Clinical applications of computed tomography (CT) and magnetic resonance imaging (MRI) in small animals

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INTRODUCTION
Computed Tomography (CT or CAT scan) and Magnetic Resonance Imaging (MR or MRI) are modern imaging procedures that have been established in human medicine for many years. Today, both procedures are often available in veterinary medicine and have proven their value in the detection of neurologic, orthopaedic, oncologic, and other diseases.

Definitions of CT and MR
In contrast to conventional radiology where overlying structures are superimposed, CT uses x-rays and computers to make views of the patient in transverse slices without superimposition. After the initial examination, transverse slices can be reconstructed in other planes using specific computer software (Fig. 1). With MR, the animal is placed in a magnetic field and an image is created, by using radio waves, which is based on the water molecules within the patient. With MR, the radiologist is looking for water and as pathologic processes generally have a high water content, they can be easily identified. In addition to transverse slice images, MR can obtain images in all directional planes of the patient. This procedure does not use any radiation and is considered one of the safest techniques in medical imaging (Fig. 2). The major disadvantage is the long examination time which makes general anaesthesia necessary. Also, MR equipment is more expensive to purchase and maintain than CT equipment.

Figure 1: During CT examination, the patient is positioned on the table. The table moves through the gantry of the CT device in which the X-ray tube rotates and cross sectional images are made.

Figure 2: Low-field, open MR system with a permanent magnet.

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The advantages of CT and MR

The main advantages of CT and MR include the ability to avoid the superimposition of different structures and the ability to obtain cross-sections or “cross-sectional” imaging (Fig. 3). Both procedures are complementary, but generally, CT is indicated for bone pathology and MR for soft-tissue pathology. MR can more clearly distinguish between normal and abnormal tissue, such as a tumour or inflammation. With the new “multi-slice” CT devices, which scan a volume, the examination takes only a few minutes, so studies can be done in a sedated animal. An MR study especially one using low-field equipment can take 45 minutes to an hour to perform and usually requires general anaesthesia. It may therefore not be an appropriate choice for patients in a poor condition. With both procedures, contrast can be applied to improve the detection of possible lesions. Contrast studies usually require the use of general anaesthesia to avoid motion artefacts.
Indications

CT and MR, although complementary, each have their own advantages; the expected pathology dictates which procedure should be used. CT should be used to detect skeletal disorders (Fig. 4), common small animal joint diseases, and oncologic diseases. In the latter application, CT can not only determine the size and the extent of tumours (Fig. 5) but also detect small metastases in the thorax. CT is also very accurate in diagnosing nasal, sinus and dental diseases (Fig. 6) in both small animals and horses.

MR is used mainly to diagnose neurologic disorders and soft-tissue musculoskeletal disorders, because the soft-tissue contrast is very high. Both procedures offer added value in determining the extent and severity of lesions and the stage of the patient’s cancer, which is necessary when planning the patient’s treatment and to determine its prognosis. For both procedures, a thorough knowledge of anatomy in the transverse, dorsal and sagittal planes of each body region is necessary.

Brain and skull

MR and CT are both widely used to diagnose brain diseases in animals. The first reports of CT scans of small animals were published in the 1980s and dealt with the normal CT brain anatomy and various types of tumours detected in dogs and cats. In the past few years, there has been a huge increase in the literature about MR brain anatomy and disorders. Because MR offers better soft-tissue contrast, it is more suitable than CT to diagnose brain tumours and to visualize secondary tumour features, such as oedema, cyst formation, and necrosis. Other subtle changes, such as displacement of the ventricular system, depth of the gyri, and a hernia of the temporal lobe and cerebellum are more easily diagnosed with MR. However, most space-occupying processes can be detected with CT, because the mass displaces the normal anatomical structures (mass effect) and disturbs the normal brain symmetry (Fig. 7). CT cannot clearly show lesions within the medulla oblongata, cerebellum and the piriform lobe; this is because this area is surrounded by highly opaque structures. These bony structures, such as the hard petrous temporal bones of the skull base, create an artefact, called Beam Hardening, which makes demonstration of lesions in the caudal fossa of the skull difficult, or even impossible (Fig. 8). In these cases, MR is indicated.

Unfortunately, different kinds of masses can create almost identical images, so it is not always possible to distinguish between neoplastic and non-neoplastic diseases. Certain tumours, such as meningiomas, can be easily recognized, but in most cases, a biopsy is necessary to determine the exact nature of the lesions.
Some specific features:

- Meningiomas are extra-axial lesions with a higher density than the rest of the brain parenchyma. They usually show a homogenous contrast enhancement and are well delineated. Sometimes regions of calcification are present; this type of tumour hyperostosis can be seen in 50 percent of cat meningiomas. A typical feature of this tumour, which is often seen on MR, is the presence of a so-called “Dural tail,” which connects the tumour to the neighbouring meninges (Fig. 9).

- Astrocytoma and oligodendroglioma are intra-axial lesions that usually have a very variable pattern. After intravenous contrast administration, the image produced can show peripheral contrast uptake with a central hypo-dense region, as well as heterogeneous, non-uniform contrast uptake. Peripheral contrast uptake is a relatively non-specific sign that could indicate a brain abscess or inflammation which can appear similar; MR can distinguish between these two conditions.

- Choroid plexus tumours are typically intra-ventricular, well-defined, hyper-dense masses that are enhanced after intravenous contrast administration (Fig. 10).

- Large pituitary tumours, which can be identified by their typical localization at the level of the sella turcica, show a uniform contrast uptake (Fig. 11).

Non-neoplastic processes, such as infection and inflammation, can be visualized by CT and MR. However, even with MR, differentiation of neoplastic versus non-neoplastic space-occupying lesions is not always clear. The presence of multifocal, granulomatous lesions in several parts of the brain is specific for primary inflammatory disorders such as granulomatous meningo-encephalitis (Fig. 12). Multifocal regions of reduced opacity are typical for necrotizing encephalitis which is mainly seen in Yorkshire terriers. Although an asymmetric increase in the size of one of the lateral ventricles is often associated with pathology, it is also a common finding in healthy dogs and must
always be related to the clinical picture. There is limited available information about ventricle size and normal variants in the different breeds.

To determine the type of brain tumour, a biopsy or surgical excision of the mass remains the best and only appropriate option. Analysis of cerebrospinal fluid is used to differentiate infectious lesions from neoplasia, but it has its limitations.

The use of CT-guided brain biopsy with the free hand is described in the dog. The most accurate method for biopsy of cerebral masses in dogs is CT-guided stereotactic biopsy. The animal’s head is placed in a frame whilst the orientation and location of the biopsy site is determined by coordinates derived from the CT images. Several CT-guided stereotactic devices for dogs and cats have been developed. Biopsy of brain masses larger than 6-9 mm in diameter is now possible with the correct equipment.

CT is the best procedure to detect an acute stroke which appears as a homogeneous, hyper-dense area associated with a mass effect during the first 72 hours; the lesion then becomes isodens and, after a week, hypodens. On MR, T1 weighted images show a hypo-intense pattern in the acute stage; a hyper-intense aspect becomes visible in the chronic stage. Cerebral infarction is usually detectable on certain MR sequences (Fig. 13).

Intracranial lesions that can be visualised include fluid-filled spaces in the brain. Hydrocephalus can be seen with both imaging techniques and the aetiology can sometimes be determined.

In trauma cases, CT can easily demonstrate skull fractures (Fig. 14), whereas MR is more sensitive for both intra- and extra-cerebral parenchymal lesions.

Tumours of the skull are visible on CT where bone lysis, secondary to a soft-tissue process that surrounds and invades the skull, is often present. In a Chiari-like malformation, the size of the skull’s caudal fossa is not in proportion to the volume of the cerebellum and brainstem. In these cases, the cerebellum may protrude...
caudally through the foramen magnum, blocking the cerebrospinal fluid flow, which may cause fluid-filled cavities called syringomyelia to develop inside the spinal cord. MR must be performed to determine this condition (Fig. 15). CT usually adds no value to detect inflammation and tumours of the cranial nerves, whereas MR is the best procedure to allow visualisation of most disorders of the cranial nerves (Fig. 16).

In both CT and MR, intravenous contrast agents can be administered to:

a) Determine the perfusion of the tissues; and

b) Distinguish between normal and abnormal tissue. Contrast studies are extremely useful for specific examination of the meninges, the choroid plexus, and the pituitary gland, all of which contain fenestrated capillaries that allow the contrast agent to enter their interstitium. In normal brain tissue, the contrast agents do not cross the blood-brain barrier, so they cannot get into the parenchyma. However, with lesions, including inflammation and tumours, the agents will cross the blood-brain barrier and the pathological tissue will be enhanced. Contrast agents used for MR contain a paramagnetic substance, gadolinium, such as Magnevist®. Contrast agents used for CT contain iodine such as Ultravist®.

Nose, sinus, retrobulbar region, tympanic bullae, teeth and jaw

The diagnostic information obtained with CT and MR in terms of location, extent and characterisation of lesions in the nasal cavity, paranasal sinuses, retrobulbar region, jaw, temporomandibular joints, and tympanic bullae is more accurate than those obtained with conventional radiographs.

In the nasal cavity, all structures are clearly visible with CT and MR, but CT is more accurate in detecting the location and spread of chronic nasal disease, as well as showing any degradation of the cribriform plate (Fig. 17).
Common nasal disorders have typical features. In nasal aspergillosis, destruction of the nasal turbinates creates large cavities (Fig. 17) which can be identified. In neoplasia of the nasal cavity, mass-like lesions associated with bony destruction will be seen. Additionally, the degree of destruction of the frontal bone, which will expand into the orbit, can be accurately determined (Fig. 18). In non-specific rhinitis, non-destructive processes will often effect both nasal cavities, but not the paranasal sinuses.

Disease in the retro-bulbar area is difficult to diagnose with radiographs; CT and MR allow orbital lesions and retro-bulbar masses to be more easily identified (Fig. 19). Exophthalmos and soft-palate swelling associated with the orbit or skull can be evaluated. CT can diagnose multi-lobular tumours and whether there is involvement of the zygomatic arch and frontal bone, whereas MR allows the soft-tissue components to be evaluated in more detail.

CT and MR allow visualisation of the base of the skull and the tympanic bullae without superimposition of other structures. They can also accurately diagnose otitis media and interna in dogs and cats at an earlier stage than conventional radiography. Within the tympanic bullae, MR can establish any subtle increase in soft-tissue opacity and fluid. Patients with otitis interna can develop secondary meningitis, which is visible with MR. CT, especially contrast CT, can provide useful

<table>
<thead>
<tr>
<th>CT</th>
<th>MR</th>
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<tr>
<td>Mainly bony lesions</td>
<td>Mainly soft tissue lesions</td>
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<tr>
<td>Congenital anomalies</td>
<td>Congenital anomalies, including hydrocephalus, arachnoid cysts</td>
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<tr>
<td>Infection/inflammation such as osteomyelitis</td>
<td>Infection/inflammation such as neospora infection, granulomatous encephalitis</td>
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<tr>
<td>Haemorrhage, acute and chronic</td>
<td>Haemorrhage, sub-acute and chronic</td>
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<tr>
<td>Neoplasia, usually visible after contrast administration or bony changes, including bone hyperostosis in meningioma</td>
<td>Neoplasia, including astrocytoma, brainstem tumours</td>
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<td>Skull trauma with bone destruction</td>
<td>Skull trauma, usually parenchymatous lesions</td>
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**Figure 17: Adult dog with nasal aspergillosis.** A: Transverse CT image of the caudal parts of the nasal cavities in a dog. In the right nasal cavity soft tissue and fluid density are present (asterisk). In the dorsal part of the right nasal cavity there is destruction of the nasal turbinates and the maxilla (arrowhead). B: Transverse CT image at the level of the frontal sinuses showing mucosal thickening in the right frontal sinus. There is suspected destruction of the cribriform plate dorsally (arrowhead). C: Dorsal CT reconstructed image confirming lysis of the cribriform plate (arrowhead). Evaluation of the cribriform plate in this type of lesion is very important to determine prognosis and therapeutic planning.
Information about the external ear canal, the inner ear, the nasopharynx and the extent of the involvement of the bony bullae (Fig. 20).

Disorders of the mandible and maxilla and any eventual involvement of the teeth can be evaluated with both CT and MR. CT provides clear images of the bony components (Fig. 21), while MR provides more detail about the expansion of the soft-tissue structures.

Figure 19A: Dorsal MR image (T2-weighted) of the retrobulbar region in a dog. At the left retrobulbar region a hyper-intense structure is seen (arrowheads). Part of the frontal sinus is missing and there is invasive growth into the sinus (*). B: Dorsal MR image (T1-weighted, post-contrast). The contrast enhancement at the level of the mass is suggestive for a tumour.

Figure 20: Post-contrast transverse CT image of a cholesteatoma of the right tympanic bulla in a dog. The right tympanic bulla is completely filled with soft tissue opacity. Lysis of the wall and os petrosum is present. Intracranial invasion is seen with contrast enhancement at the border of the mass (black arrow).
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Back and spinal disorders

Today CT and MR are replacing conventional radiography and myelography for the diagnosis of spinal cord diseases. Both techniques give different, but complementary, information about the spinal cord and its surrounding structures.

CT is very useful for detecting bony changes such as osteolysis and calcification. It also gives an accurate representation of the anatomy of the vertebrae and facet joints (Fig. 22). The presence of gas between the vertebrae in the intervertebral area, known as the vacuum phenomenon, is a sign of degeneration of the intervertebral disc and a frequent finding on CT. Abnormalities of the disc with the occurrence of mineralized and non-mineralized material, spinal tumours and cervical spondylosis can be evaluated with CT, which is as accurate as myelography for detecting extradural lesions, but less accurate in differentiating intramedullary from extradural lesions.

Mineralized material of an intervertebral disc in the spinal canal can be detected with CT without myelography (Fig. 23); however, material with soft-tissue density may not be visible on native CT. In these cases, CT, myelography, or MR is indicated.

CT is more accurate than conventional myelography for the diagnosis and localization of an intervertebral disc herniation; a lateralized disc herniation, in particular, will be more visible with CT and/or MR than with myelography (Fig. 24). Also, post-processing CT images can be obtained in the sagittal and dorsal plane providing more information.

MR is the procedure of choice to evaluate the soft tissues within the spinal canal such as the ligaments, intervertebral discs, and the spinal cord itself. MR provides additional information about the spinal parenchyma and the peri-vertebral soft tissues and distinguishes between the extradural and intradural parts of nerve sheath tumours, the intervertebral foramen, and extradural spaces. Intramedullary lesions can also be assessed (Fig. 25).

In cases of spinal arachnoid cysts, both CT and MR provide more information in more detail than...
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myelography. This is achieved by visualisation of the caudal edge of the cyst, the topographic position, and the degree of spinal cord compression.

CT and MR are valuable in the diagnosis and evaluation of lumbosacral lesions. Remodelling of bone, intervertebral disc bulging, and evidence of compression of the cauda equina, the facet joints, and the sacro-iliac intervertebral foramina can all be evaluated without superimposition (Fig 26).

The individual nerve roots of L5-S3 can be visualized and tracked to the exit point at their foramen. The epidural fat provides an inherent contrast medium.

CT and MR are also used to evaluate the extension of nerve sheath tumours such as brachial plexus tumours in the axillary region. The lumbosacral plexus can be seen as a soft-tissue mass cranial to the sacrum. The lumbosacral nerves and the sciatic nerve can also be evaluated.

Intravenous administration of contrast helps to identify the vascular structures (Fig. 27), but the differentiation between a nerve sheath tumour and a neuritis is still a challenge and not always possible.

With CT, the presence and extent of haemorrhage in the spinal canal can be properly evaluated in the acute stage. With MR, sometimes an infarct in the spinal cord can be seen. These lesions are intramedullary with a hyper-intense appearance (Fig. 28).

CT can clearly demonstrate bony lesions caused by trauma to the spinal canal. By contrast, lesions in the spinal cord are not always clearly visible and are sometimes missed. Intravenous contrast enhances images of inflammatory and neoplastic lesions and helps distinguish these lesions from disc material and haemorrhage.

The use of different MR sequences, combined with or without an intravenous injection of a paramagnetic contrast agent (e.g., Magnevist®), allows visualization of a large number of spinal cord lesions and their surrounding structures.

Thorax

CT is the best imaging procedure to detect and evaluate masses, malformations and effusion in the thoracic cavity. The exact size and shape of a mass can be determined, as

Figure 23: Dog with a herniated disc at the level of the first and second lumbar vertebrae. (A: transverse, B and C: a sagittal and dorsal CT reconstructed image). There is severe extradural compression by an extruded mineralized disc. The reconstructed images allow accurate lesion localization.

Figure 24: Transverse MR image of a herniated disc in the region of the cervical spine (white arrow). Prominent compression of the nerves at the level of the intervertebral foramen is present in this dog.
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Figure 25: A: Sagittal MR image (T2 weighted) of a dog. A hyper-intense area is visible at the spinal cord at the level of the first 2 cervical vertebrae. B: Transverse image (T1 post-contrast) showing prominent contrast enhancement of a cervical meningioma.

Figure 26: Sagittal MR image (T2-weighted) at the lumbosacral region of a dog with lumbosacral stenosis. Dorsal and ventral (arrowhead) compression of the cauda equina is seen at the level of L7-S1. At this level the disc is dehydrated and the disc is bulging into the vertebral canal.

Figure 27: A: Transverse MR image (T1-weighted) of the lumbosacral region of a dog with neoplasia of the lumbosacral plexus. A hyper-intensity is seen at the level of the nerves extending from the lumbosacral plexus (arrowhead). B: Transverse MR image (T1) showing prominent muscle atrophy at the level of the gluteus and iliopsoas muscles (*). C: Dorsal MR image (STIR). At the level of the extending nerves L4-L5 and L6, and also at the level of the muscles, a hyper-intense signal is visible.

Figure 28: Sagittal MR image (T2-weighted) of the cervical spine of a dog. A delineated hyper-intensity is seen in the spinal cord at the level of the 6th cervical vertebra (arrowhead). This is suggestive for a fibrocartilaginous infarct.
well as the presence of early mineralization within a mass (a sign of neoplastic change), and the extent of spread into the surrounding tissues (Fig. 29). This information is important when planning surgery.

Due to the large air-tissue contrast, the lung structures can be seen in great detail. Changes to the pleura and the medial aspect of the ribs can also be evaluated. Various windows can be used to evaluate soft tissues in the mediastinum, the body wall and the bone. Masses in the thorax can be differentiated from mediastinal or pleural fluid. CT images of similar views with and without an intravenous contrast agent can differentiate between the blood vessels of the mediastinum and other structures. CT is considered the most sensitive method for the detection of pulmonary metastases. Nodules can be detected from 2mm (Fig. 30). MR is used less frequently for thoracic diseases because structures that contain air give no signal and appear black, and respiratory and cardiac motion blur the images.

Abdomen

Abdominal CT produces very good anatomical images of abdominal organs and blood vessels, although it is used less frequently for abdominal pathology, except in very obese animals. This is largely due to the extensive use of ultrasound to make clinical diagnoses in the abdomen. CT is often used to evaluate the involvement of surrounding vital structures in cases with abdominal masses; to evaluate lesions in the spinal and pelvic canals; for early detection of renal carcinoma; and to differentiate between cysts and solid tumours.

A bolus injection of contrast medium can differentiate between solid, vascular or avascular renal masses, and cysts. CT is also indicated to image the adrenal glands and to evaluate the size, shape and topography of adrenal masses. In cases of hyperadrenocorticism, CT distinguishes between unilateral and bilateral enlargement of the adrenal glands (Fig. 31) and any infiltration of the vena cava. Additionally, with CT guidance, fine-needle aspiration of an adrenal mass can also be performed.

CT images obtained at the time of maximal expiration provide a detailed overview of the normal parenchyma of the pancreas, but the normal biliary ducts cannot be visualised. The main technical problem in CT studies of the pancreas is the delineation of adjacent organs, particularly the liver, spleen and stomach. CT with intravenous contrast

### Indications for CT and MR in spinal disorders

<table>
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<tr>
<th>CT</th>
<th>MR</th>
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<tr>
<td>Mainly bony lesions</td>
<td>Mainly soft-tissue lesions</td>
</tr>
<tr>
<td>Disc pathology, including mineralized disc material</td>
<td>Disc pathology</td>
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<tr>
<td>Neoplastic lesions, usually with bone involvement</td>
<td>Spinal cord tumour, including intramedullary neoplasia</td>
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<tr>
<td>Ischemic myelopathy</td>
<td></td>
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<tr>
<td>Discospondylitis, usually osteolysis of endplates</td>
<td>Infection/inflammation among others, including myelitis, meningitis, discospondylitis, epidural empyema</td>
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<tr>
<td>Congenital spinal anomalies such as atlanto-axial malformation, hemivertebrae</td>
<td>Congenital spinal anomalies, including caudal occipital malformation syndrome with syringohydromyelia, Chiari malformation in Cavalier King Charles spaniels</td>
</tr>
<tr>
<td>Spinal trauma, including fractures, dislocations</td>
<td>Spinal trauma, usually affecting the spinal cord</td>
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<tr>
<td>Lumbosacral stenosis</td>
<td>Lumbosacral stenosis</td>
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offers a combination of topographical and functional evaluation of the spleen and can accurately diagnose splenic torsion in the dog. CT with contrast is also useful for the diagnosis of porto-systemic shunts. The current devices use a short examination period and provide an arterial, hepatic, and venous phase image. Post-processing 3D images give a fair representation of the type of porto-systemic shunt (Fig. 32).

It is necessary to administer contrast medium to differentiate mesenteric masses from normal bowel and vascular structures. Detailed images of both the small and large intestine suggest that CT could be used to evaluate gastrointestinal pathologies, but gastrointestinal imaging in dogs is limited because it is difficult to assess the dynamic activity of the intestine. Because of the high-contrast resolution and lack of superposition, CT is valuable when evaluating the ureters and their endings in

Figure 29: Transverse CT image of the thorax of a dog with chondrosarcoma. A soft tissue mass present is centred on the rib cage with osteolysis of the rib. Intrathoracic extension of the process can be evaluated.

Figure 30: Transverse CT image of the caudal lung lobes of a dog with metastatic lung neoplasia. Several poorly marginated nodules are seen (arrowheads).

Figure 31: Post-contrast transverse CT image of the abdomen of a dog with a left adrenal gland tumour. Medial to the left kidney a contrast enhancing soft tissue mass is seen (white arrowhead).

Figure 32: CT angiogram, dual phase, sagittal reconstructed image of a cat with an extrahepatic portosystemic shunt. An anomalous vessel diverges from the portal vein and travels to the left between the stomach and liver. The shunt vessel terminates in the caudal vena cava at the level of the hepatic veins near the diaphragm.
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Skeleton and joints

CT is widely used in human medicine to evaluate skeletal disorders and muscle and tendon injuries. Today, CT in animals is more frequently used to diagnose orthopaedic disorders. CT of the skeleton may help in clinical cases where standard radiographs are negative or doubtful and pathology is strongly suspected. Joint pathology in small animals is often difficult to determine on radiographs, because of the complex radiographic anatomy of some smaller joints and the superimposition of bony structures. CT facilitates the study of complex joints such as the elbow and the tarsus, because it prevents superimposition of other structures (Fig. 34). Osteolysis, sclerosis, and new bone formation can be detected very early on because of CT’s high sensitivity for bony lesions. CT can detect changes in density of 0.5 percent, compared to approximately 30.0 percent with conventional x-rays. CT is the most accurate procedure to evaluate the extent of osteosarcoma in dogs (Fig.35).

Skeleton and joints

CT has been proven to be superior to radiography for the diagnosis of fragmented medial coronoid processes in the elbow joint (Fig.36). As well as the diagnosis, CT may be used to determine the degree of elbow incongruity (Fig. 37), although this matter is still under discussion. CT is also superior for the diagnosis of incomplete ossification of the humeral condyle (Fig. 38). CT can be used to assess the dorsal aspect of the acetabular rim when treating hip dysplasia, an important criterion when a triple pelvic osteotomy is considered. Stifle CT is indicated to determine the origin of avulsions and fragments (Fig. 39). CT can also be used to determine the volume and density of bones and the orientation of angular deformities (Fig. 40).
Figure 36: Transverse CT slice, bone window, of a canine elbow at the level of the radius and ulna. A small displaced fragment (arrowhead) is present at the medial coronoid process of the ulna.

Figure 37: Transverse slice (A) and sagittal (B) and dorsal (C) reconstructed CT images of an incongruent elbow joint. The black arrow points out the widened and diverging joint space. The white arrows show the step present, between radius and ulna.

Figure 38: Transverse CT slice, bone window, at the level of the distal part of the humerus. A radiolucent area surrounded by a sclerotic rim is visible (white arrow) representing an intercondylar fissure.

Figure 39: Transverse CT image at the level of the femoral condyles of a stifle in a young dog. The avulsed proximal attachment of the cranial cruciate ligament is clearly visible at the medial part of the lateral condyle with associated subchondral sclerosis (white arrow).

Figure 40: 3D CT reconstruction of a stifle joint with medial patella luxation. The depth of the trochlear groove and angular deformities can be evaluated.
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CT’s ability to view images in different planes makes a complete evaluation of the joint possible. With fractures, it enables the orientation of the fracture lines to be determined, which is necessary when planning fracture treatment and possible surgery (Fig. 41).

Visualisation of cartilage in small animal joints remains difficult. Arthro-CT, using a small amount of contrast medium in the joint, is potentially useful to delineate cartilage and is sometimes used to assess the menisci and cruciate ligaments (Fig. 42).

MR has clear advantages over CT in the visualization of peri-articular and intra-articular soft-tissue structures. In the area of the shoulder and elbow joint, injuries of the muscles, tendons, and joint capsule can be clearly seen (Fig. 43). However, even with MR, the assessment of cruciate ligaments and menisci is difficult because they are so small (Fig. 44).

MR is particularly sensitive to the detection of changes in the bone marrow, but, again, even with MR, canine cartilage is difficult to visualise. This is because small animals have very thin cartilage and the resolution of the MR equipment is too low to directly visualize it. The distinction between cartilage and synovial fluid is not clear, at least not in young dogs (Fig. 45). The intra-articular administration of gadolinium-containing contrast media may give added value, but is still under investigation. Intravenous injection of contrast agents may be useful to detect inflammatory processes and evaluate the extent of neoplastic processes (Fig. 46).
Conclusion

CT and MR are imaging procedures that provide many applications in various clinical disciplines. They have become more frequently available for veterinary use and are especially valuable for the detection and diagnosis of brain disorders. They are more accurate than conventional radiography in evaluating the location and extent of lesions in the nasal cavity, paranasal sinuses, eye socket, jaw, temporomandibular joint, and tympanic bullae.

Both procedures are also useful when planning treatment and surgery for back and spinal cord injuries. CT is one of the best imaging procedures available for the detection and description of masses, malformations and effusions in the thorax, and is considered the most sensitive procedure to detect pulmonary metastases. Although ultrasound is considered the imaging procedure of choice to examine the abdomen, CT does give an excellent anatomical overview of the organs and blood vessels.

CT of the skeleton is useful in clinical cases where standard radiographs are negative or doubtful. CT is superior to radiography for the diagnosis of coronoid disease and other pathologies of the elbow and is generally useful to evaluate joint pathology. MR provides
better images of the peri-articular and intra-articular soft-tissue structures. It is expensive to purchase both CT and MR devices; however, second-hand CT equipment is now available and more affordable for private practitioners. MR devices, even low-field, remain expensive, with substantial maintenance costs. Moreover, only specialists, who are also expensive, can make optimal use of each device because expert knowledge is required for the correct interpretation of both procedures.

**Additional reading**

**CT/MRI technique:**


**Brain and skull:**


**Spine:**


Thorax:


Abdomen:


Orthopaedics:


Gielen I., van Bree H., Van Ryssen B., De Clercq T. The use of computerized tomography (CT) in tarsocural OCD in the dog: a comparison with radiography and arthroscopy. The Veterinary Record, 2002; 150: 442-447.


