PEER REVIEWED

Advanced Imaging: Its Place in General Practice

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In the last 2 decades, use of advanced imaging modalities, such as computed tomography (CT) and magnetic resonance imaging (MRI, or MR), has become more available in veterinary medicine at a relatively low cost to clients.

The ability to offer same-day imaging and board-certified radiologist interpretation in many facilities provides veterinary patients with a better quality and level of care than is often available to their human owners. However, the availability of advanced imaging varies:

- In most cases, imaging centers, specialty hospitals, and universities work together to provide state-of-the-art, noninvasive imaging for veterinary patients.
- In some areas, imaging centers are competing with specialty/referral hospitals and universities for business.
- In other areas, however, CT and MRI are still unavailable and some general practitioners are considering adding these modalities to their practices.

The goals of this article are to:

1. Help identify patients that will benefit from advanced imaging
2. Assist with setting pet owner expectations regarding the referral process
3. Discuss advanced imaging for general veterinary practice
4. Review recent advances in imaging modalities that may result in increased availability to underserved areas.

SIX INDICATIONS FOR ADVANCED IMAGING

In human medicine, CT and MRI are used as primary studies to:

- Image the brain, spine, and gastrointestinal (GI) and vascular systems
- Evaluate musculoskeletal disorders
- Screen for metastasis.

Conversely, in veterinary medicine, advanced imaging has a much smaller role because survey radiographs and ultrasound are our primary imaging modalities, which is due to a combination of availability, cost, and requirement for general anesthesia during advanced imaging. However, CT and MRI play an essential role in cases where the benefit of the diagnostic yield outweighs the cost and necessity for general anesthesia.

Although CT and MRI are used for many different applications in veterinary medicine, 6 clinical scenarios unequivocally warrant pursuit of advanced imaging. These recommendations are based on my clinic experience as no guidelines regarding indications for advanced imaging have been established in veterinary medicine.

Figure 1. *MRI image of a contrast enhancing brain mass*

1 Brain Imaging

Indications. Patients with seizure disorders, head tilt, ear disease, or behavioral changes believed to be caused by intracranial disease, such as tumors, infectious lesions, or congenital brain abnormalities (**Figure 1**).

Prereferral Imaging. Thoracic radiographs, which provide metastatic and pre-anesthetic screening.

Advanced Imaging. In most cases, MRI is recommended for brain imaging; however, CT is indicated in some situations and provides a less expensive alternative.

In my opinion, CT imaging of the brain should be reserved for older, large breed dogs, such as golden retriever and boxer dogs, that are predisposed to development of neoplastic brain lesions, which have a high likelihood of identification on CT.

Prereferral Client Preparation. Pet owners should be advised that:

- MRI can identify many brain lesions, such as mass lesions, inflammation, or hemorrhage, but may be normal in cases with subtle brain inflammation or idiopathic seizure disorders.
- Cerebrospinal fluid (CSF) analysis often accompanies brain MRI to rule out inflammatory disease and adds additional cost and risk.
- A negative brain MRI or CT is an important finding. For example, failure to identify a mass lesion indicates that neoplastic disease is less likely. This finding helps guide therapy and narrow the rule out list.

2 Spine Imaging

Indications. Patients with back pain, ataxia, or paraparesis.

Prereferral Imaging. Thoracic radiographs, which provide metastatic and pre-anesthetic screening.

No additional radiographs are necessary if the patient will be referred for advanced imaging. Rarely, spinal radiography may identify a bone lesion in older, large breed dogs; however, bone loss must be greater than 50% per unit area to be seen on radiographs. Therefore, if a lesion is seen on a radiograph, it is very advanced.

Advanced Imaging. In most cases, MRI is recommended for spinal imaging. CT with contrast medium, or CT myelography, can be used as a less expensive alternative to rule out or identify *surgical* spinal disorders, such as tumors (intramedullary, extradural, or intradural–extramedullary) and intervertebral disk herniations (**Figure 2**), if:

- MRI is unavailable, or finances do not provide for MRI imaging
- The patient is a small breed or chondrodystrophic dog (ie, dachshund) and the lesion is not localized to the cervical spine.

CT with contrast or myelography, however, may fail to identify nonsurgical lesions of the spinal cord, such as inflammatory disorders, neurodegenerative disorders (eg, degenerative myelopathy), or fibrocartilaginous emboli, but it would rule out the need for surgery, allowing medical management to be pursued.

Prereferral Client Preparation

Pet owners should be advised that:

- MRI and CT are generally sensitive diagnostic tests for evaluation of the spine and spinal cord; in nearly all cases, CT and MRI will identify surgical spinal lesions.
- MRI and CT may be negative (normal) in cases with some inflammatory/infectious disorders and degenerative disorders, such as degenerative myelopathy.
- CSF analysis often accompanies spinal imaging to rule out inflammatory disease and adds additional cost and risk.

Figure 2. *CT myelogram demonstrating intervertebral disk herniation, with compression of the spinal cord*

3 Nasal Imaging

Indications. Patients with nasal cavity disorders, such as epistaxis and nasal discharge.

Prereferral Imaging. Thoracic radiographs, which provide metastatic and pre-anesthetic screening.

In the past, survey radiographs of the nasal cavity were recommended; however, as a general rule, radiographs are insensitive for evaluation of nasal cavity disorders because radiographic changes are often only apparent late in the disease course. Nasal radiography also *requires* general anesthesia and skilled technical staff. Therefore, in my opinion, if advanced imaging is being pursued, survey radiographs of the nasal cavity are not recommended.

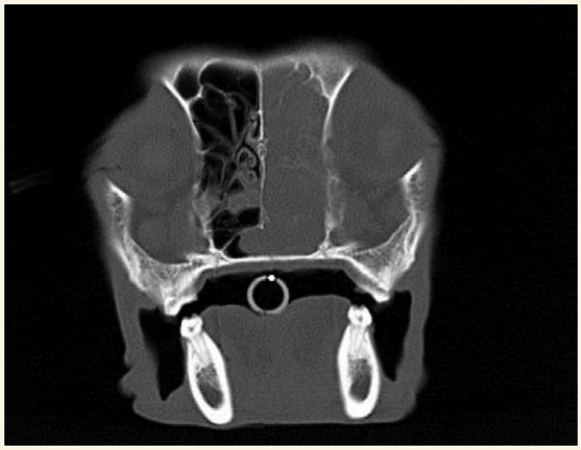

Figure 3. *CT image demonstrating an aggressive nasal mass, with extension into the nasopharynx; this type of lesion is characteristic of a nasal tumor*

Advanced Imaging. CT is recommended for the evaluation of nasal cavity disorders (**Figure 3**); MRI yields similar information but carries additional cost.

Prereferral Client Preparation. Pet owners should be advised that:

- CT is a highly sensitive diagnostic tool for evaluation of nasal cavity disorders (ie, if there is significant disease in the nasal cavity it will be readily identified on CT).
- Although CT findings can be suggestive of a specific disease, a biopsy is always needed to obtain a definitive diagnosis. Nasal biopsy adds additional cost to the diagnostic process, and will require additional general anesthesia.

4 ELBOW IMAGING IN YOUNG PATIENTS

Indications. Immature patients with chronic lameness, which can be localized to the elbow joint in breeds predisposed to elbow dysplasia.

Prereferral Imaging. Survey radiographs of the elbow joint, which are necessary to rule out osseous trauma and identify some of the lesions associated with elbow dysplasia (eg, ununited anconeal process, osteochondritis dissecans).

In some cases (eg, fragmented medial coronoid process), survey radiographs may not identify lesions until late in the disease process, when surgical intervention is less valuable. Therefore, advanced imaging is necessary to evaluate elbow dysplasia when survey radiographs are within normal limits (WNL).

Advanced Imaging. CT is recommended for evaluation of elbow disorders in immature patients (**Figure 4**); MRI yields similar information but carries additional cost.

Prereferral Client Preparation. Pet owners should be advised that:

- Survey radiographs do not rule out elbow dysplasia because they may be WNL until late in the disease process.
- If a surgical lesion is present, advanced imaging will identify the lesion, allowing early surgical intervention before secondary osteoarthritis progresses to the point where surgical intervention is less effective.
- Appropriate surgical intervention is more successful when performed at a young age. Delay of advanced imaging is not recommended if there is a clinical suspicion for elbow dysplasia, even if survey radiographs are WNL.

5 Incontinence Imaging in Immature Patients

Indications. To rule out ureteral ectopia in immature, incontinent patients.

Prereferral Imaging. Abdominal radiographs to rule out spinal disorders or other gross abnormalities that could account for incontinence.

In the past, radiographic urography was recommended. In my experience, if CT is available, a radiographic IV urogram is not the optimal diagnostic test because it can be insensitive and difficult to interpret.

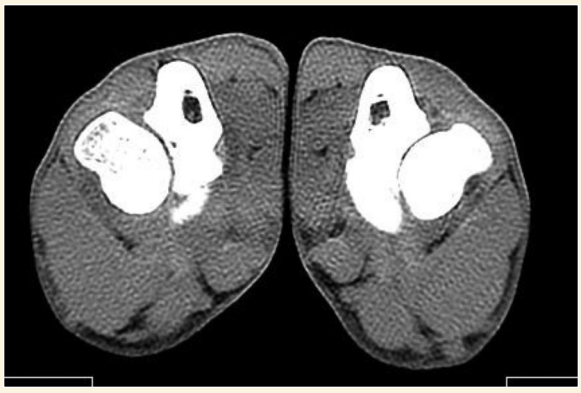

Figure 4. *CT image of a young dog with elbow dysplasia; a fragmented medial coronoid process is present*

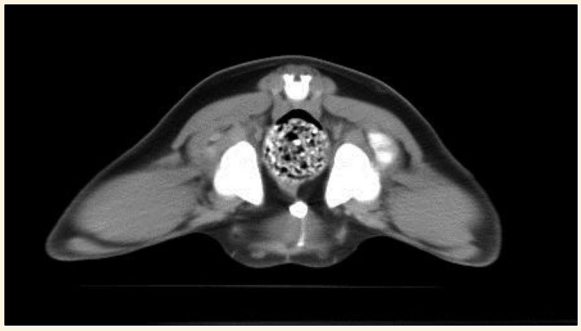

Figure 5. *Large ectopic ureter inserting distal to the urinary bladder; the ureter in this image is the white ovoid structure ventral to the colon.*

Advanced Imaging. A CT IV urogram is recommended for evaluation of incontinence in immature patients to rule out ureteral ectopia (**Figure 5**).

Prereferral Client Preparation. Pet owners should be advised that:

- A CT IV urogram is extremely sensitive for identification of ureteral ectopia.
- If the CT is negative, it essentially rules out ureteral ectopia as the cause of incontinence.

6 Presurgical Evaluation Before Mass Removal

Indications. Patients with mass lesions, in which a presurgical evaluation of disease extent helps with surgical planning. Examples of mass lesion locations that may benefit from presurgical CT evaluation include cutaneous, thoracic body wall, hepatic, and mandibular mass lesions.

Prereferral Imaging. Prereferral imaging will vary depending on the location of the mass.

- Thoracic and survey radiographs are generally recommended for metastatic screening and initial evaluation of the mass lesion.
- Abdominal ultrasound may be of value to rule out disseminated disease in cases of hepatic masses.

Advanced Imaging. CT is recommended to evaluate mass lesions for surgical planning. MRI generally offers similar information, and also provides more information about edema and inflammation associated with the mass, but carries a higher cost.

Prereferral Client Preparation. Pet owners should be advised that:

- The reason for advanced imaging in these patients is to define disease extent, which will help with surgical planning. During surgery, it is necessary to obtain clean margins but, in many cases, it is difficult to determine the disease extent at time of surgery.
- Initial cost of advanced imaging will far outweigh the costs associated with revision surgery if clean margins are not obtained during the initial surgery.
- In most cases, advanced imaging will not alter a diagno-

sis; in some cases, however, advanced imaging can identify metastatic lesions or secondary bone involvement that survey radiographs cannot.

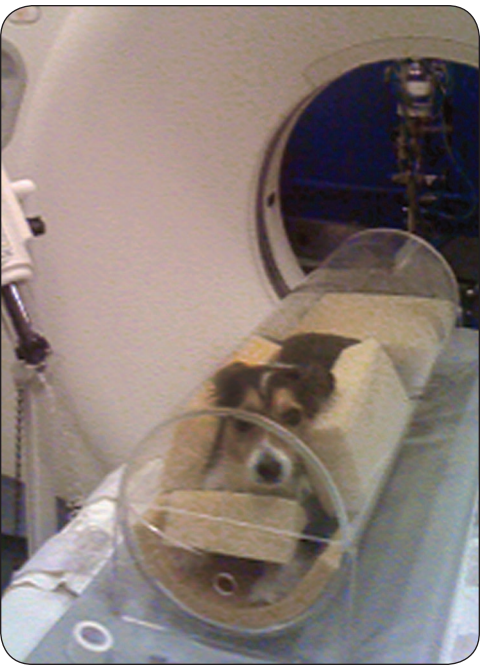

Figure 6. Patient in the VetMoustrap. Courtesy University of Illinois

RECENT ADVANCES IN VETERINARY CT

The overall use of CT in veterinary medicine has been relatively static for several years. The necessity for general anesthesia introduces risk and/or artifact, making CT more complicated and expensive for us to use in situations where it can be very beneficial in humans, such as trauma, abdominal/GI, and many thoracic evaluations, including chronic pulmonary disease and metastatic screenings. In the near future, though, this may change.

Researchers at the University of Illinois[1] introduced the use of an ultrafast 16-slice CT scanner, which is able to image an entire veterinary patient in a few seconds, combined with a clear box called the *VetMousetrap* in which nonanesthetized patients are imaged (**Figure 6**).

- This image acquisition speed allows researchers to image the patient without general anesthesia; the speed also keeps motion artifacts to a minimum.
- This type of scanner also obtains isotropic data volume; in other words, the data acquired can be reformatted into any imaging plane, which means that patient positioning during imaging is not a significant consideration.
- It is possible to use light sedation while obtaining images, which allows for proper patient positioning and limits movement and patient stress.

With this new CT imaging technique for veterinary patients, CT can be performed in lieu of radiography and ultrasound, and for indications that were once limited to human patients. The main limitations of CT in this application are:

- Initial cost and ongoing maintenance of the CT scanner
- Due to the size of the VetMousetrap, the technique is currently limited to cats and small to medium dogs.

CT IN GENERAL VETERINARY PRACTICE

Up until this point, this article has focused exclusively on advanced imaging at referral hospitals. Traditionally, referral hospitals have been the only location that offer advanced imaging because:

WHY NOT MRI IN GENERAL PRACTICE?

Although MRI imaging is commonplace in referral hospitals and veterinary universities, the cost of purchasing, installing, maintaining, and staffing an MRI scanner is a significant barrier to widespread adoption of MRI in general veterinary practice.

Smaller and inexpensive MRI scanners are often marketed to veterinarians but, in my experience, the quality of the studies obtained by these systems is inferior to that offered by MRI scanners available at referral hospitals and universities.

In the near future, technical and cost barriers will continue to limit widespread adoption and availability of MRI in general veterinary practice.

1. The initial expense can be difficult to recover in general veterinary practice
2. Maintenance costs preclude advanced imaging as a reasonable investment
3. Expert interpretation is not available onsite in general practice
4. Equipment interfaces require specialized training and technical staff
5. Large, dedicated rooms are necessary to house these machines.

Recent developments in imaging equipment and teleradiology have removed some of these barriers, opening the door to advanced imaging in the general veterinary practice.

A new type of CT scanner—the cone beam CT—has been introduced to the veterinary market (**Figure 7**). Cone beam CT uses an imaging plate rather than the array of detectors used in traditional CT machines. This plate reduces the size of the scanner and maintenance costs. While image quality and resolution rivals (and may even surpass) that of traditional CT machines, the speed of image acquisition is significantly slower.

Figure 7. Three-dimensional image reconstruction of a patient imaged in a cone beam CT scanner.
Courtesy Epica Medical Innovations

While speed is important in human CT imaging, in veterinary medicine, patients are anesthetized during scanning, making image acquisition speed a secondary consideration. Therefore, cone beam CT offers veterinarians access to CT with a small footprint, a competitive price, and lower maintenance costs.

In addition, teleradiology has advanced, providing expert imaging interpretation in quasi real time to any practice, anywhere. These advances are expected to result in increasing availability of CT in general veterinary practice. ■

SUCCESSFUL REFERRAL FOR ADVANCED IMAGING

A successful advanced imaging referral starts with the general veterinary practitioner. Before the patient is referred, it is critical to identify and localize the lesion, if possible.

Radiographs and abdominal ultrasound provide a good, general overview (the use of these modalities for prereferral imaging is discussed under **Six Indications for Advanced Imaging**). They also provide a less invasive method of evaluation since animals require general anesthesia for CT and MRI. These initial imaging results combined with a thorough physical examination and neurologic evaluation allow the practitioner the best opportunity to identify and localize the lesion before CT or MRI.

Although MRI and CT are common in human medicine, as a general rule, pet owners are not familiar with the process of referral for advanced imaging in veterinary medicine. For an advanced imaging referral to be successful, pet owners must be properly prepared. Preparation should begin as soon as a patient that may benefit from advanced imaging is presented; the practitioner should address the reason for referral, the risks of general anesthesia, what the owner should expect with advanced imaging, and costs associated with referral.

Finally, in the case of referral to an imaging center, pet owners should be advised that the results of the imaging test may not be immediately shared with the owner, but sent to the referring veterinarian, who will discuss the test results with the owner.

CSF = cerebrospinal fluid; CT = computed tomography; GI = gastrointestinal; MRI = magnetic resonance imaging; WNL = within normal limits

Reference

1. Oliveira CR, Ranallo FN, Pijanowski GJ, et al. The VetMousetrap: A device for computed tomographic imaging of the thorax of awake cats. *Vet Radiol Ultrasound* 2011; 52(1):41-52.

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