaluation of the brain and spinal cord is one of the few situations where conventional radiography is of little value unless there is adjacent bone involvement.

Computed tomography provides diagnostic information for many brain and spinal lesions. Two scan series are usually performed with CT, the first being a survey and the second after intravenous iodinated contrast injection. Intravascular contrast agents usually enhance masses and demonstrate vascular alterations and areas of disruption of the blood-brain barrier. Certain canine brain tumors may have distinguishing features on CT images based on location and pattern of contrast enhancement.

Magnetic resonance imaging is the technique of choice for imaging brain and spinal cord neoplasia. MRI is ideally suited for imaging of intracranial neoplasia because of its inherent property of producing excellent contrast between normal and abnormal tissue. Intravenous gadolinium contrast may also be valuable to show blood-brain barrier disruption.

ADRENAL SCREENING

Radiographic changes of the adrenal are detectable if the adrenal tumor is large or mineralized. Large unilateral adrenal masses may displace the kidney or other adjacent abdominal organs, providing additional evidence of adrenomegaly. Mineralization of adrenals can occur with neoplasia as well as with nonneoplastic disease. Other changes that might be radiographically apparent with an adrenocortical tumor are large blunted pulmonary arteries secondary to pulmonary thromboembolism and pulmonary interstitial mineralization. If tumor invasion of the caudal vena cava is suspected, a nonselective venogram can be diagnostic.

Adrenal ultrasound is very sensitive for the diagnosis of adrenal neoplasia. The one problem is that nodular hyperplasia may mimic the appearance of an adrenal adenoma, although adenomas are usually unilateral and may not disrupt the architecture (or disrupt it far less than malignant tumors do). Adenomas (nodular hyperplasia) may appear as hyperechoic foci within a normal-sized and -shaped adrenal. Tumors may appear hypoechoic or have a mixed echogenicity. Invasion of the caudal vena cava may be detected. Diagnosis of an adrenal mass with ultrasound is not diagnostic for tumor type. The liver, abdominal lymph nodes, and adjacent structures can be evaluated for invasion and metastasis.

NASAL SCREENING

There are basically four different radiographic patterns of change that occur in the nasal passages:

- Increased soft tissue opacity (focal or diffuse) overlying a normal conchal pattern
- Increased soft tissue opacity (focal or diffuse) overlying areas of conchal destruction
- Areas of conchal destruction without accompanying increase in soft tissue opacity
- A combination of the above patterns

Rather than indicating an etiology, these patterns reflect a level of aggressiveness and duration. Most nasal neoplasia originate from the level of the ethmoid conchae and cribriform plate. Disruption of the nasal and vomer bones (bony nasal septum) can be seen. Large areas of the cartilaginous nasal septum may be destroyed and may not be evident radiographically other than as a bilateral increase in soft tissue opacity. Because radiographic changes are nonspecific, definitive diagnosis should be based on nasal flushes and cytologic studies, biopsies, and culture.

Computed tomography is superior to conventional radiography for demonstrating changes associated with nasal neoplasia in dogs. This superiority is a result of the higher contrast resolution and the ability to minimize superimposition of overlying structures. Several CT findings are strongly correlated with a diagnosis of neoplasia:

- Patchy areas of increased opacity within soft tissue
- Destruction of all or part of the ethmoid bone
- Abnormal soft tissue in the retrobulbar space
- Destruction of the lateral maxilla
- Destruction of the nasal bone or the rostral dorsal maxilla
- Hyperostosis of the lateral maxilla

CT is more helpful in differentiating fluid versus masses in the frontal sinuses. Because the extent of nasal neoplasia can be more accurately determined with CT, it is recommended when surgery or radiation therapy is to be used as a treatment modality.

Magnetic resonance imaging appears superior to CT for detection of cribriform plate involvement and provides better anatomic detail of the tumor and secondary pathology.

ABDOMINAL SCREENING

Conventional abdominal radiographs are still an excellent screening technique for suspected abdominal neoplasia. Radiographic differentiation of abdominal masses depends on a good working knowledge of normal radiographic anatomy. An abdominal mass that is palpated is not always visualized on survey radiographs directly but may indirectly demonstrate dis-

placement of bowel or other abdominal organs. Conventional radiographs help to guide the diagnostic workup as well as determine the use of other imaging modalities. Before resorting to contrast radiography to enhance visualization of a poorly demarcated mass, one should consider positional or compression radiography. Positional radiography may consist simply of obtaining the opposite lateral view, a DV view, or an oblique view. Positional radiography may also include horizontal beam projections with erect and decubitus patient positioning. Compression radiography creates anatomic separation of adjacent abdominal structures, which may help define the appearance of the mass as well as the organ of origin.

Ultrasound is an excellent follow-up to radiographs as it can define the organ of origin and internal architecture and evaluate the rest of the abdomen (including other abdominal organs as well as lymph nodes) for metastasis. Abdominal effusion, which may be present with cancer (carcinomatosis), usually does not hamper and can even enhance the diagnosis of neoplasia via ultrasound. Ultrasound is also very helpful in guiding fine-needle aspiration and biopsy. CT also provides excellent abdominal detail, but cost and the necessity of general anesthesia limit its current use.

RENAL SCREENING

Conventional radiographs are the first line of imaging when renal disease is suspected. Small mass lesions that do not affect renal opacity, contour, or size will not be appreciated on survey radiographs. Neoplasia generally will appear radiographically as large irregularly or regularly shaped smooth or roughly margined kidneys. An enlarged neoplastic left kidney may displace the colon ventrally and may displace the small intestine ventrally and to the right. Mass lesions of the right kidney may result in displacement of the small intestine ventrally, caudally, and to the left. Excretory urography is useful in that it can help to better define kidney size, shape, contour, and the appearance of the collecting system. Neoplasia can cause disrup-

tion of the collecting system or, if large enough, obstruction and secondary hydronephrosis of the kidney.

Ultrasound may demonstrate a variety of appearances of renal neoplasia, including hypoechoic or hyperechoic masses, small masses that do not disrupt renal size or contour, masses of mixed echogenicity (due to hemorrhage, necrosis, vascular invasion), multiple mass lesions, and large masses with complete disruption of the normal renal appearance.

BIOPSY TECHNIQUES

Biopsy techniques can be used in association with fluoroscopy (thorax), ultrasound (anywhere ultrasound can provide information), or CT (anywhere). At present biopsies are most often performed blindly or with ultrasound guidance. In many instances neoplasia is just part of the differential diagnosis, and a definitive diagnosis is necessary for prognosis and accurate treatment. Percutaneous ultrasound-guided fine-needle aspiration and tissue core biopsy are minimally invasive and cost-effective techniques for obtaining diagnosis. Risks that should be considered include neoplastic dissemination, infection, and hemorrhage. Ultrasound-guided tissue samplings have yielded few risks and even fewer that are life threatening. Benefit versus risk dictates that these high-yield, low-risk procedures provide helpful information necessary for the diagnosis and treatment of cancer in veterinary patients.

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