CT imaging in small animals

RAD Magazine, 39, 457, 13-15

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Introduction
In recent years, there has been a rapid increase in the availability of cross-sectional imaging techniques in veterinary medicine. CT is now readily accessible in many veterinary universities and referral institutions and is gaining acceptance for the investigation of many diseases. The last 10 years have seen a significant increase in CT related clinical research and various comparative studies have demonstrated the advantages of this modality compared to the previous cornerstones of veterinary imaging – radiography and ultrasonography.

Currently CT is used mainly at secondary referral centres after radiography and ultrasonography has been performed at veterinary first opinion level. Eventually CT may become a standard first-line choice in imaging just as it is in human medicine. The general public has grown increasingly aware of the availability of cross-sectional diagnostic imaging techniques for companion animals and may trigger raised demands for cross-sectional imaging in veterinary medicine.

The purposes of this article are threefold: To give an overview of the current availability of CT for veterinarians; to present the challenges facing the veterinary profession in delivering CT to their patients; and to review some current clinical applications of veterinary CT.

Current availability of CT in small animals
Fifteen years ago, the only way to obtain a CT examination for a veterinary patient was to contact a human hospital. Motivated veterinary practitioners would deliver their patients under the cover of darkness to a local hospital that had kindly agreed to scan patients after its normal daily list. This situation was not a long-term solution given that most NHS hospitals are not adapted for veterinary patients and are understandably reluctant to mix ‘furry’ species with their human patients.

Dedicated veterinary CT scanners have become more available in recent years and there are now approximately 20 veterinary CT units functioning in the UK. Most of these scanners are installed in universities and referral centres. Unlike human medicine, purely dedicated radiology centres are not common in the veterinary world and CT units are usually integrated in multidisciplinary hospitals. Mobile CT units have also been developed and make frequent visits to veterinary practices all over the UK. These mobile units have greatly contributed to increased access to veterinary CT.

Increased availability of CT in veterinary medicine is largely due to reduced equipment costs. As human hospitals have constantly upgraded their systems, older equipment is passed on to the veterinary market at a discounted rate. Second-hand CT scanners therefore became a popular choice for veterinary clinics wanting to get started with CT at a reasonable cost. The downside of this situation was that the scanners often came via resellers without a service contract and were installed by third party contractors. Since 2009 there has been a move towards buying new scanners and mainstream manufacturers (GE, Toshiba, Philips and Siemens) are beginning to create products targeted towards the veterinary market and with accompanying service contracts that are more in line with veterinary usage.

There continues, however, to be a broad gap between veterinary CT and CT in human medicine. Bridging this gap requires an understanding of the veterinary profession in general, and an appreciation of the difference between CT users in veterinary medicine and human medicine. Contrary to popular belief, the types of CT scanner present in veterinary practices are not veterinary specific. A frequent telephone inquiry at veterinary institutions from our human counterparts is whether a veterinary scanner has a larger bore and can accommodate obese patients. In fact, veterinary CT scanners are mainly identical to human scanners and most have not even had software adaptation or protocol changes.

The race for ever-increasing slice number has not yet started in the veterinary industry and 16-slice CT scanners are currently considered sufficient for most veterinary indications. There are only three 128-slice units in use in veterinary medicine, one in Scandinavia, one in Germany and another in the United States.

Veterinary radiology has been a speciality for a number of years and stems back to the creation of the American College of Veterinary Radiology (ACVR) in 1961 and the European College of Veterinary Diagnostic Imaging (ECVDI) in 1994. These two organisations provide structured residency training programmes, specialist examinations and infrastructure in veterinary radiology and can be likened to the Royal College of Radiologists (RCR). To become a specialist veterinary radiologist, a normal vet must complete a three or four year approved residency programme in an approved centre, designed to provide in-depth training in all aspects of veterinary diagnostic imaging. They must then meet the requirements of the credentials committee of the respective college in order to sit a rigorous three-part examination. As of January 2013, there are approximately 700 members of the ECVDI and ACVR scattered throughout the world and 200 residents in training, the latter mainly in veterinary universities or large referral centers. Despite the fact that reporting of radiologic studies by a veterinary radiologist is not yet mandatory, the current numbers of specialists are insufficient to fulfill the large and increasing demand for radiologic expertise.

The challenge of performing CT in animals
Performing a CT examination in an animal is considerably more challenging than in a human. First, patient compliance and positioning can only be achieved with the help of deep sedation or general anaesthesia in veterinary patients (figure 1). This inevitably complicates set-up and significantly increases the time between scanning successive patients. Various monitoring equipment is required to enable personnel to leave the room during actual scanning.

Correct positioning of the patient is key to optimal image quality and CT scanner tables and positioning aids are not
designed for veterinary patients. Veterinary radiologists are therefore required to show imagination and creativity in adapting to the anatomy of the patient. For example, a common indication for veterinary CT would be scanning the elbows in a young dog for the evaluation of elbow dysplasia. Positioning for this study involves lateral flexion of the head away from the legs to avoid beam hardening and photon starvation artefacts originating from the skull. The patient is positioned in a trough with the legs pulled cranially and the whole arrangement is maintained using a variety of wedges, ropes and sandbags (figure 2).

It is also important to consider control of respiratory motion. Veterinary patients cannot be instructed to ‘hold their breath’ and, hence, a period of gentle hyperventilation is generally employed to induce a period of apnoea under general anaesthesia. Other tricks of the trade include scanning the thorax from caudal to cranial, and the abdomen from cranial to caudal to avoid diaphragmatic motion as the patient begins to breathe again. Many veterinary CT scan protocols are designed to limit the effects of motion and also the inevitable effects of recumbency on pulmonary atelecctasis.

There is great variation in size between the different veterinary species and it is therefore necessary to adapt the scanning protocols accordingly. For instance, all CT units have special protocols with low mAs settings (usually 80mAs or lower) for infants to minimise radiation exposure levels. Despite the fact that most small animals usually are close in size to an infant, these low mAs settings do not always generate high quality images for the head, spine and abdomen in dogs and cats. Some guidelines have therefore been developed to help in the selection process of the CT settings and used to set up specific veterinary CT protocols. Due to the shorter lifespan of our companion animals and the fact that multiple CT scans are unlikely to be performed during the life of a dog or a cat, radiation dose limitation is less of an issue in veterinary medicine.

Image orientation and positioning nomenclature in CT also differ from human medicine. The majority of veterinary CT scans are performed with the patient prone rather than supine, and head first or feet first varies with the type of examination.

**Indications for CT in small animals**

At the time of writing, CT use is mainly confined to the diagnosis of specific conditions, the further investigation of challenging medical/surgical conditions and evaluation of oncologic cases. Evidence-based diagnostic algorithms to facilitate decision making and choice of CT have not yet been developed in veterinary medicine. Therefore, in most cases patients scheduled for a CT have already had radiography or ultrasound as part of the normal workup.

A discussion of all the indications for veterinary CT is beyond the scope of this article, but some typical examinations will be described here as an overview.

CT followed by arthroscopy is the current gold standard for imaging canine elbow dysplasia. Canine elbow dysplasia is a complex condition and encompasses osteochondrosis, medial coronoid disease (figure 2) and joint incongruity. CT is also used in the evaluation of complex fractures, limb and vertebral deformities and various other joint diseases. Multiplanar reconstructions (figure 3) are essential, and 3D printing may become more frequently used in surgical planning.

CT is used commonly for the assessment of sinonasal disease (nasal aspergillosis, nasal adenocarcinomas, rhinitis), ear disease (otitis media, nasopharyngeal polyps, aural neoplasia), facial swellings and masses, migrating foreign bodies (in particular oropharyngeal stick injuries) and oral masses.

Thoracic radiography remains the first tool for the assessment of pulmonary metastatic disease, but CT is increasingly used for pulmonary screening when it is first employed for assessment of a neoplastic mass elsewhere in the patient. Thoracic CT is also used for the evaluation of mediastinal pathology, complex pulmonary disease (including interstitial disease and pulmonary fibrosis), lung lobe torsion and primary lung tumours.

Abdominal CT is often used for the assessment of hepatic, adrenal and pancreatic masses. Lesions are evaluated for their origin and extent; local and distant metastasis and CT is frequently used for surgical planning purposes.

CT is well suited to identifying and following the ureters, particularly in cases of suspected ureteral ectopia. Ectopic ureter is the commonest cause of incontinence of juvenile female dogs; the Golden Retriever breed is predisposed. Ventral recumbency is preferred but with the hind legs raised on a foam block. This serves to prevent contrast pooling near the bladder neck, thus obscuring the ureteral entrances. Pre- and post-contrast scans are then performed to include the kidneys cranially to the tuber ischii caudally. The post-contrast scans are repeated until both ureteral entrances are seen.

Veterinary trauma patients are generally assessed by radiography in the first instance, mainly due to the lack of availability of CT. Studies are currently underway into the benefits of CT as a first line modality in trauma patients, particularly road traffic accident victims.

CT angiography is used relatively frequently at sites where rapid-injection pumps are installed. Some examples include the evaluation of portosystemic shunts, assessment of PTE cases, and dual-phase investigation of various types of neoplasia, such as insulinoma.

Portosystemic shunts are relatively rare vascular anomalies found in dogs and cats (figure 4) and are defined as an anomalous connection between the systemic venous and portal venous system. Commonly, the communication is established between the portal vein or one of its tributaries and the caudal vena cava or azygos vein. In the majority of cases, the abnormal vessel is congenital in origin with intracoronary or hepatic portal types being described. Acquired shunts due to portal hypertension or hepatic cirrhosis are very rare in small animals. Should such a condition arise, however, then multiple shunting vessels within the peritoneal cavity are a much more common sequel than oesophageal varices. The latter are extremely rare in veterinary species. CT is the diagnostic tool of choice and is also used for treatment planning, such as surgical ligation, attenuation or coil embolisation.

**Conclusion**

Though the use of CT in veterinary medicine is underdeveloped compared to human medicine, CT is currently a hot topic in veterinary discussion forums and demand has rocketed in recent years. Manufacturers are beginning to understand the global market potential of veterinary CT products and to target their services accordingly. It is possible that every practising vet will want access to CT in the near future.

CT is currently finding its place in the diagnostic workup of various veterinary conditions and the next five years will bring more research, comparative studies and trials to further justify appropriate use of this powerful tool. It is expected that the inherent advantages of veterinary CT will make it a standard first-line choice in the investigation of specific conditions, just as it is in human medicine.

**References**

1. European College of Veterinary Diagnostic Imaging. www.ecvdi.org
2. American College of Veterinary Radiology. www.acvr.org
Figure 1
CT scan of a three-year-old male lynx presented for ataxia. Note that the patient must be anaesthetised for this type of examination, as veterinary patients cannot be instructed to hold their breath.

Figure 2
Elbow CT in a dog. (A) Positioning involves lateral flexion of the head away from the legs to avoid beam hardening and photon starvation artefacts (Picture courtesy of Tobias Schwarz). (B) There is fragmentation of the medial coronoid process (arrow) of the ulna (U), a very common pathologic entity in dogs, part of the canine elbow dysplasia complex.

Figure 3
3D volume rendered image of the skull of a normal cat. 3D reconstructions are increasingly used to teach normal anatomy to veterinary undergraduates.

Figure 4
CT angiography sagittal plane MIP, portal phase in a dog. There is a tortuous blood vessel extending from the portal vein (P) in a dorsal direction, joining the azygos vein ventral to the thoracic vertebrae. Diagnosis: porto-azygos shunt (sh). (Ao) Aorta, (CVC) caudal vena cava, (P) portal vein.

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