Severe head tilt in a Siamese cat with vestibular syndrome. MRI and CT are invaluable diagnostic tools for confirming whether cases such as this are due to peripheral or central vestibular disease and in planning treatment. Picture, Simon Platt

Advanced imaging: indications for CT and MRI in veterinary patients

RUTH DENNIS

COMPUTED tomography (CT) and magnetic resonance imaging (MRI) are increasingly being used in veterinary diagnosis due to greater accessibility of the equipment, advances in treatment options and increasing owner expectations. However, CT and MRI scanning are complex and expensive procedures that warrant careful patient selection. They should be used to supplement, rather than replace, conventional diagnostic tools. This article describes the most important indications for CT and MRI in veterinary patients and indicates which technique is preferable, should a choice exist. It also discusses the basic principles of the two imaging modalities, together with their limitations.

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PRINCIPLES OF COMPUTED TOMOGRAPHY

CT preceded MRI as a medical and veterinary imaging technique, although it is now less widely performed on veterinary patients. CT is essentially cross-sectional radiography, with image production being a function of the absorption of x-ray photons by the tissues. Computer enhancement of the electronically detected image produces much greater tissue definition than is achieved with conventional radiography, and post-processing techniques allow expansion of selected areas on a greyscale in order to emphasise either soft tissue or bone detail.

The interpretation of CT scans is similar in principle to radiographic interpretation, with mineralised and bony material appearing radiopaque, fluid and soft tissue producing intermediate grey shades and fat being more radiolucent (see images overleaf). However, unlike radiography, differentiation between soft tissue and fluid is possible and internal soft tissue architecture is visible. In particular, CT is highly sensitive for subtle bone changes.

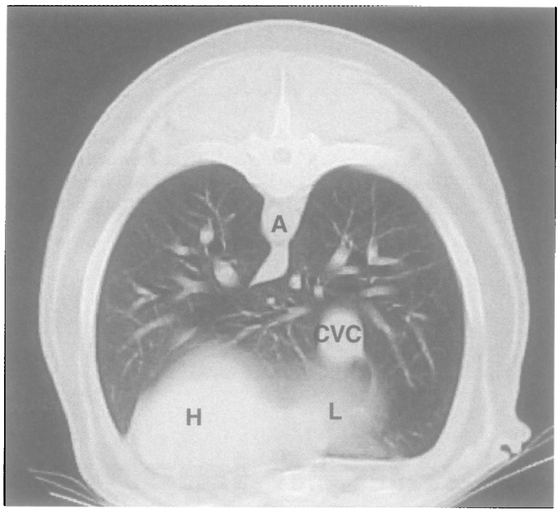
When is CT/MRI appropriate?

CT or MRI may be chosen over conventional imaging techniques in situations where:

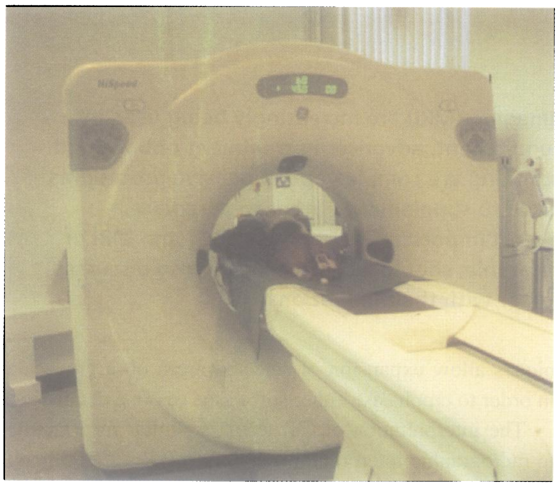
- THE AREA OF THE SUSPECTED LESION CANNOT BE EVALUATED USING OTHER MEANS. Intracranial disease, for example, is rarely visible using other imaging techniques and, in animals with suggestive neurological signs, advanced imaging (preferably MRI) would be indicated at an early stage in the work-up
- THE INFORMATION PRODUCED BY CONVENTIONAL IMAGING TECHNIQUES IS LIMITED. In the investigation of spinal disease, for example, survey radiography of the spine can produce false negative or false positive results and thus myelography is often used for confirmation of spinal cord compression or swelling. However, myelography gives no information about pathology within the spinal cord itself or lesions affecting the spinal nerve roots, and assessment of the lumbosacral area is inadequate in many animals. If MRI is not readily available, myelography may be performed initially, with a plan for subsequent MRI if a confident diagnosis cannot be made
- A LESION IS EVIDENT ON CLINICAL EXAMINATION OR WITH OTHER IMAGING TECHNIQUES, BUT MORE THREE-DIMENSIONAL INFORMATION IS REQUIRED FOR TREATMENT PLANNING. Examples include surgical or radiotherapy planning for tumours, and detection of foreign bodies or sinus tracts. Of equal importance is information that a lesion is too extensive for meaningful treatment; in such cases, advanced imaging may save a patient from undergoing major surgery or other intervention that would not be in its best interest

NB Both CT and MRI require patient immobility and non-manual restraint and, therefore, general anaesthesia is usually necessary

CT scan of a normal canine nasal cavity using a bone window. Picture, University of Glasgow Veterinary School



CT scan of a normal canine thorax using a soft tissue window; the heart (H) and liver (L) are visible ventrally. A Aorta, CVC Caudal vena cava. Picture, University of Glasgow Veterinary School



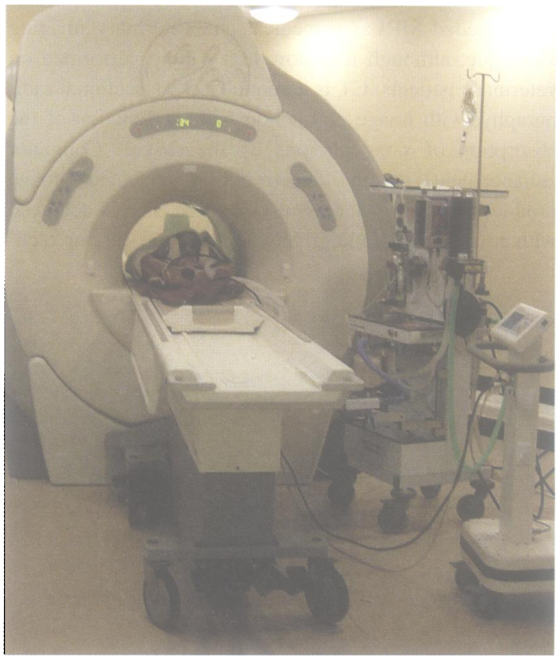
CT imaging of a canine patient. The ring-like gantry of the CT scanner houses a rapidly moving x-ray tube head and electronic detectors. x-ray photons emerging from the patient at all points around the circumference are detected, and the information is converted by a computer into a cross-sectional radiographic image. The patient table moves in small increments between the exposures so that each exposure creates a new 'slice' image. Picture, Davies White Veterinary Specialists

CT scanners acquire primary data in the transverse plane. Images in other planes are produced by computer reformatting, which results in some loss of detail. However, this disadvantage is reduced with the new generation of spiral CT scanners which produce reformatted images of higher resolution. Some systems can also produce three-dimensional (3D) images which may be viewed from any chosen angle. Each CT exposure results in a single cross-sectional image and the patient table is advanced through the gantry in small increments between exposures. Radiographic contrast media may be given intravenously to show the vascularity of a lesion or to demonstrate breakdown of the blood-central nervous system (CNS) barrier. CT myelography may also be performed using conventional radiographic contrast media at approximately half the normal dose rate. CT image acquisition is faster than with MRI, with the actual scanning procedure taking only a few minutes.

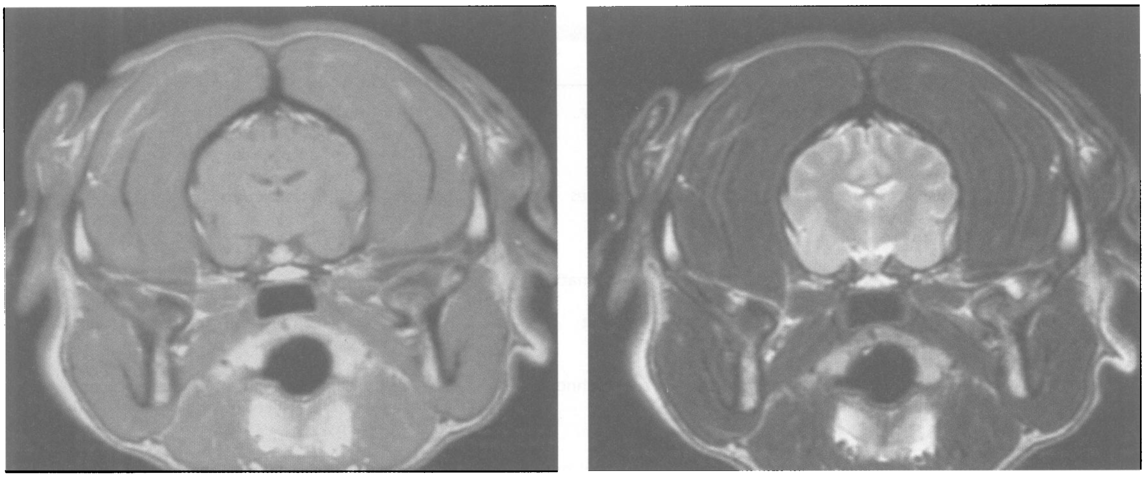
Although the potential hazard from ionising radiation means that veterinary patients must be anaesthetised or heavily sedated for CT, conventional anaesthetic and monitoring equipment may be used and the open gantry of the CT scanner (see above) allows easy access to the patient. With a suitable table, scanning of large animals is possible and CT is especially helpful in imaging the equine head.

PRINCIPLES OF MAGNETIC RESONANCE IMAGING

MRI uses a combination of a magnetic field and radiofrequency (RF) energy to create cross-sectional images of the area under examination. The scanner itself is a powerful magnet and this places restrictions on the type of equipment which may be used within the scanning room, most importantly anaesthetic and monitoring equipment. This is an important consideration when scanning patients in a human hospital away from normal



The high-field (1·5 Tesla), closed-bore MRI scanner at the Animal Health Trust; note the MRI-compatible anaesthetic and monitoring equipment. The magnetic field is created by the large cylindrical gantry within which the patient lies. Radiofrequency signals are produced and detected by an RF coil surrounding the area to be scanned, in this case the brain of a boxer. The frequency and strength of the emitted RF signal is converted into a series of cross-sectional images by a computer. Spatial information is generated as a result of slight modification of the main magnetic field by applying weaker, 'gradient' magnetic fields in three orthogonal planes during scanning



Normal transverse MRI scans of the brain of a Staffordshire bull terrier at the level of the pituitary gland. (left) Contrast-enhanced T1-weighted scan; (right) T2-weighted scan. CSF in the ventricular system and subarachnoid space is dark on T1-weighted and bright on T2-weighted images

veterinary facilities, especially since scanning times are longer than for CT (MRI studies usually take 30 to 60 minutes). Scanning of large animals (mainly horses) is limited by patient handling constraints and the shape of the scanner; however, with a suitable non-ferrous table, the head and lower limbs of anaesthetised horses may be studied.

Magnetic resonance (MR) images are also cross-sectional slices of the area under investigation, a variable number of adjacent slices being obtained simultaneously during the acquisition period. Unlike CT, any image plane may be used for primary data acquisition, although for ease of interpretation three orthogonal planes – transverse, sagittal and dorsal to the area of interest – are usually used. More advanced MR systems can also acquire 3D data which produce very thin slice images or images which may be viewed in any plane. Many types of RF pulse sequence can be performed; each produces a greyscale image based on chemical binding of the tissue molecules and this is utilised to give tissue-specific information. For example, fluid is bright or hyperintense on spin-echo T2-weighted images and dark or hypointense on T1-weighted images (see above). The signal from cerebrospinal fluid (CSF), other fluid and fat may be selectively suppressed to increase visibility of adjacent tissues, and haemorrhage may be aged approximately by comparing its signal characteristics on different pulse sequences. Paramagnetic contrast media (usually chelated gadolinium) can be injected intravenously and used to demonstrate areas of blood-CNS barrier breakdown or increased tissue vascularity through 'enhancement', which is seen as a brightening of the affected areas on T1-weighted scans.

MRI produces highly detailed images of soft tissues, far in excess of the detail provided by CT. However, it is less sensitive than CT for subtle bony lesions, such as minor osteolysis, or for areas of calcification. Despite this, it is an excellent tool for imaging larger orthopaedic structures because it can show articular cartilage, synovial fluid and various articular and periarticular soft tissues.

The low-field (0·2 Tesla), open MRI scanner at Cambridge veterinary school. The magnetic field is produced by the two horizontal discs above and below the patient. The RF coil is more clearly seen surrounding the dog's head. With low-field systems, siting of the MR equipment is simpler, and the use of conventional anaesthetic equipment at a distance from the patient may be possible. However, scanning times are longer than with high-field systems

RELATIVE ADVANTAGES AND DISADVANTAGES OF CT AND MRI

	CT	*MRI*
Access to the patient	Relatively easy due to ring-like gantry	Harder with closed, cylindrical systems because of the need to position the patient in the centre of the scanner's bore; easier with open systems
Time taken for study	Shorter – usually about 5 to 10 minutes	Longer – usually about 30 to 60 minutes
Relative cost per patient*	++	+++
Image planes	Transverse to gantry; others by reformatting	Any plane
Anaesthetic and monitoring equipment	Any; heavy sedation may be sufficient	Must be non-ferrous and MR-compatible if positioned near to the scanner
Contrast studies	Possible using intravenous or subarachnoid iodinated radiographic material	Require special paramagnetic media; myelographic and angiographic effects may be obtained without contrast agents
Tissue detail	Excellent detail of mineralised parts of bone; good soft tissue detail. Viewing of images using different greyscales allows emphasis on soft tissue or bone	Excellent soft tissue detail; very good for skeletal structures. Many different pulse sequences are possible, giving extra information about the nature of tissues/lesions. For most purposes, better than, or as good as, CT
Safety considerations	Use of high doses of ionising radiation prevents presence of personnel during scanning	No ionising radiation risk, so the patient may be attended to if necessary. However, the risk of ferrous objects becoming missiles, especially with high-field systems, means that great care must be taken to check people and equipment entering the area

*Reflects the costs of installation and maintenance of the equipment and the length of the procedure

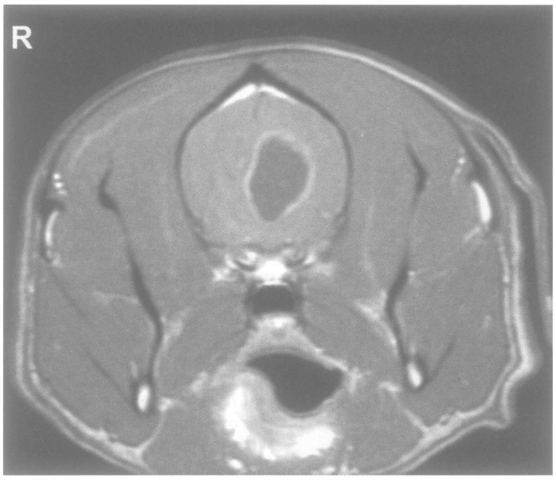
BRAIN DISEASE

The use of CT and MRI for brain imaging has revolutionised the treatment options for intracranial disease, and brain surgery and radiotherapy of brain tumours are increasingly performed, often with extremely rewarding results. Conversely, structural brain disease can be ruled out in animals with idiopathic epilepsy. MR brain images are far superior to those produced by CT, and thus MRI is the imaging modality of choice for all brain investigations.

Brain tumours

Brain tumours are not unusual in dogs and may reach a considerable size before clinical signs first become evident; in some cases, they manifest as apparently acute disease due to sudden increases in intracranial pressure. The most common types of brain tumour in dogs are gliomas (affecting brain parenchyma – see below left) and meningiomas (arising from the meninges). Pituitary and choroid plexus tumours are also often seen, but other types of primary brain tumour and brain metastases are uncommon. In cats, meningiomas occur most frequently (see below right) and are often amenable to curative surgery. Cranial nerve tumours may be small but can usually be readily recognised on MRI, aided by an accurate neurological examination and a sound knowledge of neuroanatomy.

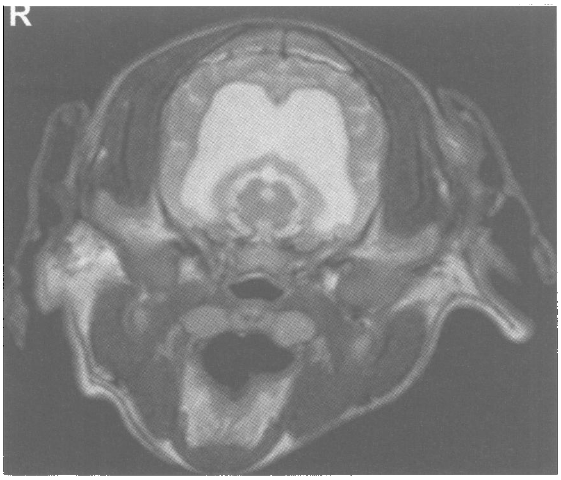
Although CT and MRI, as with other imaging techniques, are non-specific with respect to the histology of a lesion, the nature of the tumour can usually be predicted



Transverse, contrast-enhanced T1-weighted MRI scan of a left frontal lobe glioma in a seven-year-old boxer. There is a large, well-defined parenchymal mass with a non-enhancing centre surrounded by a rim of enhancing tissue. Gliomas typically show such ring-enhancement around a variably sized necrotic centre

Transverse, contrast-enhanced T1-weighted MRI scan of a right parietal lobe meningioma in a seven-year-old domestic longhaired cat. A large, unevenly enhancing extra-axial mass displaces the brain and compresses the ipsilateral lateral ventricle. Meningiomas usually show intense, uniform contrast enhancement, and in this cat the non-enhancing areas are due to extensive calcification of the tumour. There is overlying hyperostosis which is seen as thickening of the cranial bone with loss of the normal bright marrow signal

Transverse, gradient-echo MRI scan of a five-year-old collie-cross with seizures and a focal cranial swelling. The scan shows the inward extent of a mixed osteolytic/proliferative bone lesion which was visible radiographically. This lesion was removed surgically and found to be an osteosarcoma



Hydrocephalus in a three-month-old German shepherd dog, seen on a transverse T2-weighted MRI scan of the brain. The lateral ventricles are markedly dilated for the breed; they should be about the same size as those in the right-hand MRI scan on page 245

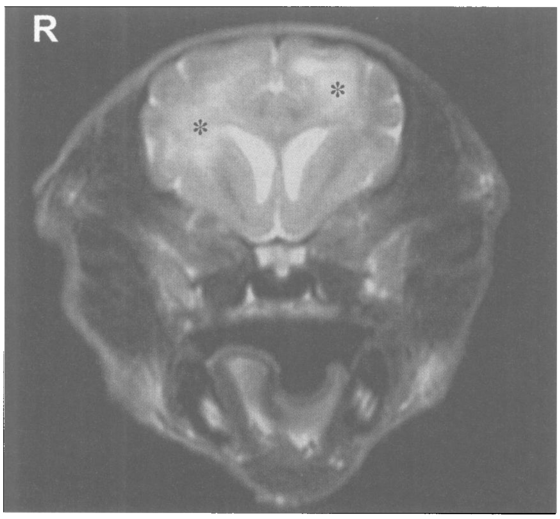
from its imaging features. Secondary features such as obstructive hydrocephalus and parenchymal oedema are also seen. In some patients, tumours may have arisen outside the brain and caused clinical signs by inward invasion, such as caudal nasal tumours and those arising from cranial bones (see above). In these animals, CT is also rewarding since some bony change will be evident. In many cases, associated clinical signs are absent or have been overlooked; for example, occasional sneezing or snorting may be a significant finding in an animal with seizures, suggesting possible nasal neoplasia with extension into the brain. In such cases, radiography is a more logical first step than CT or MRI.

Inflammatory brain disease

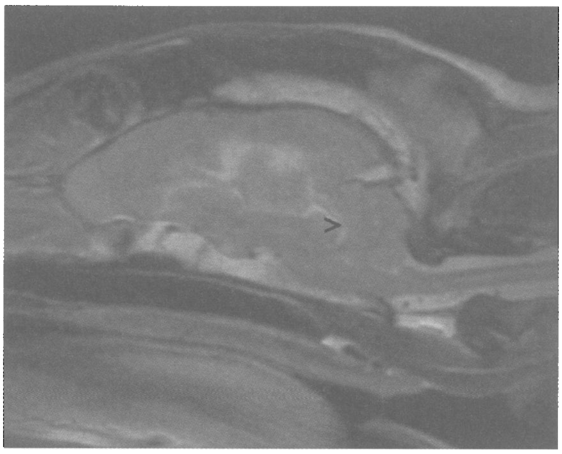
Inflammatory brain disease such as granulomatous meningoencephalitis or necrotising encephalitis will also usually produce highly suggestive MR changes; CT, meanwhile, is much less sensitive. These conditions usually result in multifocal lesions which show a variable mass effect and contrast enhancement (see below left). Confirmation often relies on CSF analysis, and it is desirable to perform MRI prior to this in order to identify patients in which a spinal tap may be hazardous due to brain swelling. The central slice of a sagittal T2-weighted scan is the image of choice for demonstrating subtentorial cerebral herniation or herniation of the cerebellum into the foramen magnum, both of which would render a spinal tap hazardous (see below right). Therefore, if MRI is planned, CSF analysis should be delayed until after the imaging.

Congenital, developmental and metabolic brain disease

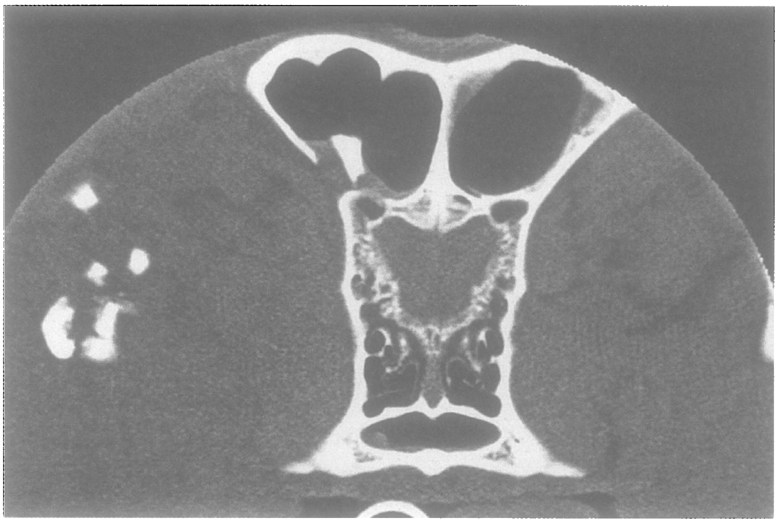
Congenital, developmental and metabolic brain lesions are less frequently diagnosed than intracranial neoplasia and inflammatory disease. Hydrocephalus may be identified using ultrasound in patients with an open fontanelle but otherwise requires advanced imaging (see above). However, care must be taken not to over-diagnose hydrocephalus as a cause of neurological signs, as most dogs of breeds with dome-shaped heads have large lateral ventricles. Cerebellar hypoplasia is unusual and the imaging features are rather subjective; cerebellar abiotro-



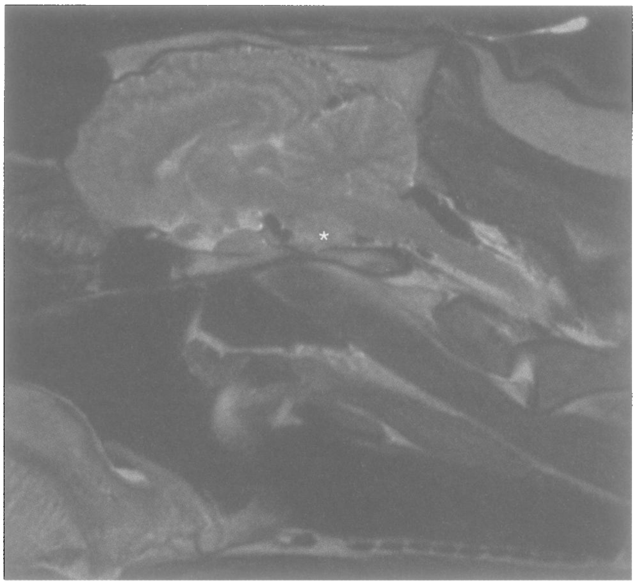
Granulomatous meningoencephalitis in a four-year-old Yorkshire terrier. This transverse T2-weighted MRI scan at the level of the frontal lobes shows two ill-defined areas of increased signal, or hyperintensity (*), indicating inflammation or oedema. Dorsal to the left-sided lesion is a more discrete, cystic area. There is no associated mass effect. Note the prominence of the lateral ventricles, which is typical for the breed



Midline sagittal T2-weighted MRI scan of a seven-year-old German shepherd dog with severe subtentorial herniation of the cerebral hemispheres which are compressing the cerebellum (>). A large tumour with surrounding oedema is visible in the brain just rostral to the tentorium



CT scan of the frontal area of a dog with head trauma, showing comminuted fractures of the frontal and zygomatic bones. Although some skull fractures may be seen radiographically, cross-sectional imaging provides more 3D information, as well as showing associated soft tissue damage. Picture, University of Glasgow Veterinary School



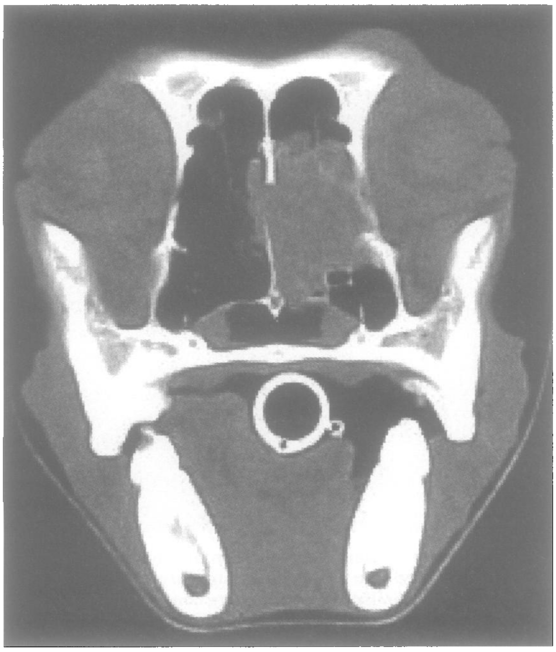
Sagittal T2-weighted MRI scan of the head of an 18-year-old Welsh pony that had neurological signs, showing an extra-axial mass ventral to the brainstem (*). The histological diagnosis was meningioma. Although this image was obtained on a detached head postmortem, MRI of the head is possible in anaesthetised equine patients. Specimen provided by Philip Dyson

phy may cause no obvious changes. Occasionally, animals with a history of trauma when young may be found to have large CSF-filled cerebral defects or cranial malunion.

Hitherto undiagnosed metabolic and breed-specific diseases, such as L-2-hydroxyglutaric aciduria in Staffordshire bull terriers (Abramson and others 2003), have been recognised using MRI.

Acute head trauma

CT is an excellent diagnostic tool for cases of acute head trauma as it shows small bone lesions and brain haemorrhage clearly (see above). CT is often also a more practical option than MRI in critical patients with acute head trauma. MRI is less suitable for such patients due to the longer scanning times and the problems of anaesthesia and monitoring arising from the magnetic field, if MRI-compatible equipment is not available. However, if the animal is stable for anaesthesia, MRI also provides an invaluable means of detecting brain oedema and haemorrhage, intracranial bleeding and subtle cranial bone lesions, allowing decision-making regarding the need for surgical intervention.



Transverse CT scan of the caudal nasal cavity in a 10-year-old crossbred dog with a nasal tumour. A soft tissue mass is visible causing destruction of nasal turbinates and part of the nasal septum, with minor extension into the contralateral nasal cavity. Picture, Davies White Veterinary Specialists

Brain imaging in horses

CT and MRI of the brain are also possible in anaesthetised horses, provided that suitable handling equipment is available and the horse's conformation allows positioning of the head in the active area of the scanner (see above). Although treatment options for brain diseases in horses are limited, an accurate diagnosis may be important in order to allow decisions to be made about a horse's future.

OTHER LESIONS OF THE HEAD

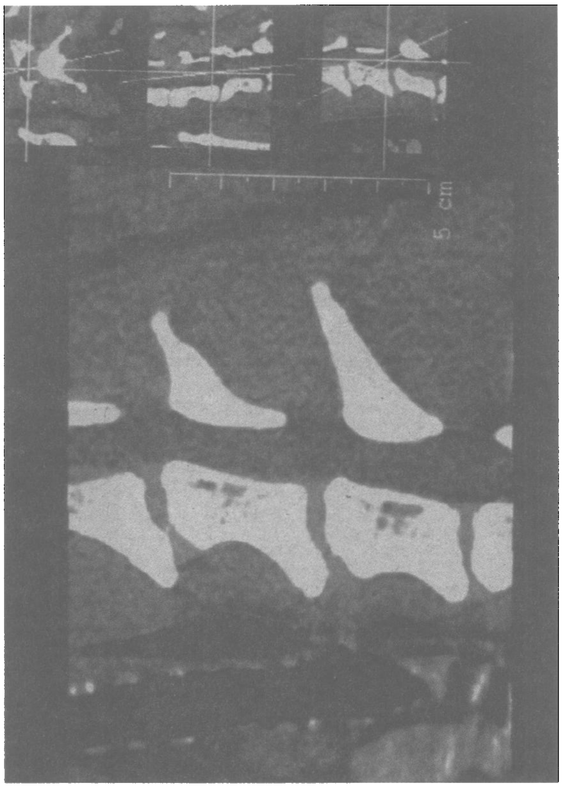
Both CT and MRI are excellent tools for further investigation of other head lesions, such as nasal, orbital and middle ear disease (see images left and right), when conventional imaging techniques fail to allow a full diagnosis. CT provides more information about bone changes, while MRI is superior for soft tissues. Patients should first be investigated using radiography, with advanced imaging reserved for those cases with normal or equivocal radiographs or for which surgical or radiotherapy planning is essential.

In animals with clinical signs relating to the nasal cavity, it may be possible to see early turbinate destruction or focal rhinitis which is not visible radiographically. For orbital disease, MRI is indicated when radiographs are unremarkable and ocular ultrasound is normal or equivocal; CT is less helpful unless osteolysis has occurred. Both MRI and CT will demonstrate radiographically occult middle and inner ear disease, and both techniques will assist preoperative planning for jaw and cranial surgery. Extension of primary pathology into the sinuses or cranium will also be evident on CT or MRI and this will have important implications for treatment and prognosis. However, if only conservative treatment is planned, advanced imaging is not usually justified.

In horses, CT and MRI may also be used to image other areas of the head – for example, in the investigation of sinusitis, dental disease and trauma. CT is easier and quicker because of the patient handling constraints of MRI, but both techniques give more information than either radiography or endoscopy.

SPINAL DISEASE

CT of the small animal spine gives excellent information about bone lesions in the transverse plane, which is not possible radiographically. Sagittal images, which are important for spinal imaging, must be created by computer reformatting, which results in some loss of detail (see right). Information about soft tissue components of the spine is limited and CT myelography is needed to show spinal cord dimensions.

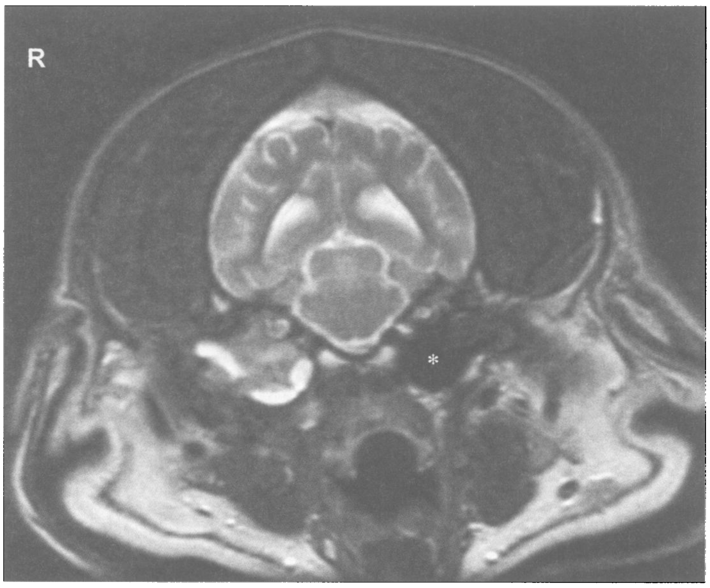


Reformatted sagittal CT scan of the lower neck of a dobermann with cervical spondylopathy (wobbler syndrome). Picture, University of Glasgow Veterinary School

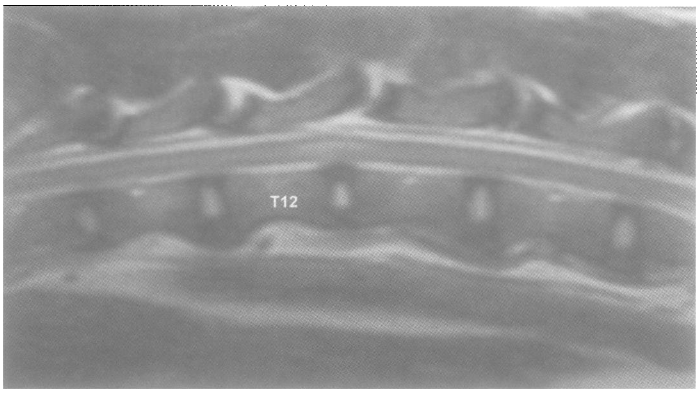
Suspected spinal disease is a common indication for MRI in small animals. Although much information about spinal disease may be obtained using radiography, especially if contrast studies such as myelography and epidurography are performed, this provides no information about the spinal cord parenchyma other than whether it is compressed, displaced or swollen. A normal myelogram therefore does not rule out parenchymal disease. MRI shows spinal cord changes such as inflammation, oedema, gliosis, neoplasia and syringohydromyelia, as well as nerve root pathology, allowing a more detailed diagnosis to be made (see top images overleaf). The acquisition of transverse images, which is not possible with radiography, greatly assists localisation of compressive tissue such as disc material, ligament hypertrophy and synovial joint disease and therefore facilitates surgical planning. The excellent soft tissue definition on MRI scans will also show soft tissue masses extending beyond the vertebral canal into paraspinal soft tissues, which are usually not visible radiographically.

MRI is of particular value in assessing the lumbosacral junction. Many older dogs will show changes at this site on survey radiography and such changes are therefore not a reliable indicator of significant disease. With myelography, the contrast column often lies too far dorsally over the lumbosacral disc space or terminates too far cranially to allow accurate assessment of the area, and other contrast techniques are difficult to perform and to interpret. MRI is a perfect tool for imaging the area as it will show the cauda equina, nerve roots, surrounding CSF and epidural fat, bony structures, disc material and ligaments (see bottom images overleaf). However, great

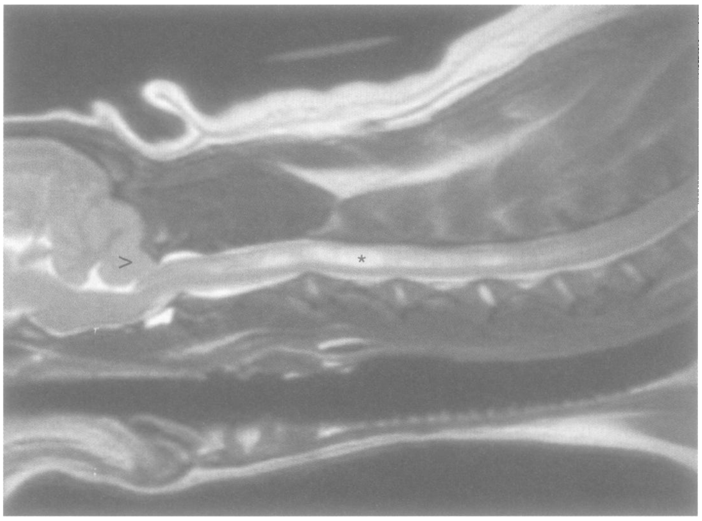
Dorsal plane, contrast-enhanced T1-weighted MRI scan of the orbital area of a four-year-old labrador with left-sided exophthalmos. The left eye is displaced and compressed by an unstructured mass of mixed signal intensity in the medial part of the orbit, which is displacing the normal orbital soft tissues laterally. Diffuse contrast enhancement of the orbital soft tissues indicates severe inflammation. The clinical and MRI diagnosis was orbital cellulitis and abscessation, and the dog recovered following medical treatment



Severe right-sided middle ear disease in a nine-year-old English setter. The normal left tympanic bulla (*) is seen as a round signal void, due to the absence of an MR signal from normal cortical bone and from air within the bulla. The affected bulla is filled with fluid and soft tissue, and there is a small defect in the ventrolateral part of the bulla wall. The inner ear structures dorsomedial to the bulla appear unaffected. MRI and CT are more sensitive than radiography for investigation of middle ear disease



Sagittal T2-weighted MRI scan of the thoracolumbar spine of a six-year-old labrador suffering from acute paraplegia. The spinal cord overlying the T12-13 disc space is swollen and hyperintense, and the disc itself shows a subtle change in architecture and dorsal bulging compared to the neighbouring discs. The diagnosis was a high-velocity, low-volume (type III) disc extrusion

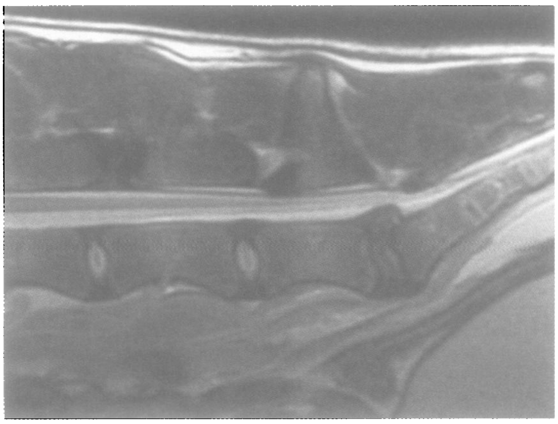


Cervical syringohydromyelia in an 18-month-old Cavalier King Charles spaniel with neck pain. The central canal of the spinal cord (*) is markedly dilated and CSF has dissected into the spinal cord parenchyma. The underlying cause is occipital dysplasia, leading to foramen magnum crowding (>) and, in turn, abnormal CSF flow. The condition is thought to be similar to Chiari syndrome in humans

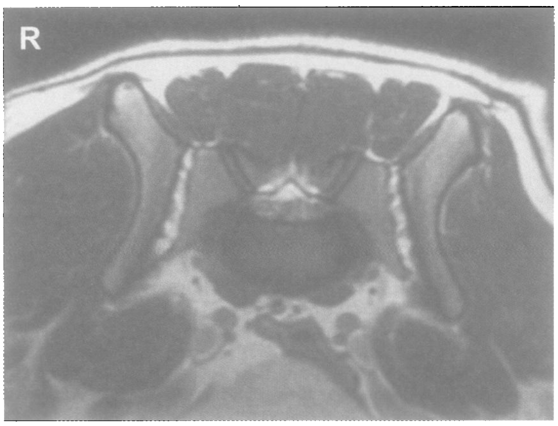
caution should be exercised in relating lumbosacral changes on MRI scans to clinical signs, as experience has shown that many dogs have disc degeneration at this site (and apparent discomfort on lumbosacral manipulation) despite it not being their primary clinical problem. The diagnosis of significant lumbosacral disease often rests on clinical examination and exclusion of pathology elsewhere, rather than on MRI features.

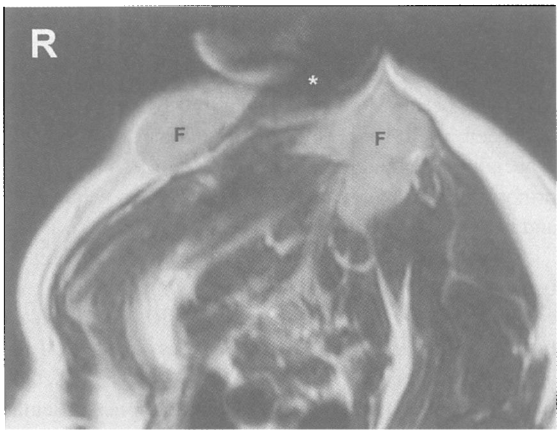
MRI is safer than conventional and CT myelography for investigation of spinal disease as no subarachnoid injection is required, and the procedure is therefore non-invasive. With accurate neurological localisation of the expected site of the lesion, the duration of the procedure is comparable to myelography, the effort involved in positioning is reduced and the cost is not significantly greater. However, it must be appreciated that MRI also has limitations. Evaluation of large areas of the spine is extremely time-consuming, especially in large dogs, and thus MRI is not recommended for a spinal survey. Careful positioning is important since the images represent slices of tissue, and the spine must therefore be straight and not curved in the sagittal plane. Finally, the importance of accurate neurological localisation cannot be over-emphasised in order to avoid over-diagnosis of incidental changes such as mildly protruding discs. For example, upper motor neuron deficits in the hindlimbs may result from lesions as far cranially as T3, and the MRI field must include the whole area of possible interest. Clearly, a radiographic study is more likely to include the whole area of interest, even when neurological localisation is not precise, and in addition will show bony landmarks such as ribs more clearly.

In practical terms, CT is not usually the best modality for spinal investigation and MRI is unlikely to be used routinely unless there is ready access to a scanner. Where MRI is not immediately available, acute spinal



Sagittal (left) and transverse (right) T2-weighted MRI scans of the lumbosacral area of a three-year-old German shepherd dog with cauda equina syndrome. The neural tissue is seen as a tapering dark band surrounded by hyperintense CSF and epidural fat. The lumbosacral disc is protruding dorsally causing moderate compression of the overlying cauda equina





Interscapular fibrosarcoma in a nine-year-old domestic short-haired cat. This transverse, contrast-enhanced T1-weighted MRI scan shows two separate areas of recurrent tumour tissue (F) following previous surgical excision of the original mass. Image distortion and signal loss dorsally (*) is due to the presence of a microchip; the metallic nature of the chip interferes with the images, although the identity code is not lost. Focal artefacts resulting from the presence of microchips rarely cause significant problems in interpretation

Transverse T2-weighted MRI scan of the mid-abdomen of a five-year-old English springer spaniel with recurrent left flank swelling and sinus formation. An irregular, fluid-filled pocket is seen within diffuse soft tissue swelling but the lesion appears fairly localised with no intra-abdominal or sublumbar extension. At surgery, a grass seed was found within an area of abscessation. A Abscess, LK Left kidney, S Spleen

cases which may require urgent surgery still need to undergo radiographic myelography. However, MRI is the technique of choice for less urgent cases, especially for suspected lumbosacral disease, Chiari-type defect with syringohydromyelia, and inflammatory disease. If given a choice, many owners are also opting for MRI – despite the increased cost and possible waiting time – because of its safe and non-invasive nature.

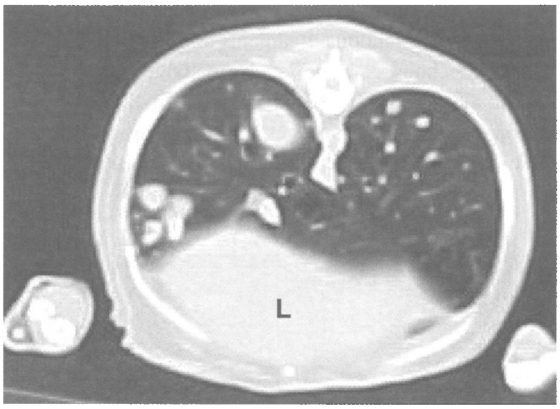
SOFT TISSUE LESIONS

MRI, in particular, is invaluable for presurgical planning for soft tissue lesions, especially tumours for which wide surgical margins are required. Examples include thyroid carcinomas, interscapular fibrosarcomas in cats (see above), infiltrative lipomas and other soft tissue tumours of the neck, trunk, pelvis and limbs. Clearly, MRI is much more helpful than CT in such cases because of its superior soft tissue contrast and multiplanar capability. When major surgery is proposed, the extra cost of an MRI scan can be justified in terms of the increased likelihood of a surgical cure and the implications of failure for the patient and owner. MRI has also proved to be excellent for delineation of foreign body reactions; larger foreign bodies such as cervical wood fragments may themselves be visible and, although small amounts of organic matter in flank and sublumbar lesions are not usually recognised directly, the surrounding reaction can easily be seen (see image, top right).

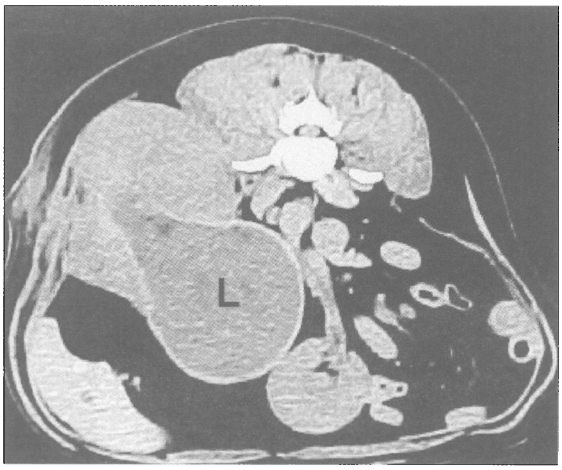
CT is the preferred modality for investigation of thoracic and abdominal cavity diseases since the short exposure times needed mean that movement blur is not usually a problem (see images on the right). Transverse images alone are usually sufficient for a diagnosis, and intravenous contrast medium may be given to highlight blood vessels and other vascularised tissue. MRI is widely used in humans for such investigations but, unless respiratory and cardiac gating is used in veterinary patients, MRI scans of the trunk are often degraded by motion artefacts. Angiography may be performed using MRI (both with and without the use of contrast medium) and 3D MR angiograms may be constructed (see overleaf). Although not currently widely employed, there is some interest in the future use of MR angiography for the characterisation of portosystemic shunts.

ORTHOPAEDIC CONDITIONS

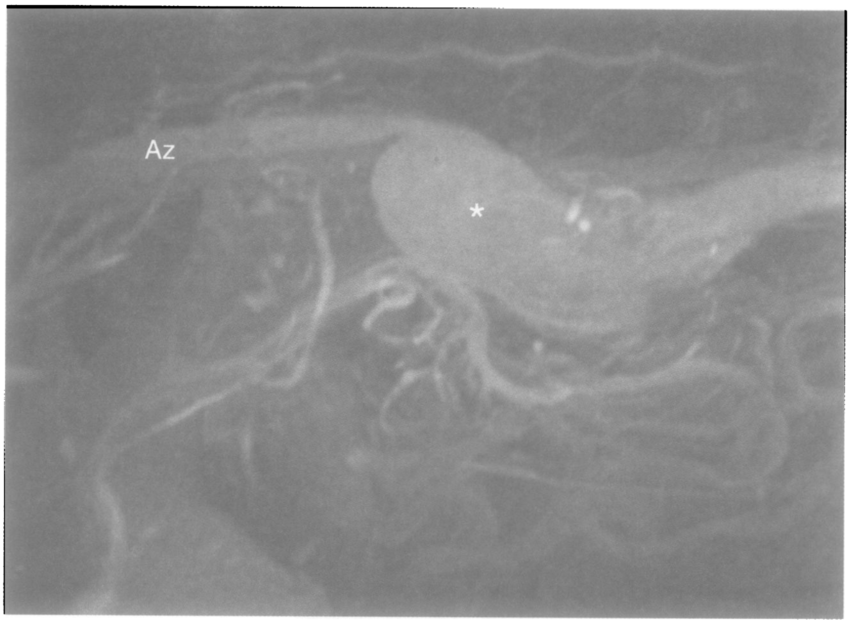
Despite being commonly used in humans for orthopaedic imaging, CT and MRI are less frequently used in the veterinary field for this purpose. This is probably due to lack of availability of the equipment and the fact that minor orthopaedic ailments are well tolerated in small animals.



Transverse CT scan of the chest of a nine-year-old Jack Russell terrier with an adrenal tumour. Numerous small pulmonary nodules are visible, due to metastatic spread. L Liver. Picture, Davies White Veterinary Specialists



Transverse CT scan of the abdomen of a 10-year-old crossbred dog with an abdominal lipoma (L). The radiopacity of the mass is less than that of other soft tissues, although greater than that of normal intra-abdominal and subcutaneous fat which appears black using this greyscale window setting. Contrast enhancement of a capsule of soft tissue around the lipoma is seen. Picture, Davies White Veterinary Specialists



Contrast-enhanced, 3D MR angiogram of an eight-year-old English pointer with an abdominal venous malformation in which an aneurysmal distension of the caudal vena cava (*) drains into the azygos vein (Az)

The very small size of canine and feline joints also creates problems in terms of image acquisition and interpretation.

CT is routinely used for small animal orthopaedics in a few centres worldwide and is particularly valuable for the detection of small mineralised fragments in osteochondrosis lesions. CT of the elbow joint in small animals with elbow dysplasia is probably the main single indication for its use. CT can also demonstrate, among other lesions, sclerosis, remodelling, osteophyte formation, fissure fractures, articular surface irregularity, joint incongruity and mineralisation of soft tissues.

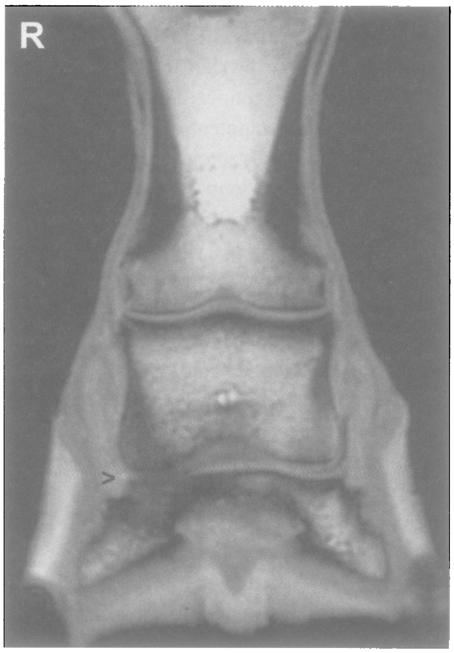
Although MRI is less sensitive for subtle bone changes, it provides superior orthopaedic images for many purposes because of its ability to demonstrate other orthopaedic components such as articular cartilage, synovial tissue, tendons, ligaments and menisci. Changes within subchondral bone, such as 'bone bruises', can also be identified. MRI can therefore be used to diagnose orthopaedic conditions affecting soft tissue components which would not be detectable using conventional radiography or CT. In some cases, the use of intra-articular paramagnetic contrast media may be beneficial. While most interest has been directed at MRI of the small animal stifle because of the complexity of this joint, MRI has been used successfully to examine other joints, especially the shoulder. However, MRI of small animal orthopaedic structures requires great skill in acquisition and interpretation of the images.

CT can be used in large animals for examination of bone lesions – for example, in planning the repair of comminuted fractures. However, it is MRI which is likely to revolutionise equine orthopaedics because of its ability to demonstrate all components of the musculoskeletal system, including subchondral bone, articular cartilage, synovial fluid, joint capsules, ligaments and tendons. Since most lesions are subtle (eg, bone bruises, cartilage defects and changes in the distal part of the deep digital flexor tendon), high quality images obtained using very thin image slices are usually required. Although only a small number of centres worldwide currently have the capability to image live horses in this way, the demonstration in life of hitherto undetectable lesions will have a major impact on equine orthopaedic diagnosis. Limitations of the technique are dictated again by patient handling constraints and scanner construction. With closed-bore scanners, only the lower limb and head may be placed sufficiently far into the machine for imaging. Open (bipolar) systems may allow slightly more of the large animal patient to be scanned but these are, by necessity, low-field magnets in which image resolution may be lower and/or scanning times longer. The ideal system would allow MRI of the standing horse and there is currently great interest in developing such technology with prototype systems being installed at several UK sites. While the clinical utility of such systems is still being established in terms of image quality, they offer hope for wider use of MRI in horses in the future.

Reference

ABRAMSON, C. J., PLATT, S. R., JAKOBS, C., VERHOEVEN, N., DENNIS, R., GAROSI, L. & SHELTON, G. D. (2003) L-2-hydroxyglutaric aciduria in Staffordshire Bull Terriers. *Journal of Veterinary Internal Medicine* (In press)

An anaesthetised horse positioned for MRI of the forefeet using the closed-bore MRI scanner at the Animal Health Trust. The patient table is constructed of non-ferrous materials



Dorsal plane MRI scan of the lower right forelimb of a four-year-old thoroughbred colt with chronic lameness (3D fast spoiled gradient-echo [SPGR] image, 1·5 mm slice thickness). Lateral collateral ligament damage is visible and there is associated arthrosis with articular cartilage erosion and bone sclerosis affecting the lateral portions of the middle and distal phalanges (>)

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In Practice 2003 25: 243-254
doi: 10.1136/inpract.25.5.243