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Review

The future of imaging in veterinary oncology: Learning from human medicine

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ABSTRACT

Imaging technology is critical for adequate diagnosis and staging in human and veterinary oncology. Sensitive detection of lesions is necessary to determine appropriate local or systemic therapy and to monitor therapeutic results. New technology in digital radiography, ultrasound, and computed tomography (CT) scanning are now widely available in veterinary medicine. Advanced imaging with high-detail CT scans, magnetic resonance imaging (MRI), and positron-emission tomography (PET) are now available in academic centers and some private specialty practices. This review describes the current and future applications of these new imaging systems and modalities in veterinary oncology and how advanced imaging contributes to diagnosis, staging, and monitoring of cancers. The potential of molecular imaging for accurate, minimally invasive diagnosis and monitoring is discussed.

Introduction

Diagnostic imaging is central to oncology practice to identify primary and metastatic lesions while staging patients, and then subsequently to monitor those lesions. While imaging cannot replace histology, several modalities facilitate diagnostic sampling and in the future scans may also be able to identify tissue type. The quality of image generation and contrast agents has evolved dramatically in the last few years. All imaging modalities used in human medicine are becoming available in veterinary medicine, including positron emission tomography (PET) and PET combined with computed tomography (CT) imaging. Images can be anatomic, functional, and molecular in nature. Each imaging modality has its strengths and weaknesses for the diagnosis and staging of cancer.

The purpose of this review is to describe the current state-of-the-art in veterinary oncology imaging using examples to illustrate the application for several specific disease processes.

Imaging modalities

Radiography

Radiography is routinely used to obtain baseline information of the thorax and musculoskeletal system. Radiography complements ultrasound by providing information about the relative size and position of organs and skeletal metastasis. Like in humans, thoracic radiographs are the mainstay for pulmonary metastasis monitoring, especially in light of recent concerns about cumulative diagnostic radiation dose from CT (Brenner, 2010). The increased sensitivity of digital radiography reveals pulmonary nodules smaller than possible with film-screen systems (Fig. 1).

Ultrasound

Ultrasound has become the foundation of abdominal imaging in veterinary medicine. It can better define organ-specific location of radiographically identified lesions or discover lesions not apparent radiographically. However, the identification of an intraparenchymal lesion is generally poorly specific and must be investigated cytologically or histologically for a definitive diagnosis. A notable exception is that alterations of the normal ultrasonographic appearance of gastrointestinal wall thickness, layering, and lymph node characteristics may differentiate lymphoma from inflammation (Zwingenberger et al., 2010).

Ultrasound facilitates guidance for fine needle aspirates and tissue core biopsies. Doppler ultrasound provides information about blood flow and vascular invasion. Doppler imaging has increased the safety of sampling, but does not reliably distinguish the benign from the malignant. Nonetheless, ultrasound has become a sensitive tool in the staging of cancer (Flory et al., 2007). Contrast ultrasound techniques borrowed from human medicine are also useful in differentiating benign from malignant hepatic lesions. Contrast can also increase conspicuity of lesions which may be poorly seen, if at all, on conventional ultrasound scans.

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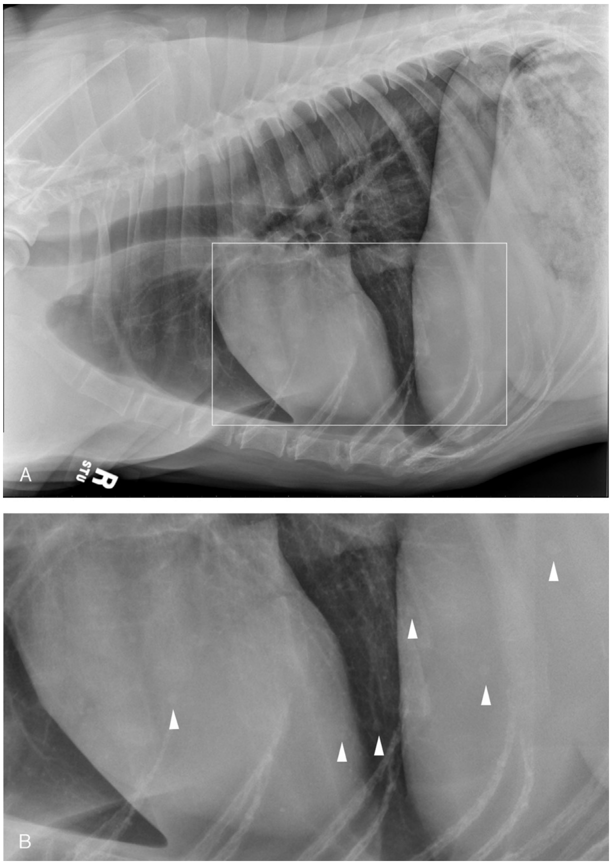

Fig. 1. Hemangiosarcoma pulmonary metastasis in a 13-year-old German shepherd dog. (A) Right lateral digital thoracic radiograph showing the resolution limits of pulmonary nodule detection. (B) Multiple, 4–5 mm soft tissue nodules are identified in the magnified image (inset, arrowheads). Digital radiography enables optimized adjustment of image contrast and magnification, essential for detection of small or subtle pathology. (Image courtesy of Washington State University).

A small number of veterinary studies have evaluated contrast ultrasound for characterization of splenic, hepatic, and renal lesions. As in human medicine, contrast ultrasound may differentiate malignant from benign lesions (Rossi et al., 2008; Webster and Holloway, 2008; Ivancic et al., 2009; Kanemoto et al., 2009; Haers et al., 2010). Contrast has also been used to assess lymph node pathology and to increase conspicuity of small sentinel nodes for biopsy (Salwei et al., 2005; Lurie et al., 2006; Gelb et al., 2010).

While human medicine often relies heavily on CT, ultrasound is the mainstay of abdominal imaging in veterinary medicine. This is mostly due to smaller patient size, lack of need for general anesthesia, lack of ionizing radiation exposure, and the lower cost of ultrasound equipment relative to CT. In addition, most abdominal ultrasound examinations of humans are technologist-acquired regional or focal examinations. In veterinary medicine most abdominal scans can be considered an 'abdominal exploratory' requiring a veterinarian to directly perform or monitor the entire scan.

Perhaps the biggest inadequacy of abdominal ultrasound is the limited cross-sectional field-of-view when compared to CT or magnetic resonance imaging (MRI). This can manifest as unrecognized or misidentified lesions. The inability to visualize the entire lesion within the field-of-view makes it impossible to accurately measure large lesions. Ultrasound yields poorly reproducible measurements in the urinary bladder, making therapy monitoring of bladder masses difficult (Hume et al., 2010).

The newest ultrasound machines have extended field-of-view capability, allowing the sonographer to create a panoramic image of the entire lesion (Fig. 2). This is a very useful feature, but cannot provide accurate measurements and is a static image (vs. real-time). Although ultrasound is used in practice to assess the extent of cancer and its margins for surgical resection and radiation therapy, it is of limited value in this application; CT and MRI provide better information. Despite these inherent limitations, ultrasound is used appropriately to screen for disease, assess for multi-organ involvement in known disease, acquire guided samples, and re-evaluate disease during or following therapy.

Computed tomography

CT is a cross-sectional imaging modality that can be reconstructed in essentially unlimited multiplanar and three-dimensional orientations following single data acquisition. CT data can be acquired rapidly using sedation or even gentle restrain, in place of general anesthesia for most studies (Oliveira et al., 2011). Large field-of-view permits a global perspective for accurate assessment of large and complex lesions for surgical and radiation therapy planning (Fig. 3). Detailed reconstructions are particularly useful for identifying margins and vasculature in surgical planning for complex bony tumors. Algorithms control image acquisition following contrast injection to generate arterial and venous phase studies, enhancing visualization of tumor vascular supply and invasion (Nitzl et al., 2009).

CT is the most sensitive modality for detection and assessment of pulmonary lesions in human and veterinary medicine (Fig. 4) (Nemanic et al., 2006; Choi et al., 2010; Somboonporn et al., 2010). However, CT has not replaced thoracic radiography due to cost and more limited availability. While CT is also preferred for evaluation of human abdominal disease, its use in veterinary medicine is far more limited. Newer CT technology available to veterinarians will expand collective expertise in image evaluation (Fig. 5).

Recent press attention has raised public awareness of health risks associated with the possible high radiation dose received from CT scans. It is worth noting that current algorithms do include optimizing protocols that minimize patient dose in the scanning process (Mayo, 2008; Brix et al., 2009; Sodickson et al., 2009; Brenner, 2010). A similar health risk has not yet been identified in companion animals, but is likely to exist as this technology is increasingly available.

Magnetic resonance imaging

MRI is the standard technique for neuroimaging in human and veterinary medicine with application to essentially all body systems. Large field-of-view cross-sectional images can be obtained in any chosen plane. Use of a variety of imaging sequences enables the selective enhancement and fine-detail resolution of soft tissues based on the molecular composition of tissues. The soft-tissue detail is far superior to CT (Fig. 6). MRI requires much longer data acquisition time compared to CT and therefore general anesthesia for animals. Many radiation planning systems cannot use MRI data as they rely on the X-ray density data present in CT scans to calculate absorbed dose.

Because of the superb detail, MRI is most useful for the identification of tumors and tumor margins within soft tissue before surgery or radiation therapy. MRI is also a very sensitive monitoring tool following therapy that carries some risk of identifying other abnormalities with unknown relationship to the primary disease process (Koppelmans et al., 2011). Compared to other imaging modalities, lesions identified on MRI appear to be more extensive (Kafka et al., 2004). This may reflect true disease extent or may overestimate lesion size.