

COMPUTED TOMOGRAPHY (CT) IN SMALL ANIMALS

PART 2. CLINICAL APPLICATIONS

Computer tomografie (CT) bij kleine huisdieren Deel 2. Klinische toepassingen

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ABSTRACT

CT is an imaging tool with many applications in various clinical disciplines that is becoming increasingly available to the veterinary profession. CT is particularly valuable for the detection and diagnosis of brain diseases associated with mass lesions. The fact that some intracranial lesions may not be visible on CT is probably due to diffuse distribution, attenuation levels similar to those of the surrounding normal tissue, and minimal or absent contrast enhancement. CT is more accurate than conventional radiography in evaluating the localization, extent and characterization of lesions of the nasal cavity, sinuses, orbital, jaws, temporomandibular joints and tympanic bullae. CT appears to be remarkably accurate in revealing the location and extent of nasal diseases and is superior to conventional radiography for detecting middle ear disease. CT is useful in the investigation of spinal lesions in the event of doubtful radiographic and/or myelographic findings, and can be of help in surgical planning. CT is one of the best imaging modalities for the detection and description of masses, malformations and fluid collections in the thoracic cavity and is considered the most sensitive method for the detection of pulmonary metastases. CT of the abdomen gives excellent anatomic images of the organs and vessels, although the availability of ultrasound may have decreased the demand for abdominal studies. Skeletal CT may be helpful in clinical cases in which standard radiography is negative or inconclusive even though there is a high suspicion of pathology. CT has been proven to be superior in the diagnosis of fragmented coronoid process and other affections of the elbow joint.

SAMENVATTING

CT is een beeldvormingstechniek, die meer en meer toegankelijk wordt voor diergeneeskundig gebruik, met toepassingen in verschillende klinische disciplines. CT kan vooral in de neurologie erg nuttig zijn voor opsporing van hersentumoren. Diffuse hersenaandoeningen of aandoeningen die niet aankleuren na contrasttoediening, zijn met CT slecht in beeld te brengen. Aandoeningen van de neus, sinussen, orbita, kaakgewrichten en bulla tympanica kunnen met CT beter in beeld gebracht worden dan met radiografie. De lokalisatie en uitbreiding van neusaandoeningen en de vroege diagnose van middenoorontsteking kan zeer accuraat gebeuren. Ook bij onderzoek van spinale aandoeningen, waarbij de radiografische en/of myelografische bevindingen onduidelijk zijn, kan CT bijkomende nuttige informatie verschaffen zeker als chirurgische behandeling overwogen wordt. Ook thoraxpathologie kan een indicatie voor CT zijn. CT is superieur voor opsporen van metastasen en evalueren van thoracale massa's en vochttopstapelingen. CT kan ook heel mooi buikorganen en bloedvaten in beeld brengen maar hiervoor wordt meer beroep gedaan op echografie zodat hier de praktische toepassingen minder evident zijn. In de orthopedie is de toepassing van CT nuttig in die klinische gevallen waar röntgenonderzoek geen, of twijfelachtige, bevindingen geeft en er toch pathologie verwacht wordt. Het nut van CT is al geruime tijd bewezen in de detectie van gefragmenteerde processus coronoideus en andere elleboogaandoeningen.

INTRODUCTION

Computed tomography (CT) was introduced in the 1970s in human medicine, and since then it has become an established and important radiological procedure (Seeram, 2001d). Although over the last decade CT has become more readily available to the veterinary profession, its general application is still limited. It requires animal patients to be anesthetized for examination (Jeffery *et al.*, 1992). Another disadvantage is the cost of purchasing and maintaining the equipment. Superior soft-tissue differentiation and the absence of superimposition are the major advantages of CT over conventional x-ray techniques (Hathcock and Stickle, 1993). The predominant emphasis is the evaluation of affections of the head and central nervous system, and orthopedic disease. Besides its use in diagnosing abnormalities, CT is also used for better evaluating the extent and severity of lesions, all these features being useful for treatment planning. A thorough knowledge of the cross-sectional anatomy is required in examining each region of the body.

BRAIN AND SKULL

In cases of trauma, fractures of the cranium can be identified easily with CT because of its greater sensitivity for bony tissue (Jeffery *et al.*, 1992; Dennis, 1996).

CT is particularly valuable for the detection and diagnosis of brain diseases. The first reports of CT scanning in small animals were published in the 1980s and concerned the normal brain anatomy as seen on CT (Fike *et al.*, 1980; Fike *et al.*, 1981a; Fike *et al.*, 1984; Legrand and Carlier, 1986; Zook *et al.*, 1981; George and Smallwood, 1992) and various types of tumors in dogs and cats (Fike *et al.*, 1981b; LeCouteur *et al.*, 1981; LeCouteur *et al.*, 1983; Turrell *et al.*, 1986; Lang *et al.*, 1988). Intracranial masses and fluid-filled cavities are usually clearly demonstrated with CT (Stickle and Hathcock, 1993).

During the examination, the dog is best placed in prone position with the head extended. The head should be held with cushions to maintain a straight and symmetric position. A scout view is performed in the lateral and ventrodorsal planes. The area of interest extends from the cranial aspect of the first cervical vertebra to the cribriform plate and transverse slices are set perpendicular to the hard palate (Fike *et al.*, 1981b; LeCouteur *et al.*, 1981). The scan thickness is generally 5 mm for large dogs and 3 mm for small dogs and cats (Jeffery *et al.*, 1992; Stickle and

Hathcock, 1993). We routinely use a window level of 50 Hounsfield units (HU) and a window width of 150 HU for brain scanning. A survey scan series is performed, followed by the IV administration of iodinated contrast medium and a second series of scans (Fike *et al.*, 1981b). The falx cerebri, tentorium cerebelli, and ventricular system are readily visible on survey CT images (Fig. 1) (Stickle and Hathcock, 1993; Jeffery *et al.*, 1992). Intracranial mass lesions seen on CT scans are generally classified on the basis of a midline shift in the position of normal structures (mass effect) (Fig. 2) (Fike *et al.*, 1981b; Fike *et al.*, 1986). Edema may be visible as decreased opacity in the brain parenchyma (Plummer *et al.*, 1992; Stickle and Hathcock, 1993). Both primary brain tumors and metastases can be identified. The visibility of intracranial lesions is enhanced on CT because of the leakage of contrast medium through a disrupted blood-brain barrier and/or an increase in vascularity (Fike *et al.*, 1981b; Fike *et al.*, 1986). Unfortunately, different types of lesions can have virtually identical characteristics on CT, often making the differentiation between neoplastic and non-neoplastic or inflammatory diseases impossible (Plummer *et al.*, 1992; Wolf *et al.*, 1995). Nevertheless, certain tumor types, such as meningiomas can often be recognized. These are extra-axial lesions which appear to be hyperdense compared to the brain parenchyma. They may show areas of calcification and tend to have a homogeneous enhancement with sharp demarcation from normal tissue (Fig. 3) (Lang *et al.*, 1988; Turrell *et al.*, 1986; Jeffery *et al.*, 1992). In this type of tumor, hyperostosis is seen in 50% of the cats (Gordon *et al.*, 1994). Astrocytomas and oligodendrogliomas are intra-axial lesions and typically show peripheral enhancement with central lucency or heterogenous, non-uniform enhancement (LeCouteur *et al.*, 1981; Turrell *et al.*, 1986; Jeffery *et al.*, 1992). However, ring-enhancement is a relatively non-specific sign and a brain abscess or inflammatory disease may also exhibit this feature (Turrell *et al.*, 1986; Plummer *et al.*, 1992; Wolf *et al.*, 1995). Choroid plexus tumors are intra-ventricular, well defined hyperdense masses that enhance markedly after contrast administration (Fig. 4). Pituitary tumors may be recognized by their location in the sella turcica and typically show uniform contrast enhancement (Fig. 5) (Turrell *et al.*, 1986.; Jeffery *et al.*, 1992).

Several infectious and non-infectious inflammatory disorders can cause CT abnormalities in dogs. The presence of multifocal granulomatous lesions in more than one region of the brain is considered to be speci-

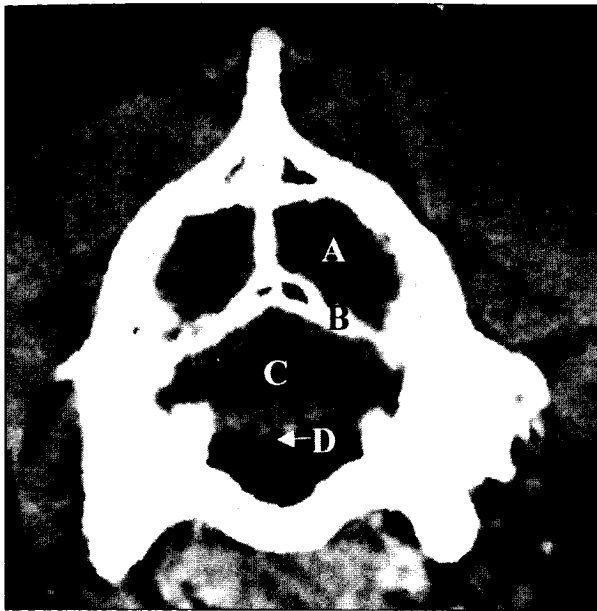


Fig. 1. Transverse CT image of the canine brain, made at the level of the fourth ventricle. The occipital region of the brain (A), tentoria cerebelli (B), cerebellum (C) and fourth ventricle (D) are easily visible on survey CT images.

3a

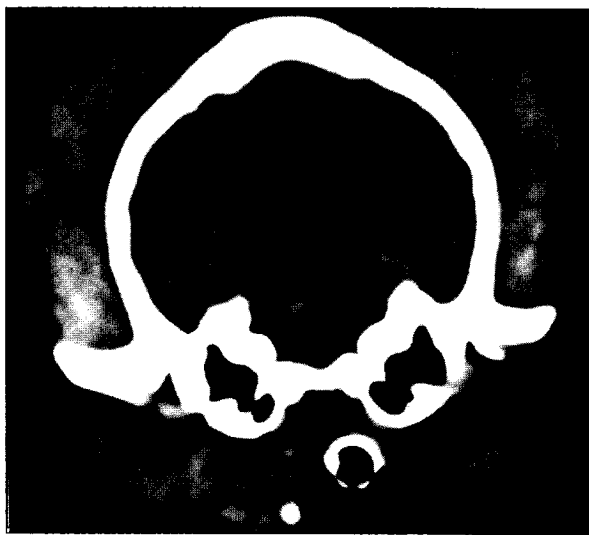


Fig. 3. Representative pre- and post-contrast transverse CT scan of the brain of a dog. The pre-contrast image (a) shows normal symmetry of the brain parenchyma. The ventricles are not enlarged and there is no mass effect. On the corresponding post-contrast scan (b), intense contrast enhancement of a mass with a broad base on the dura (black arrow) is visible. This extra-axial mass lesion is suggestive of a meningioma.

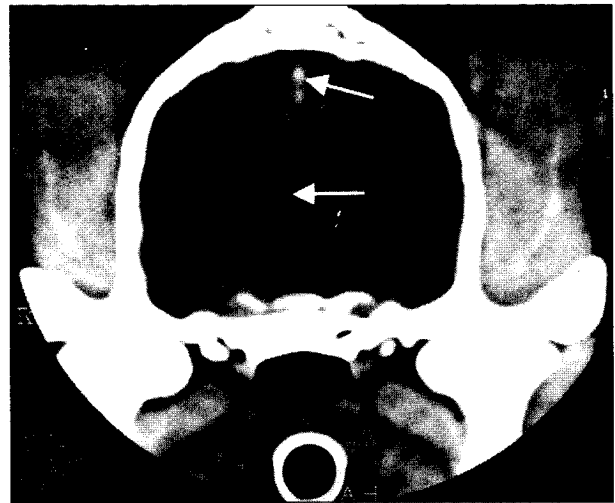


Fig. 2. Pre-contrast transverse CT image of the brain of a dog showing a mass effect. A lateral displacement of the falx cerebri (white arrow on top) and the third ventricle (white arrow in the middle) towards the right is visible. There is a midline shift in the position of normal structures, probably due to an intracranial mass on the left side.

3b



fic for primary inflammatory diseases such as granulomatous meningoencephalitis (Fig. 6) (Ducoté *et al.*, 1999; Speciale, 1992; Plummer *et al.*, 1992). CT findings such as multifocal areas of decreased opacity have been found to be characteristic for Yorkshire Terrier necrotizing encephalitis (Ducoté *et al.*, 1999). Although asymmetric enlargement of the lateral ventricles is often associated with this disease, this is also a common feature in normal dogs (Dennis, 1996).

Interbreed variation complicates ventricular size assessment. Unfortunately, information about ventricle size and normal variation with regard to breed is still scarce. A recent study demonstrated a statistically significant difference between Yorkshire Terriers and German Shepherd dogs, but no age-related difference could be determined (Esteve-Ratsch, 2001).

Areas of acute hemorrhage appear as homogenous, hyperdense areas associated with edema and mass-ef-

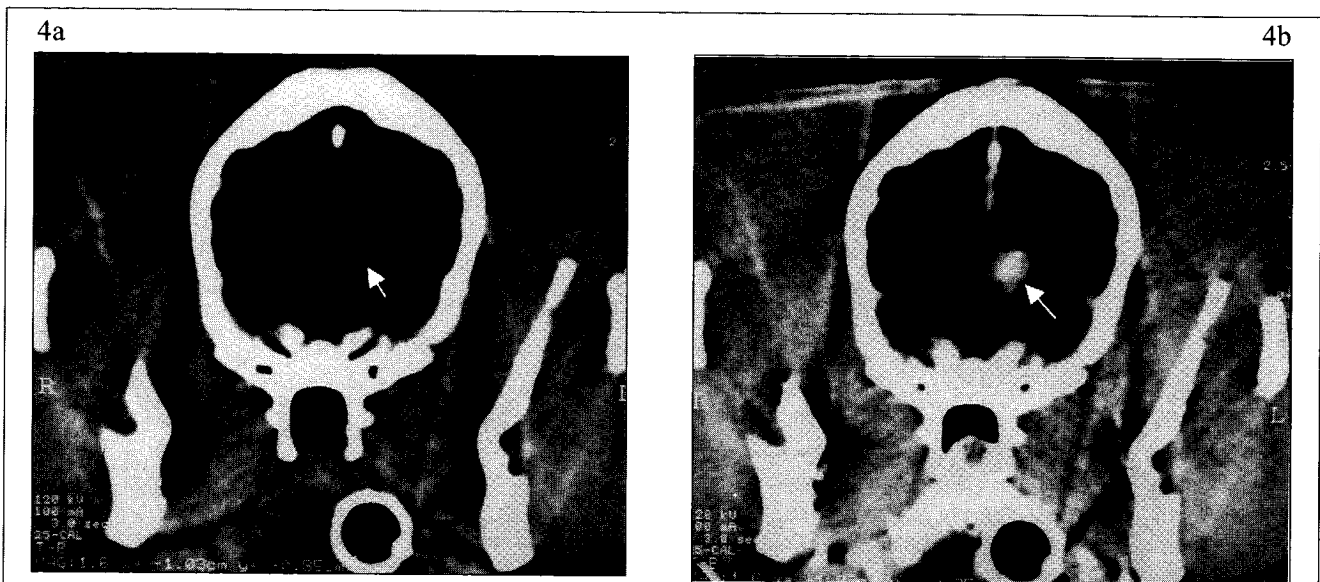


Fig. 4. Pre-contrast (a) and post-contrast (b) CT scan of the canine brain at the level of the lateral ventricles. The pre-contrast image shows asymmetry and a mass effect of the left lateral ventricle (white arrow). After intravenous contrast administration (b), a well-defined hyperdense intraventricular mass is visible. This lesion is suggestive of a choroid plexus papilloma.



Fig. 5. Tumor in a 9-year-old dog. On the non-contrast enhanced transverse scan (a), a slight hyperdense mass is visible at the midline above the pituitary fossa. Use of contrast medium (b) revealed intense, homogeneous enhancement (black arrow).

fect (LeCouteur *et al.*, 1981; Jeffery *et al.*, 1992; Stickle and Hathcock, 1993). Other intracranial lesions that are well visualized are those related to the fluid filled spaces of the brain. The appearance of hydrocephalus can be detected, and the cause can sometimes be demonstrated (Fig. 7).

Some intracranial lesions may not be visible on CT, probably due to diffuse distribution, attenuation similar to that of the surrounding normal tissue, and mini-

mal or absent contrast enhancement (LeCouteur, 1999).

A definitive diagnosis of intracranial diseases and lesions can only be reached by obtaining a tissue sample for histological examination. Preoperative biopsy of a lesion may provide information needed to establish a treatment protocol and to give prognostic information to the owner. One report describes the use of CT guided free-hand needle biopsy to perform brain biopsies in dogs. The success rate was rather

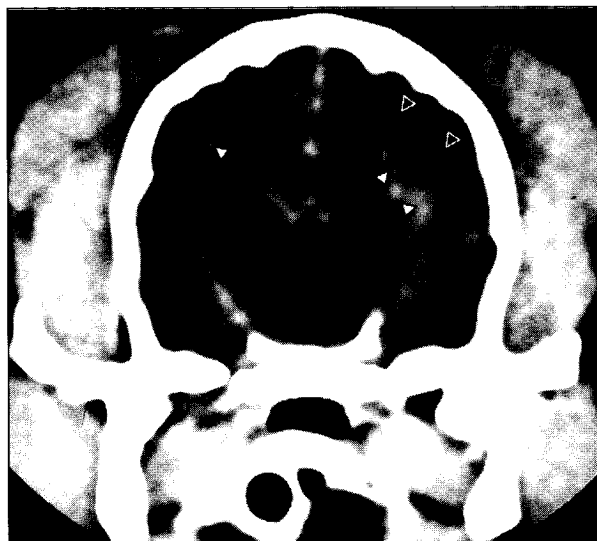


Fig. 6. Transverse CT image of the brain of a patient with granulomatous meningoencephalitis, after IV administration of contrast medium. There are multifocal regions of increased contrast enhancement suggestive of inflammatory granulomatous foci (white arrowheads) and areas of decreased density of the brain parenchyma compatible with edema (black arrowheads).

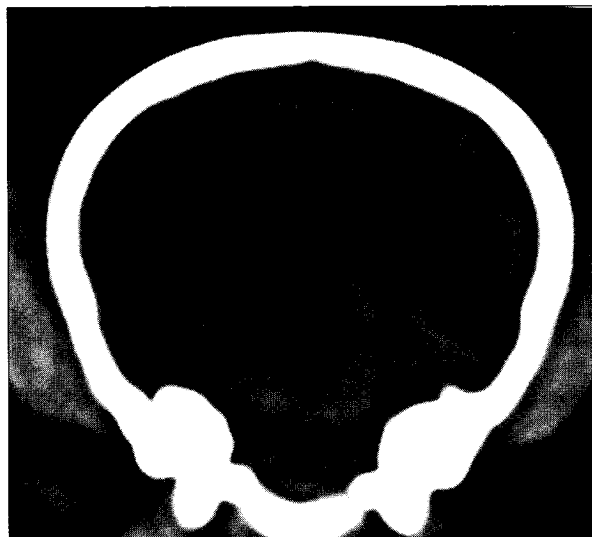


Fig. 7. Transverse CT image of the brain of a dog with hydrocephalus. The complete ventricular system is enlarged and the size and shape of the fluid-filled spaces of the brain are remarkable.

low due to the inadequate sample size obtained and clinical complications after biopsy (Harari *et al.*, 1994). The most accurate method for obtaining samples of a cerebral mass in dogs is CT-guided stereotactic biopsy. This technique uses a frame to hold the head in place while the orientation and insertion of the biopsy needle is guided using coordinates derived from imaging data. Different stereotactic CT-guided devices for dogs and cats have been modified and developed (Coffey and Lunsford, 1987; LeCouteur *et al.*, 1998; Koblik *et al.*, 1999a; Moissonnier *et al.*, 2000; Flegel *et al.*, 2002; Giroux *et al.*, 2002). With the required instrumentation, small unknown brain lesions exceeding 6-9 mm in diameter can be biopsied (Koblik *et al.*, 1999b; Moissonnier *et al.*, 2000; Moissonnier *et al.*, 2002).

NASAL CAVITY, PARANASAL SINUSES, ORBITA, TYMPANIC BULLA

The diagnostic information obtained using CT concerning localization, extent and characterization of lesions of the nasal cavity, sinuses, orbital, jaws, temporomandibular joints and tympanic bulla, is more accurate than conventional radiography (Feehey *et al.*, 1991b; Stickle and Hathcock, 1993; Dennis, 1996).

Patients are positioned in sternal recumbency and horizontally in the CT gantry. Symmetric positioning of the patient is critical for acquiring images in which the left and right sides can be compared (Losonsky, 1997).

Commonly, multiple window levels and widths are used for the evaluation of bony and soft tissue structures (Stickle and Hathcock, 1993). All nasal structures can be made clearly visible by manipulation of the grey scale. CT appears to be remarkably accurate in revealing the location and extent of nasal diseases (Codner *et al.*, 1993; Forrest, 1999).

All commonly seen nasal disorders have their typical CT features. The CT features of canine nasal aspergillosis are destruction of the turbinates, cavitating lesions, patchy areas of increased soft-tissue opacity, destruction of the ethmoid bone and a rim of soft tissue in the frontal sinus (Fig. 8) (Burk, 1992a; Codner *et al.*, 1993; Schwartz, 1995; Saunders *et al.*, 2002). The CT features of nasal neoplasm include space-occupying lesions associated with bone destruction (Fig. 9). The extent to which a nasal neoplasm has destroyed the frontal bone and extended into the orbit can be established very accurately (Thrall *et al.*, 1989; Burk, 1992a; Park, 1992; Codner *et al.*, 1993; Schwartz, 1995). The CT features of non-specific rhinitis include non-destructive proces-

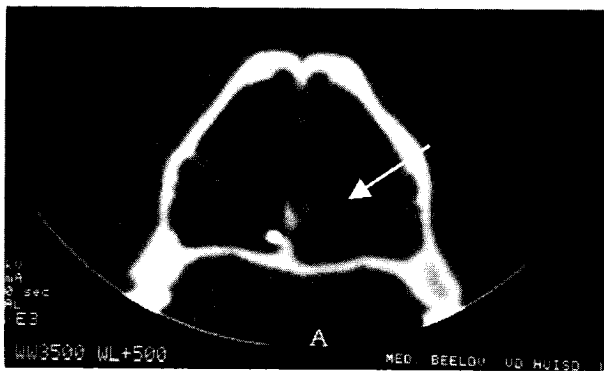


Fig. 8. Transverse image of the nasal cavity illustrating nasal aspergillus. There is a complete turbinate lysis (arrow) and mucosal thickening visible in the nasal cavity.

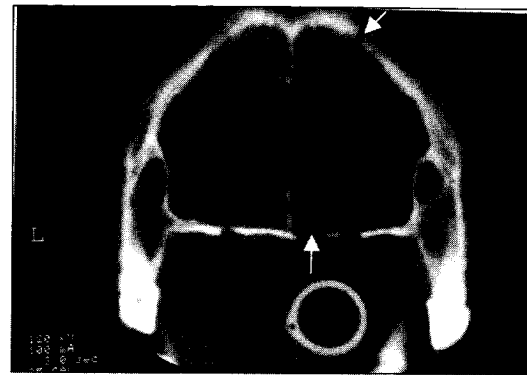


Fig. 9. CT image of the nasal cavity of a dog with nasal neoplasia. A low density mass fills both sides of the nasal cavity. Nasal turbinate destruction and lysis of the nasal septum is present. Note the lytic areas in the maxilla (arrow on top) and a defect in the hard palate (vertical arrow).

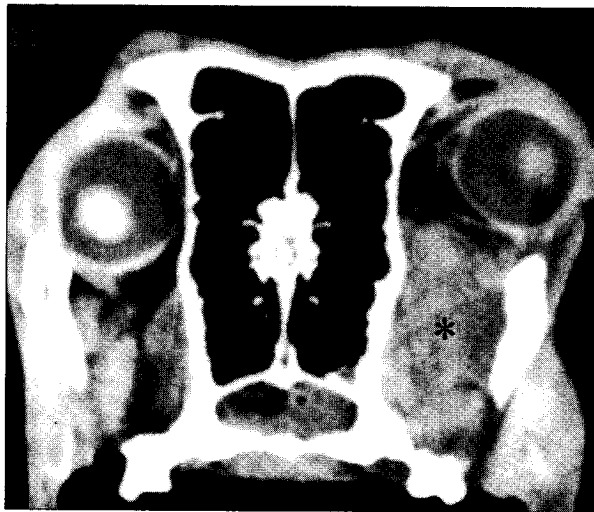


Fig. 10. Transverse CT scan of a dog at the level of the mid-zygomatic arch. A diffuse mass is present in the orbit (asterisk), displacing the globe laterally and rostrally.

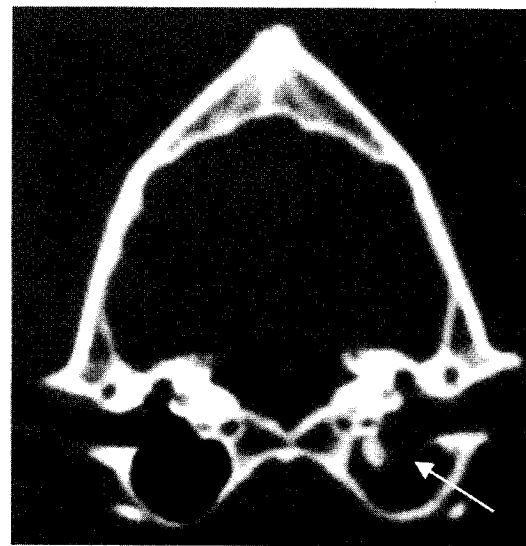
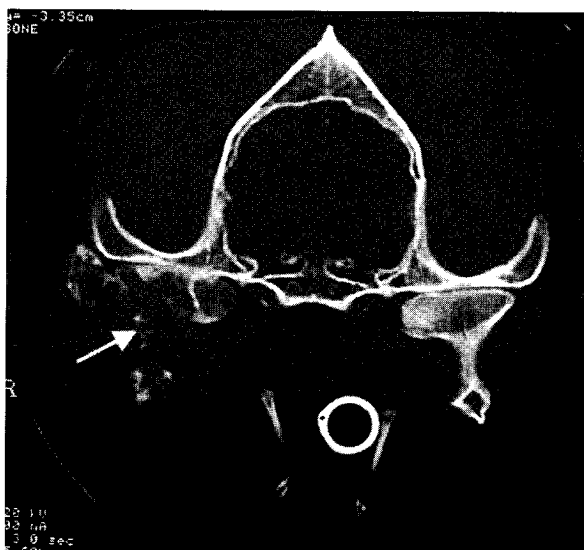


Fig. 12. CT image at the mid-tympanic bulla. The tympanic bulla (white arrow) and ear canal are filled with soft tissue opacity. There is no osseous thickening of the wall of this tympanic bulla. The tympanic bulla on the other side is normal and filled with air.

11a



11b

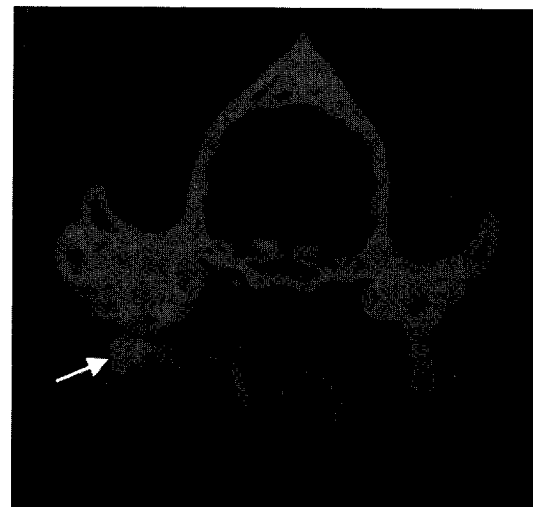


Fig. 11. Pre-contrast (a) and post-contrast (b) transverse CT image of the head of a dog. The pre-contrast image (bone window) displays lysis of the right mandibula (white arrow). On the corresponding post-contrast image (soft tissue window), enhancement of the surrounding soft tissue of the mandibula is clearly visible.

ses that spare the paranasal sinuses and affect most often both nasal cavities (Codner *et al.*, 1993).

CT also provides accurate information on the extension of the process for treatment, surgery planning and radiation therapy of these nasal lesions (McEntee *et al.*, 1991, Codner *et al.*, 1993; Mathews *et al.*, 1996).

Studies are available on the normal nasal cavity and paranasal sinuses in the dog and cat to assist in interpretation of CT images (Burk, 1992b; Losonsky *et al.*, 1997).

Because radiographic examination rarely is conclusive in orbital diseases, CT is increasingly being used for the investigation of orbital lesions and the detection and involvement of retrobulbar masses (Fig. 10) (Feeney *et al.*, 1991b; Calia *et al.*, 1994; LeCouteur *et al.*, 1982). Exophtalmus and soft tissue swelling associated with the orbit or calvarium can be evaluated using CT. Multilobular tumors and their bone involvement in the zygomatic arch and in the rostral and frontal bone can best be visualized on non-contrast CT images using a bone window (Hathcock and Newton, 2000).

CT provides excellent image detail of bony changes and small fractures of the temporomandibular joint in dogs and cats (Schwarz *et al.*, 2002). We noted that the injection of contrast medium in the pathologically affected zone in the area of the mandibula or zygomatic arch is useful as it enhances the borders of non-mineralized soft tissue masses (Fig. 11).

CT imaging allows clear visualization of the base of the skull and tympanic bullae without superimposed structures creating confusion (Hoskinson, 1993; Seitz, 1996) and can be used to accurately diagnose otitis media in dogs and cats in the early stages of the condition (Hoskinson, 1993; Love, 1995; Seitz, 1996; Forrest 1999). CT can detect subtle increases in soft tissue opacities (fluid or mass) in the tympanic bulla and is therefore superior to conventional radiography for detecting middle ear disease (Love *et al.*, 1995) (Fig. 12). One must be aware that on CT images there is an apparent increase in thickness of the tympanic bulla wall when it is filled with fluid. A window of +2000 and a small slice thickness must be used to reduce this volume average artifact (Barthez *et al.*, 1996). CT is also valuable in evaluating the external ear canals, the inner ear, the nasopharyngeal area and the extent of osseous bulla involvement in inflammatory polyps in cats (Seitz, 1996).

Good knowledge of the normal anatomy of the middle and inner ear is mandatory for optimal interpretation of clinical CT images (Russo *et al.*, 2002).

SPINE

For a CT examination of the spine, the patient is positioned in sternal recumbency. The gantry tilt is used so that the scan plane through the primary site of interest is nearly perpendicular to the long axis of the spinal canal. In cats and small dogs, sagittal CT images for visualizing the entire thoracic and lumbar spine can be acquired after positioning the animal in ventral recumbency across the table with the long axis of the spine transverse to the direction of table movement (Kneissl and Schedbauer, 1997). The interpretation of spinal and vertebral CT images is performed both in bone and soft tissue windows (Stickle and Hathcock, 1993).

CT examination of the spinal cord should be performed post-myelography (Drost *et al.*, 1996). CT is useful in the investigation of spinal lesions in the event of doubtful radiographic and/or myelographic findings (Stickle and Hathcock, 1993; Drost *et al.*, 1996). With CT, the localization and extent of spinal lesions can be accurately evaluated, which is of help in surgical planning. The spinal cord, the intervertebral discs and the vertebrae can be visualized. Cord and nerve root compression can also be demonstrated (Dennis, 1996).

Spinal cord compression can be more accurately assessed with CT than with standard radiographs (Stickle and Hathcock, 1993). In spinal arachnoid cysts, CT provides additional information to myelography by improving visualization of the caudal limits of the cyst and eventual lateralization. The degree of spinal cord compression can accurately be measured using CT (Galloway *et al.*, 1999).

For dogs with cervical spondylomyelopathy, CT myelography is an additional diagnostic procedure that provides extra information on the exact location and degree of compression (Sharp *et al.*, 1995). Also for dogs with cervical intervertebral disc protrusion, CT myelography performed pre- and postoperatively has proved to be quite useful in planning the surgical technique and in establishing the prognosis (Hara *et al.*, 1994).

Mineralized intervertebral disc material in the vertebral canal can also be detected using CT without myelography. However, herniated disc material with soft tissue attenuation may not be visible on non-contrast images. The accuracy of CT in diagnosing and localizing herniated disc material compares favorably with myelography (Olby *et al.*, 2000). Also the incidence and extent of acute hemorrhage in the vertebral canal can be identified using CT. In one study,

spinal cord lesions (intradural/extramedullary and intramedullary) were less correctly classified using CT than using myelography (Drost *et al.*, 1996). CT has proved to be superior when bony changes are involved.

Gas in the vertebral canal (the vacuum phenomenon), which is a sign of disc degeneration, can be identified with computed tomography (Hathcock, 1994).

CT can also be of great value in the diagnosis and evaluation of lumbosacral lesions (Feeney *et al.*, 1991c; Jones *et al.*, 1994; Jones *et al.*, 1995; Jones *et al.*, 1996; Feeney *et al.*, 1996; Ramirez and Thrall, 1998). For this examination, the dogs are positioned in dorsal recumbency with the hind limbs entering the gantry first. This positioning allows consistent neutralization of lumbosacral lordosis (Jones *et al.*, 1994; Jones *et al.*, 1995). Bone remodeling, evidence of cauda equina compression, articular process joints, sacroiliac joints and the intervertebral foramina can be evaluated without superimposition (Stickle and Hathcock, 1993; Jones *et al.*, 1995). Structures visible on CT include disc margin bulging, nerve tissue displacement, degenerative articular process joint disease and idiopathic or developmental stenosis (Fig. 13) (Stickle and Hathcock, 1993; Jones *et al.*, 1996; Ramirez and Thrall, 1998). Epidural injection of contrast medium tends to cause uneven accumulations and hinders the interpretation of CT images (Stickle and Hathcock, 1993). When using intravenous contrast, however, the positive predictive value for compressive soft tissues involving the spinal canal was quite high (Jones *et al.*, 1999). The individual L5-S3 nerve roots can be visualized and traced to the point of exit from their respective foramina because of the inherent contrast provided by abundant epidural fat (Jones *et al.*, 1995; Jones *et al.*, 1996). Where there is an increase in soft tissue opacity in the absence of fat, cauda equina compression should be suspected, even if degenerative changes appear mild (Jones *et al.*, 1996). CT findings in older dogs, especially idiopathic stenosis and loss of canal fat, indicate that some lumbosacral abnormalities are clinically insignificant (Jones, 2000).

CT can also be used to define the extent of a lumbosacral plexus nerve sheath tumor in a dog. A soft tissue mass can be identified ventral to the sacrum, following the course of the lumbosacral trunk and sciatic nerve (Fig. 14) (Niles *et al.*, 2001).

CT provides excellent visualization of brachial plexus tumors, but it is difficult to determine the exact origin of the nerve sheath involved. The administration

of contrast medium intravenously helps to differentiate vascular structures (Fig. 15) (McCarthy *et al.*, 1993).

Avulsion of the nerve roots of the brachial plexus, which can be demonstrated using CT myelography, results in an improved prognostic assessment of brachial plexus paralysis (Forterre *et al.*, 1998).

CT anatomic studies of the normal canine spine and lumbosacral region have been described (Jones 1995; Feeney *et al.*, 1991c; Smallwood and George, 1993; Feeney *et al.* 1996).

THORAX

Sternal recumbency is preferable for imaging the thoracic cavity, as it allows more normal positioning of the heart and other mediastinal structures. CT images obtained in ventral recumbency can help to avoid overlooking a mass in the pulmonary parenchyma (Ahlberg *et al.*, 1985). Again, symmetrical positioning of the patient allows better visualization and evaluation of the structures in the thorax. Breathing and cardiac pulsation are the main causes of motion artifacts. These artifacts can be suppressed using single CT slices, short scan times and artificial respiration (Fike *et al.*, 1980).

CT is one of the best imaging modalities for the detection and description of masses, malformations and fluid collections in the thoracic cavity (Burk, 1991; Samii *et al.*, 1998). It can be used to determine the exact size and shape of a mass, the presence of early mass mineralization (indicating neoplastic transformation), and the occurrence of any changes in the surrounding structures (Stickle and Hathcock, 1993). Because of the high tissue-air contrast, lung structures are delineated with a very high degree of detail, especially when window and level are adjusted to lung tissue (-700 HU). Changes of the pleura and changes on the medial aspect of the ribs can also be evaluated (Burk, 1991). Soft tissue evaluation of the mediastinum, body wall and bone is performed using multiple window levels (Stickle and Hathcock, 1993). Thoracic masses can be differentiated from accumulations of mediastinal or pleural fluid (Feeney *et al.*, 1991d; Samii *et al.*, 1998) and can be characterized as areas of calcification, as cavitations or as solid masses (Fike *et al.*, 1980). Through the use of intravenous contrast medium, the vasculature of the mediastinum can be distinguished from structures of similar appearance (Fig. 16) (Stickle and Hathcock, 1993; Marincheck and Young, 1980).

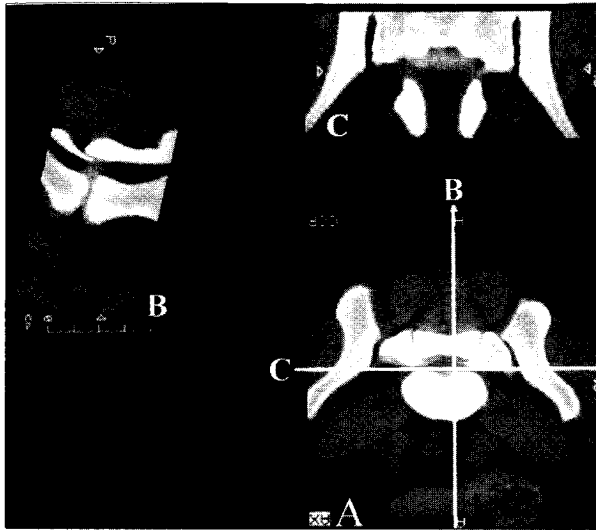


Fig. 13. Transverse CT image (A) through the space between L7 and S1, displayed using a soft tissue window. Note the convex appearance of the dorsal disk margin. At the sagittal (B) and dorsal reconstructed (C) images of the same region, the disc margin bulging (black arrow) can be clearly seen.

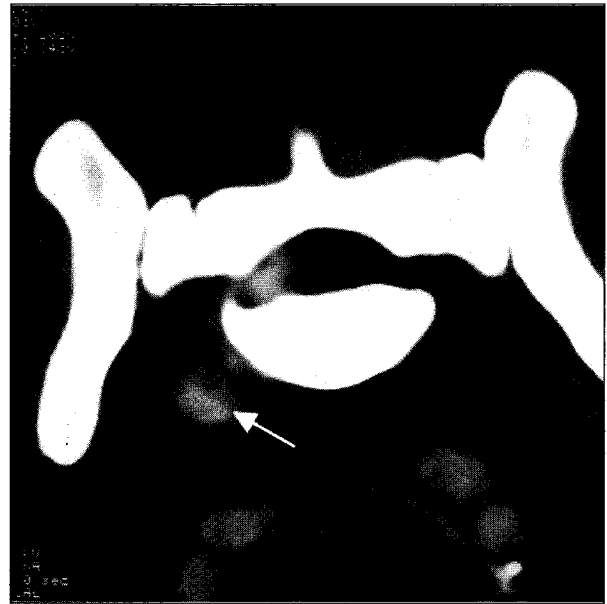


Fig. 14. Post-contrast CT view of the lumbosacral region. The lumbosacral plexus is enhanced and enlarged (arrow). The fact that the tumor follows the course of the sciatic nerve is suggestive of a peripheral nerve sheath tumor.

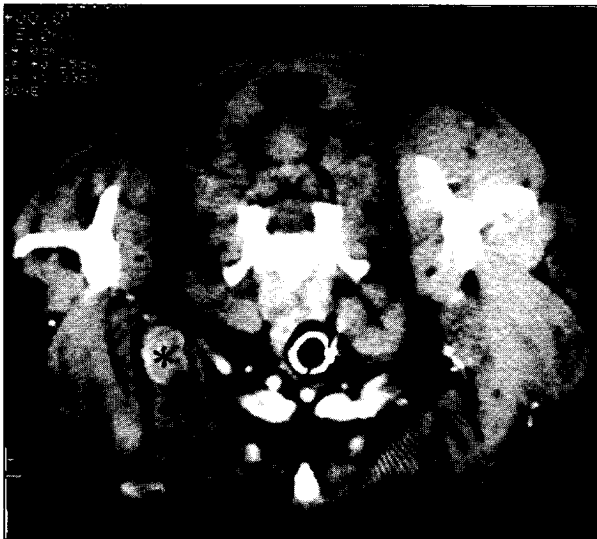


Fig. 15. Transverse CT view through the fourth cervical vertebra after IV administration of contrast medium. Note the subtle contrast enhancement of a 3 cm diameter mass (asterisk) representing a brachial plexus tumor.

Experimentally, CT has been used to identify infarcted areas of the myocardium in dogs (Ter-Pogossian *et al.*, 1976). It also has been shown in a dog model that CT is very sensitive for detecting pericardial effusion (Wong *et al.*, 1982).

CT is considered the most sensitive method for detecting pulmonary metastases (Fig. 17), but there are limitations in the detection capacity. Lesions smaller than 5 mm are often not demonstrated, and micro-metastases, the most common type, are usually overlooked (Waters *et al.*, 1998).

CT enables improved detection of small pulmonary nodules and hilar or mediastinal lymphadenopathy.

Large bullae and cavitated neoplasms can be revealed, but small (less than 3 mm) peripheral bullae are difficult to detect (Burk, 1991).

CT is also used to define the extent and the definition of contours of masses, information which is useful for planning surgery or radiotherapy (Burk, 1991; Smallwood and George, 1993).

Descriptions of normal canine and feline cross-sectional anatomy of the thorax, including correlative CT images, are available (Assheuer and Sager, 1997b; Feeney *et al.*, 1991d; Fike *et al.*, 1980; Samii *et al.*, 1998; Smallwood and George, 1993; Zook *et al.*, 1989).



Fig. 16. CT scan of the thorax after IV administration of contrast. In the cranial mediastinum a large heterogeneous enhanced mass is visible (arrow). Histological examination confirmed a thymoma.

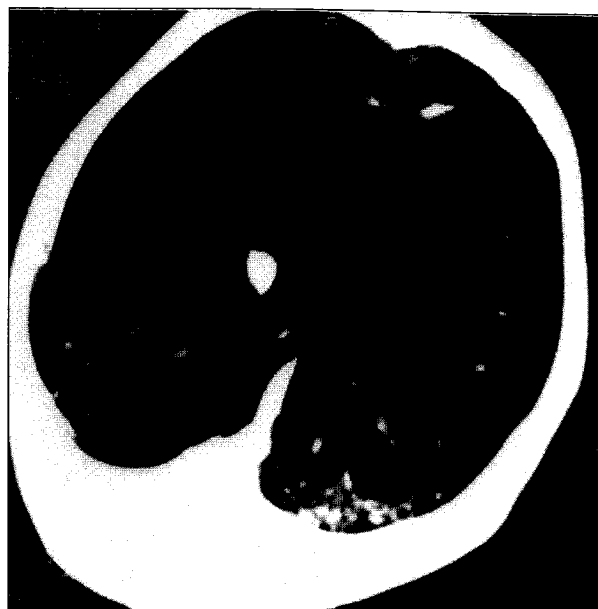


Fig. 17. Computed tomography scanning of the thorax with contrast enhancement. Diffuse nodular densities in the lungs were judged to be metastatic lesions. The primary tumor was localised within the spleen.



Fig. 18. Computed tomography scan of the abdomen at the level of the kidneys after IV administration of contrast medium. A large cyst occupies the dorsal part of the right kidney (asterisk). A large heterogeneous enhanced mass representing a left adrenal gland tumor is visible (white arrow).

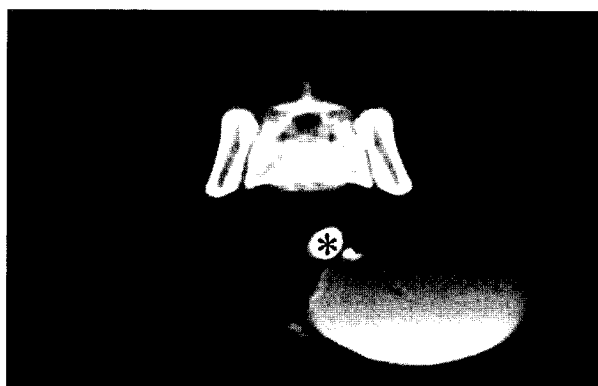


Fig. 19. Post-contrast transverse CT image of the caudal abdomen. A dilated ectopic ureter is seen bypassing the vesicouretral junction (asterisk). The other ureter (black arrow) enters the bladder at its normal location.

ABDOMEN

CT of the abdomen gives excellent anatomic images of the organs and vessels. The relative lack of CT imaging in abdominal disease in animals may be due to the need for anesthesia and artifacts due to respiratory motion. In addition, the availability of ultrasound may have decreased the demand for CT. Abdominal images usually are evaluated using a window level of

40 and a window width of 350 to 500 (Stickle and Hathcock, 1993). CT scans are usually requested for the purpose of better defining the relationship of a known abdominal mass to adjacent vital structures or for evaluating known or suspected lesions involving the spine and pelvic canal.

CT examination is very useful for the early detection of renal carcinomas and for differentiating between

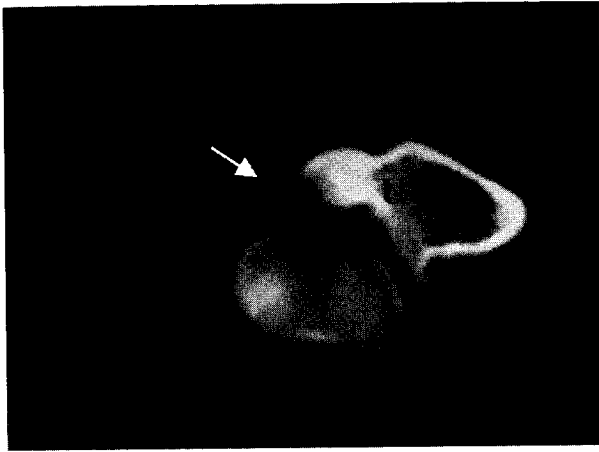


Fig. 20. Transverse image of the elbow (U: ulna, R: radial head) through the area of the medial coronoid process, showing fragmentation of the medial coronoid process (arrow).

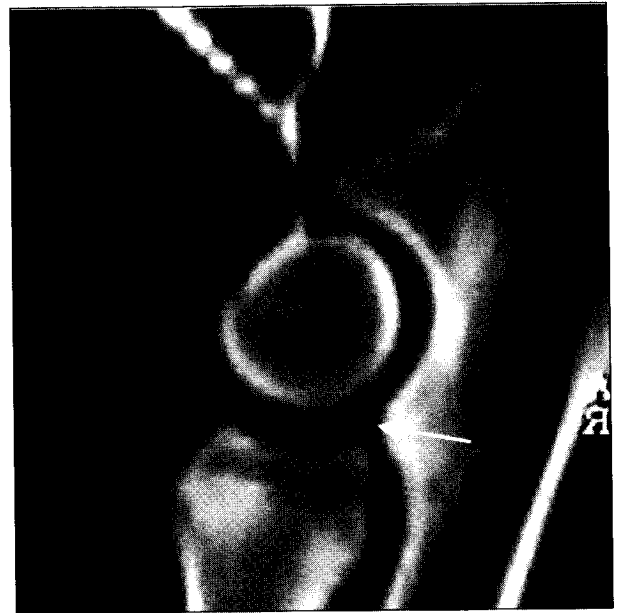
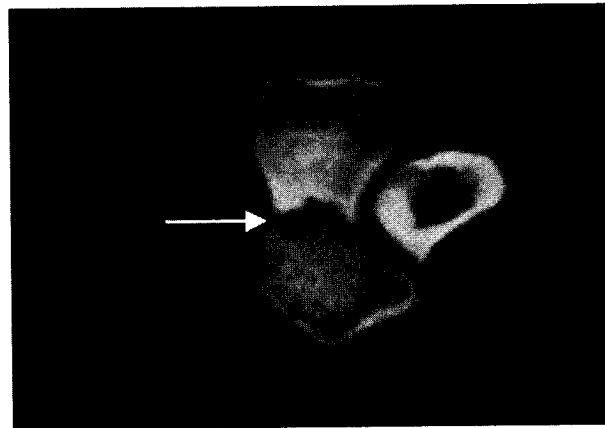


Fig. 21. Sagittal reconstruction of an incongruent elbow. Note the step between the radius and the ulna (arrow), as well as the abnormal shape of the trochlear notch of the ulna in the incongruent joint.

Fig. 22. Transverse CT image through the humeral condyle of a dog. A radiolucent line (arrow) indicates an incomplete ossification of the humeral condyle.

cysts and solid tumors (Fig. 18) (Moe and Lium, 1997). A bolus injection of contrast medium increases the possibility of differentiating a solid vascular renal mass from an avascular cyst (Evill *et al.*, 1988; Moe and Lium, 1997; Yamazoe *et al.*, 1994).

The imaging of adrenal glands and the assessment of size, shape and margination of adrenal masses is another important use of CT (Fig. 18) (Bailey, 1986; Emms *et al.*, 1986; Rosenstein, 2000; Voorhout, 1990; Voorhout *et al.*, 1990). When used to evaluate canine hyperadrenocorticism, this technique provides good differentiation between unilateral adrenal masses and bilateral adrenal gland enlargement (Emms *et al.*, 1986; Voorhout *et al.*, 1988). Fine-needle aspiration of an adrenal mass using CT guidance can be performed in dogs (Rosenstein, 2000).

CT images at maximum expiration allow a detailed view of the normal pancreatic parenchyma, whereas

pancreatic and bile ducts cannot be visualized. The main technical problem in pancreas CT imaging is its demarcation from adjacent organs, especially from liver, spleen, and stomach (Probst and Kneissl, 2001).

Contrast-enhanced CT offers a combination of topographic and functional assessment of the spleen and is an accurate method for diagnosing isolated splenic torsion in a dog (Patsikas *et al.*, 2001).

IV contrast medium may be helpful for diagnosing metastatic liver disease and it may also be of value for distinguishing benign from malignant masses. It has been reported to be useful for the diagnosis of porto-systemic shunt (Kleiter *et al.*, 1999).

Contrast enhancement is needed to differentiate mesenteric masses from normal bowel or vascular structures. The clear visualization of gastric detail, both in the small and in the large intestine, indicates that CT could effectively be used to evaluate gastroin-

testinal pathology (Fike *et al.*, 1980). However, the application of CT to gastrointestinal imaging is limited in the dog. CT has great localizing value, but it cannot assess dynamic activity of the bowel (Feeney *et al.*, 1991a).

Because of high contrast resolution and lack of superposition, CT is valuable for the evaluation of the ureters and the ureterovesicular junction; with IV administration of contrast medium, it also makes it possible to diagnose the presence of ectopic ureter (Fig. 19) (Barthez *et al.*, 1998).

Descriptions of the normal canine and feline cross-sectional anatomy of the abdomen and pelvis are available, with correlative CT images (Assheuer and Sager, 1997c; Feeney *et al.*, 1991a; Fike *et al.*, 1980; Samii *et al.*, 1998; Smallwood and George, 1992; Smallwood and George, 1993).

MUSCULOSKELETAL SYSTEM

CT is widely used to evaluate the musculoskeletal system in human medicine (Dalinka, 1989; Erickson, 1997; Pettersson, 1998; Feldman, 2000). It is often used for the examination of acute and chronic injuries involving the articular surfaces (Newberg, 1990; Pretorius and Fishman, 1995). Nowadays, the technique is increasingly being used by veterinarians for the diagnosis of orthopedic disorders in small animals (Hoskinson and Tucker, 2001; van Bree *et al.*, 2002). Despite the growing availability, reports on its use in small animal orthopedics are still infrequent (Fitch *et al.*, 1997). Skeletal CT may be helpful in clinical cases in which standard radiography is negative or inconclusive and there is a high suspicion of pathology (Hoskinson and Tucker, 2001). Radiographic identification of the cause of lameness localized in the joints of small animals may be difficult, especially considering the complex radiographic anatomy of some joints and the superimposition of the bony structures. CT enables more detailed and specific morphological diagnosis than radiography (Kippenes and Johnston, 1998) and facilitates the examination of complex joint structures like the elbow and tarsus by eliminating superimposed structures (Reichle and Snaps, 1999). Osteolysis, sclerosis and new bone for-

mation can be detected in the very early stages due to the extreme sensitivity of CT for bone and calcified tissue. CT enables the detection of density differences as low as 0.5%, as opposed to the lower limits of approximately 30% that are possible with conventional radiography (Hoskinson and Tucker 2001). Therefore CT is most accurate in evaluating the extent of appendicular osteosarcoma in dogs prior to limb-sparing osteotomy (Davis *et al.*, 2002).

CT has been proved to be superior in the diagnosis of fragmented coronoid process of the elbow joint (Fig. 20) (Carpenter, 1993; van Bree and Van Ryssen, 1994; Reichle *et al.*, 2000). Its use in the diagnosis of elbow incongruity has also been reported (Fig. 21) (Gielen *et al.*, 2001). CT is superior in the diagnosis of incomplete ossification of the humeral condyle (Fig. 22) (Marcellin-Little *et al.*, 1994; Brunberg, 2001; Meyer-Lindenberg *et al.*, 2002).

In the treatment of hip dysplasia, CT can be used to check the status of the dorsal acetabular rim, which is an important criterion when triple pelvic osteotomy (TPO) is being considered (van Bree *et al.*, 2002).

In addition to purely diagnostic imaging, CT has applications in orthopedic research. For example, CT offers the ability to non-invasively quantify the volume, density and angles of long bones (Markel *et al.*, 1990; Fitch *et al.*, 1996; Johnson *et al.*, 2001; Dueland *et al.*, 2001).

Conventional arthrography techniques with negative or positive contrast agents can be used in combination with CT scanning. High-resolution thin-slice arthrogram images produced by CT may demonstrate lesions undetected on standard contrast radiography (Davies and Cassar-Pullicino, 1989; Hoskinson and Tucker, 2001).

The ability to view images in several image planes may help to better delineate fracture orientation and to plan the repair process. It may also reveal articular involvement unrecognised with standard radiographs.

REFERENCES

A complete list of references can be obtained from Ingrid Gielen.