How to…

Decide whether CT or MRI is best for your patient

Victoria Johnson of Vet CT Specialists Ltd helps us make this decision

There has been a rapid increase in the availability of cross-sectional imaging techniques in recent years. CT and MRI are now readily accessible in many referral institutions. In addition, mobile MRI and CT units make frequent visits to veterinary practices all over the UK and some first opinion practices are investing in low field MRI systems and CT scanners. This means that vets are now faced with a situation where they have the choice between these two advanced imaging modalities and a need to understand their respective strengths and weaknesses.

This article aims to simplify that choice and guide you in selection of an appropriate imaging modality. In some situations this is easy and there is a clear clinical benefit to using one modality over the other. There are, however, some circumstances where other factors such as cost, time, accessibility or personal preference become more important in selection.

What is CT?

Computed tomography (CT) (Figure 1A) is a cross-sectional imaging modality based on X-ray technology. X-rays are produced from a high-powered X-ray tube and pass through the patient to be received by a panel of detectors. The X-ray beam is attenuated as it passes through the patient and this allows an image to be created based on the relative density of the different body parts. In most modern X-ray machines the tube rotates around the patient as the CT bed moves forwards or backwards. The bed can either move in small steps, creating a single 'slice' of the patient, or can move constantly as the tube rotates. The latter creates a helix of imaging data from the patient (so-called helical CT) that can then be reconstructed by a computer into different formats.

Usually the data are reconstructed into transverse slices of varying thickness, but sagittal, dorsal and three-dimensional reconstructions can also be created and are extremely useful. The most up-to-date CT scanners have multiple panels of detectors to receive the X-ray beam after it has passed through the patient. This multidetector CT (MDCT) technology allows extremely rapid imaging (as little as 10 seconds to image an entire dog from nose to tail) and generates a volume of attenuation information, thus enabling exquisite multiplanar and 3D reconstructions. MDCT also facilitates highly detailed CT angiography to be performed using iodinated contrast media.

CT – Key features

- Ionising radiation
- Equipment, setup and maintenance usually cost less than MRI
- Images acquired in transverse plane, but with MDCT additional planes can be reconstructed with equivalent resolution
- Extremely quick, especially MDCT
- Intravenous iodinated contrast media used for most examinations*
- Can easily perform angiography with helical CT scanners

* In general contrast medium is advised for most CT examinations with the exception of cases where its administration could compromise the health of the patient, or in cases where bone imaging alone is required.

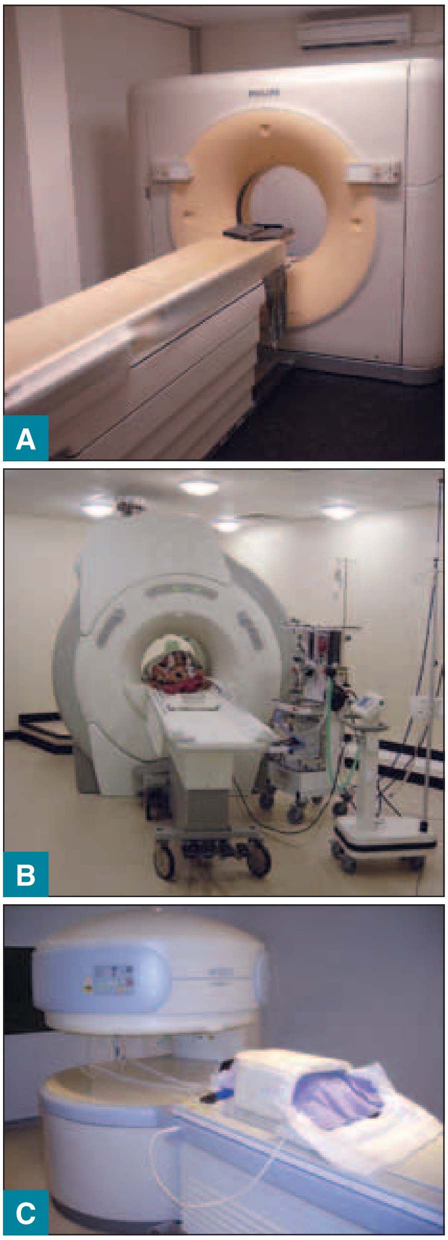

Figure 1: (A) External appearance of a CT scanner. (B) External appearance of a high field MRI scanner (image courtesy of the Animal Health Trust). (C) External appearance of a low field MRI scanner

What is MRI?

Magnetic resonance imaging (MRI) is based on the use of strong magnetic fields and radiofrequency pulses to generate cross-sectional images. The patient is placed into a large magnet and the powerful magnetic field results in the alignment of hydrogen atoms within the body. Different radiofrequency pulses and additional gradient magnetic fields are then turned on and off to create a complex set of frequency information that can be transformed into an image. Unlike CT, images of the patient can be acquired in any plane (sagittal, dorsal, transverse, or oblique).

Magnetism is measured by means of a unit, the Tesla (T). Two main types of MR scanner are available: low field and high field (Figures 1B and 1C). The low field magnets have a smaller magnetic field (0.2–0.5 T usually) and are open devices. These are considerably cheaper than high field magnets and have a smaller field of view. The image quality – especially of the brain and head – is usually good, though sequences generally take longer to acquire than with high field magnets.

High field magnets are supercooled with liquid helium. They are larger, more expensive structures with a closed gantry. The images are quicker to acquire and of high quality due to the higher signal-to-noise ratio compared to low field systems. High field MR scanners are much more suited to angiography and other advanced imaging techniques than the low field scanners.

In MR imaging different combinations of radiofrequency pulses and gradient magnetic fields are used to create sequences of images with different contrast. Many different MRI sequences are available. By utilising different sequences and techniques and also by the administration of intravenous contrast medium (gadolinium) it is possible to be very precise about the nature of a lesion. For example, haemorrhage (Figure 2), fat, proteinaceous fluid and pure water are amongst substances that have very specific imaging characteristics on MRI.

More advanced imaging techniques are also available. These include: diffusion weighted imaging (used in ischaemic strokes); diffusion tensor imaging (used in fibre mapping and demyelinating disease); and functional MRI (identifies areas of neural activity by evaluation of blood oxygen levels).

Selecting an imaging modality depending on the anatomical region

Often a patient is sent for cross-sectional imaging for evaluation of a particular body part. This usually facilitates the choice of CT or MRI, as there are some clearly defined differences between the modalities when considering specific anatomical regions.

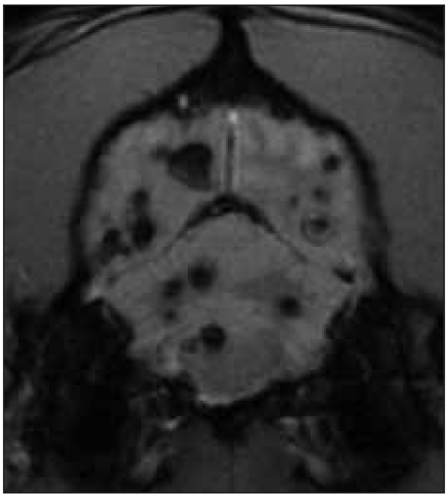

Figure 2: Transverse MR scan through the caudal fossa of a 13-year-old dog. This is a particular sequence called a gradient echo (or T2*) scan, which aids in the detection of haemorrhage. The multiple lesions present are haemangiosarcoma metastases

MRI – Key features

- No ionizing radiation
- Relies on magnetic fields and radiofrequency pulses to generate an image
- Creates a map of hydrogen atoms within the body
- Equipment, setup and maintenance usually more expensive than CT
- Two main types of scanner: low and high field strength
- Can acquire images in any plane
- Usually takes longer than CT
- Much greater contrast between the soft tissues than in CT
- Intravenous contrast medium (gadolinium) used in many examinations
- Numerous advanced techniques can be performed (generally with a high field scanner)

1. Central nervous system (CNS)

MRI is the imaging modality of choice for the central nervous system due to its superior contrast resolution. There are many subtle changes that are seen on MRI of the brain and spinal cord that simply cannot be detected on CT. Also, CT has limitations in evaluation of the brain and spinal cord due to artefacts created by the surrounding bone of the skull and vertebrae. These artefacts create more of a problem in canine and feline patients (due to their smaller brain size and thicker skull and overlying musculature), than they do in human patients.

Specific MRI sequences can also be used in the CNS and present additional

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advantages over CT. These include: gradient echo sequences for the diagnosis of haemorrhage (Figure 2); diffusion weighted imaging in the evaluation of ischaemic disease; FLAIR sequences to assist in diagnosis of perilesional oedema and identification of pure fluid; and STIR sequences to evaluate muscle, bone and nerve root changes.

The use of CT alone to diagnose spinal cord disease in the acutely paretic or plegic patient is controversial. Extruded mineralised disc material in chondrodystrophoid patients is easily visualized in non-contrast CT scans, but CT myelography is necessary to identify significant sites of spinal cord compression or expansion. CT myelography does not, however, allow detailed assessment of the parenchyma of the spinal cord. The presence of related, or unrelated, intramedullary lesions is better recognized on MRI without the inherent risks of myelography (Figure 3).

The use of CT alone to diagnose brain disease should be limited to situations where MRI is not available. CT can be used to identify an intracranial mass effect, areas of severe oedema or acute haemorrhage and contrast-enhancing brain (Figure 4) or meningeal lesions. Brain CT may overlook many subtle, but significant brain lesions that would be easily detected on MRI. Note that CT is not generally suitable for assessment of foramen magnum herniation.

CNS – Key features

- MRI preferable in almost every situation for brain and spine imaging
- MRI offers many significant advantages in terms of tissue contrast and special sequences to identify particular pathology
- CT can be used if MRI is not available:
  - To identify a mass effect, severe oedema, acute haemorrhage or contrast-enhancing lesions in the brain or spinal cord
  - With myelography for the assessment of extradural compressive lesions in acutely presenting paretic or plegic patients
- CT is often useful in addition to MRI in:
  - Trauma
  - Skull and vertebral malformations
  - Degenerative lumbosacral stenosis

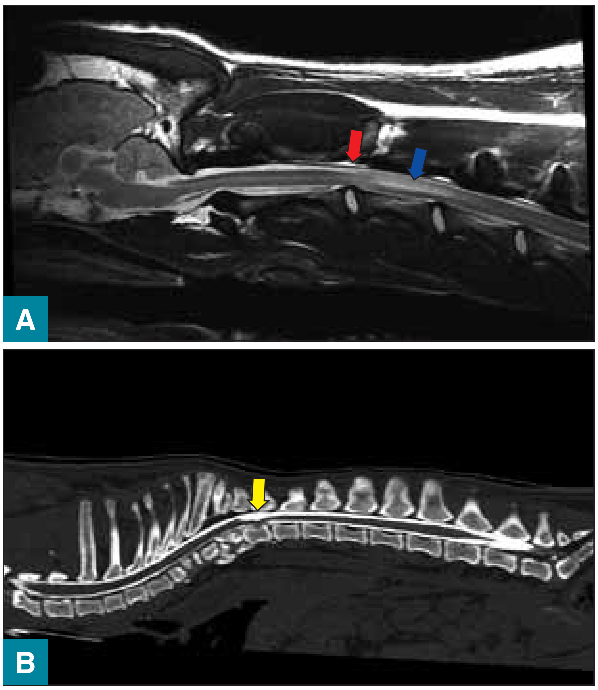

Figure 3: (A) Sagittal T2W MR scan through the cervical spine of a 3-year-old Rottweiler. The patient has a subarachnoid cyst (red arrow). MRI not only demonstrates the presence of the cyst, but also shows the associated parenchymal hyperintensity within the spinal cord at C3 (blue arrow). (B) Sagittal reconstruction from a MDCT scanner of the thoracic and lumbar spine after lumbar myelography. This patient is a 3-year-old French Bulldog and also has a subarachnoid cyst. CT myelography demonstrates the presence and location of the cyst (yellow arrow), but it is not possible to evaluate the spinal cord parenchyma. This patient also has multiple vertebral abnormalities and a kyphosis. Osseous vertebral changes are clearly demonstrated by CT

Figure 4: Transverse CT scan of the brain after intravenous contrast medium. A ring enhancing mass is present in the right parietal lobe. CT can demonstrate large contrast-enhancing mass lesions within the brain, but subtle parenchymal lesions will be missed. Note the lack of detail seen within the remainder of the brain parenchyma on a typical brain CT scan

There are many instances where CT is complementary to MRI in evaluation of the CNS – these include skull and vertebral malformations (Figure 3B), trauma cases and lumbosacral stenosis. In some trauma situations CT can be suitable for first line imaging of the CNS to assess for fractures and overt oedema/haemorrhage. This can even be performed in non-anaesthetised comatose patients due to the rapid image acquisition of CT.

2. Nasal cavities and sinuses

Both CT and MRI are extremely useful in assessment of the nasal cavities and frontal sinuses. CT and MRI are effective in the assessment of turbinate, maxillary and palatine destruction (Figure 5), mass lesions, presence of fluid, osteomyelitis, and contrast-enhancing lesions. Whilst CT and MRI are both able to detect cribriform plate destruction, rostral meningeal/brain enhancement or mass lesion, MRI has the advantage that it may also demonstrate T2W meningeal hyperintensity surrounding the olfactory lobes in cases of nasal neoplasia. The cause of this finding is, as yet, unknown but it may represent micrometastases, secondary meningitis or an accumulation of fluid. It has not been shown to have an effect on neurological deficits or survival time.

CT can be used to guide fine needle aspiration (FNA) and biopsy if required. CT of the thorax can easily be performed at the same time as nasal CT in order to evaluate for metastatic disease.

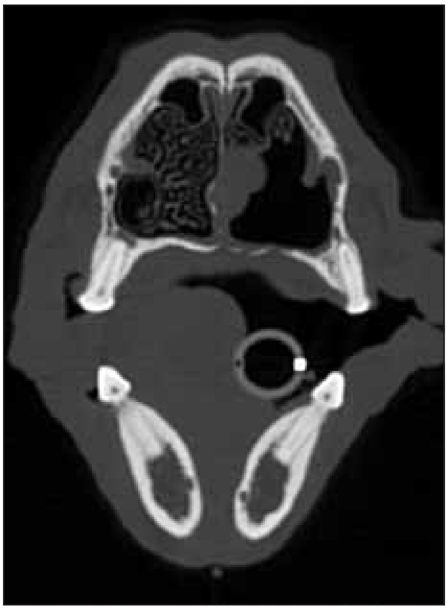

Figure 5: Transverse CT scan through the nose of a 6-year-old dog with aspergillosis. CT provides exquisite detail of the nasal chambers and demonstrates severe left-sided turbinate destruction

3. External, middle and inner ears

CT and MRI are both able to detect the presence of fluid or mass lesions within the tympanic bulla and external ear canal, sclerosis or erosion of the bulla wall, associated retropharyngeal or para-aural lesions and regional lymphadenopathy (Figure 6A). MRI has an additional advantage in enabling evaluation of the facial and vestibulocochlear nerves for thickening and enhancement (Figure 6B) and also allows visualization of the fluid signal within the cochlea and semicircular canals. Associated brain disease is also best assessed by MRI, but may be recognized on CT.

Nasal cavities and sinuses – Key features

- Both CT and MRI are very useful
- Both can demonstrate cribriform plate invasion and rostral brain involvement in nasal neoplasia
- MRI may show additional meningeal changes surrounding the olfactory bulbs in nasal neoplasia
- CT can be used to guide FNA or biopsy
- CT can be used for thoracic metastatic screening

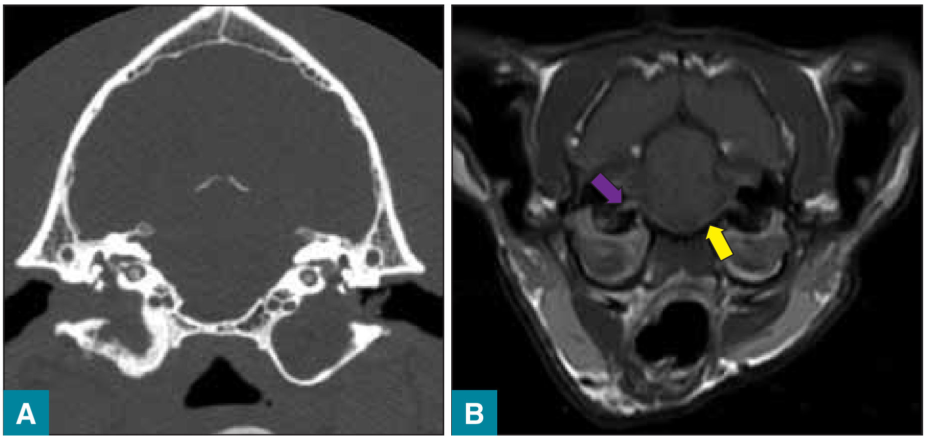

Figure 6: (A) Transverse CT scan (bone algorithm) at the level of the tympanic bullae in a 7-year-old Weimaraner with chronic otitis media. The right tympanic bulla wall is thickened and irregular, and both bullae contain abnormal material. (B) Transverse T1W/C transverse MR scan through the tympanic bullae of a cat with severe chronic ear disease and clinical signs of otitis interna. In addition to the abnormal material within the bullae, MR also demonstrates contrast enhancement of the right vestibulocochlear nerve (purple arrow) and suspected meningeal enhancement around the brainstem (yellow arrow)

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CT can be used for thoracic metastatic screening if aural/para-aural neoplasia is suspected.

External, middle and inner ears – Key features

- CT or MRI can be used
- MRI can also assess cranial nerves VII and VIII, the cochlea and semicircular canals and the adjacent brainstem
- CT can be used for thoracic metastatic screening

4. Thorax

The inherent variation in densities within the thorax makes the chest ideally suited to CT evaluation (Figures 7 and 8). Conversely, the low signal from the air-filled lungs and the presence of artefacts means that MRI is far less suited to assessment of the thorax. Overall, CT is the preferred modality for assessment of the thorax, though MRI can be useful in the assessment of the thoracic wall, mediastinal masses, the pleural space (Figure 9) and, with a suitable scanner and compatible equipment, the heart. Images using either modality should be obtained during periods of apnoea. With rapid CT machines this can usually be achieved by hyperventilating to an apnoeic state or by the use of remote ventilation and breath-hold techniques. Respiratory and cardiac gating techniques are usually required for MRI of the thorax.

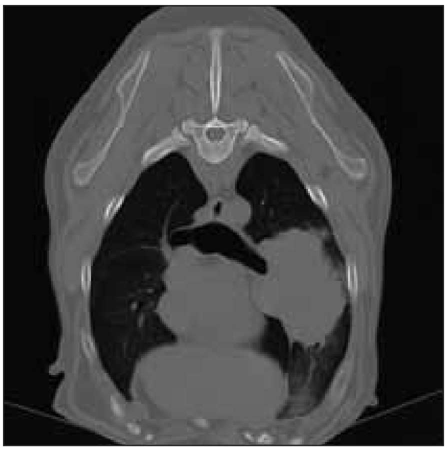

Figure 7: Transverse CT scan (lung algorithm) through the mid thorax of an 11-year-old mix breed dog. A large left-sided lung mass is present. Thoracic CT provides excellent pulmonary detail and also enables assessment of regional lymph nodes and a search for pulmonary metastases. Post-contrast images were also acquired (soft tissue algorithm)

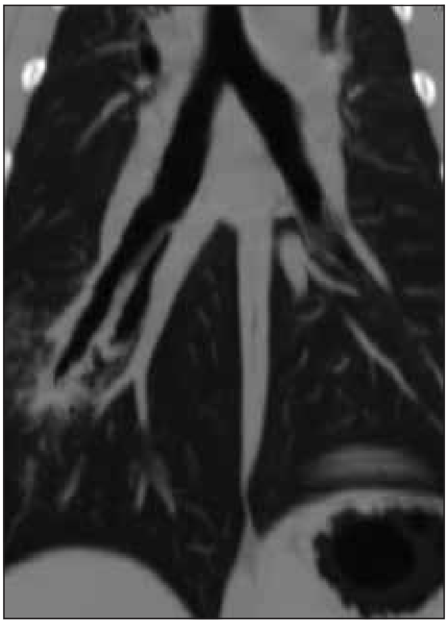

Figure 8: Dorsal MDCT reconstruction of the thorax (at the level of the tracheal bifurcation) in a young dog. The right caudal mainstem bronchus is dilated and contains an abnormal structure. This was found to be a Holly leaf at bronchoscopy and surgery was required for removal

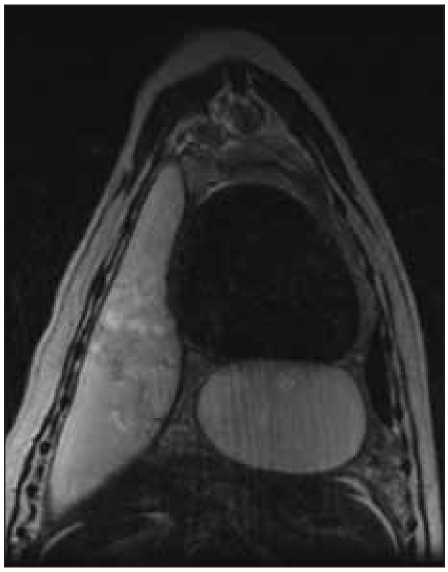

Figure 9: Dorsal T2W MR scan of the ventral part of the thorax of a 3-year-old dog with chronic pyothorax. The scans were obtained prior to surgery (CT was not available) to locate loculated fluid and to assess for possible foreign material. The areas of high signal represent fluid pockets. The low signal structure is the apex of the heart

5. Abdomen

CT provides excellent images of the abdominal organs and peritoneum (Figure 10). Contrast should always be administered (see CT – Key features, page 14) and with helical CT (particularly MDCT) it is also possible to obtain exquisite angiographic studies. Contrast CT is extremely useful for CT excretory urograms, portosystemic

Thorax – Key features

- CT is definitely the modality of choice
  - Extremely useful in the evaluation of pleural, mediastinal, bronchial, pulmonary parenchymal and thoracic wall lesions
  - Superior metastatic screening when compared to radiographs
- MRI can be used for thoracic imaging in some situations
  - Useful for mediastinal masses, thoracic wall masses and the pleural space
  - Respiratory and cardiac gating techniques are usually required
  - Cardiac MRI can be performed with extremely advanced MR scanners

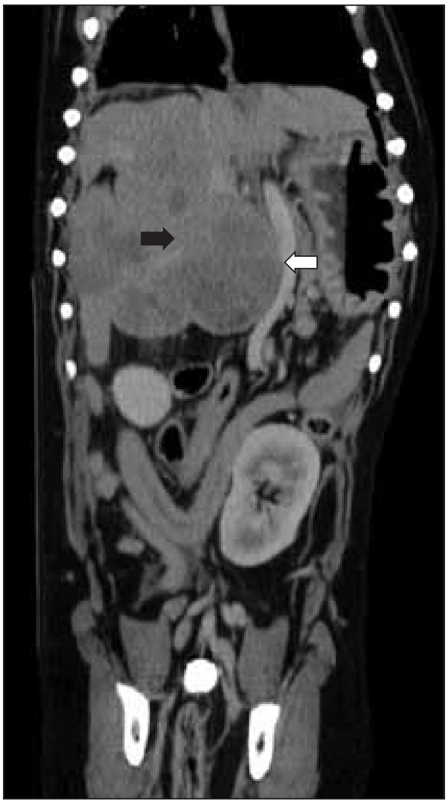

Figure 10: Dorsal MDCT reconstruction of the abdomen after intravenous contrast medium administration. This 11-year-old dog has a large heterogenous right-sided liver mass (black arrow), which can be seen displacing the portal vein (white arrow) to the left. CT was used to perform a full assessment of the mass, regional lymph nodes, other abdominal organs and the thorax

shunt diagnosis, presurgical assessment of abdominal masses, and many other indications. It may even be preferable to abdominal ultrasonography in large obese patients.

MRI of the abdomen allows excellent evaluation of the parenchyma of the organs due to the good soft tissue contrast. Body MRI is used widely in people for the assessment of hepatic, splenic and renal nodules and masses and also for prostatic disease. Once again, rapid sequences and/or gating are usually required. Expertise and experience are essential to obtain the most relevant information from abdominal MRI.

Abdomen – Key features

- CT is the current modality of choice, providing good quality images and being much easier to perform
- MRI can be used but requires special sequences and expertise
- In the future MRI may be used more for the characterization of abdominal masses and nodules in veterinary patients

6. Pelvic region

Both CT and MRI are suited to evaluation of the pelvic region. This area is not prone to movement artefact, and therefore MRI may hold the advantage over CT given its superior soft tissue contrast and the ability to assess the adjacent CNS structures more readily.

Pelvic region – Key features

- Either CT or MRI may be used
- MRI may hold a slight advantage with its benefits of additional soft tissue contrast

7. Elbow

CT has been the most widely reported cross-sectional imaging technique in the assessment of canine elbow disease. CT is ideally suited to the osseous changes of medial compartment disease, osteochondrosis (OC) lesions and incomplete ossification of the humeral condyle (IOHC). CT and arthroscopy have been shown to be complementary techniques, with CT identifying some lesions not seen on arthroscopy and *vice versa*. CT has also been used quantitatively in the assessment of elbow incongruity.

More recently MRI has been advocated in the detection of subtle intramedullary abnormalities such as bone oedema. MRI also theoretically holds the potential for cartilage imaging, but powerful scanners are required for this level of detail.

Elbow – Key features

- CT usually recommended
- Quick and provides excellent osseous detail
- Ideal for the diagnosis of common elbow conditions (medial compartment disease, IOHC, OC, elbow incongruity)
- Complementary to arthroscopy
- MRI may also be used and could provide additional information concerning bone oedema and cartilage

8. Shoulder

MRI offers significant potential for the evaluation of muscular, ligamentous and tendinous shoulder injuries in adult dogs. Some of these conditions are not seen arthroscopically and hence may be underdiagnosed. MRI is also well suited to the diagnosis of brachial plexus disease.

CT of the shoulders is generally much less useful. Osteochrondrosis lesions in young patients are usually seen radiographically and assessed and treated arthroscopically. CT may be helpful in fracture assessment and can also be used for assessment of suspected neoplasia with the addition of a thoracic metastatic scan.

Shoulder – Key features

- MRI has great potential for the assessment of muscular, tendinous and ligamentous shoulder injury
- CT is much less useful overall and is reserved for osseous disease

9. General skeleton

CT offers the advantage of superior multiplanar and volume rendered 3D reconstructions which are extremely beneficial in the planning of fracture repair

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and other orthopaedic surgeries such as angular limb deformity correction (Figure 11). MRI is more advantageous where neoplastic invasion into bone is suspected. In this scenario the altered intramedullary bone signal may be seen long before lytic changes are recognized on a CT examination.

General skeleton – Key features

- CT useful for angular limb deformities, fracture repair planning
- MRI advantageous in neoplastic disease (such as mandibular or maxillary tumours)

Figure 11: 3D CT reconstructions can be useful to assess the overall alignment of osseous elements of the axial and appendicular skeleton for surgical planning

Whole body MRI and CT for metastatic disease?

Recently protocols for whole body MRI screening for the diagnosis and staging of neoplastic disease have been reported. Some institutions are also routinely performing whole body CT examinations for the same purpose. The CT studies are quick to acquire if MDCT is used, whereas special protocols are required for fast MRI screening techniques. All of these types of studies take a long time to read, but certainly are useful in detecting previously unrecognized metastatic disease. In these whole body techniques the emphasis is generally on contrast rather than spatial resolution and MRI holds the advantage in the detection of bone marrow changes, lympadenopathy, soft tissue lesions and CNS lesions. CT remains beneficial in metastatic lung and bone imaging, but the latter is probably better assessed using bone scintigraphy.

In the future, positron emission tomography (PET) may become increasingly important in cancer staging. PET/CT or PET/MRI may eventually become the gold standard of cancer imaging in our canine and feline patients.

Patients with metallic implants – CT or MRI?

Metallic implants create problems for both CT and MR examinations.

In MRI *non-ferrous* implants may be placed into the magnet, but can create serious artefacts and hence non-diagnostic studies. The magnitude of these artefacts differs depending on the MR sequence used.

The artefacts identified on CT examinations in patients with metallic implants can also prevent interpretation, but on occasion the gantry can be angled to avoid the metallic region and certain slices and reconstructions can limit their effect on the final image.

CT and MR angiography

Both CT and MR have a role in angiography in our small animal patients. Current applications include evaluation of portosystemic shunts, assessment for pulmonary thromboembolic disesase, planning of vascular mass resection and many others. For CT angiography a helical scanner is required and a rapid injection pump is preferable (Figure 12). For MR angiography the best results are achieved with high field scanners and special techniques such as parallel imaging.

Figure 12: CT angiogram performed with an MDCT unit and a rapid injection pump. The image is displayed as a Maximum Intensity Projection (MIP) which is a useful way to view contrast-enhanced vessels or mineralized lesions

Conclusion

Veterinary practices now have unprecedented access to cross-sectional imaging modalities. In many situations CT and MRI can be used interchangeably and the decision on which to choose may be mostly affected by cost and availability. There are, however, some important situations where the correct choice is extremely important and the wrong modality may make the study non-diagnostic for the disease process in question. ■