A Basic Overview of Veterinary Computed Tomography

Linda M. Kinney BS, CVT, LATG

**What is the definition of CT?**

Computed tomography is an important diagnostic imaging modality in radiology that combines x-rays with computers to produce highly detailed cross-sectional images of the body. Computer analysis of these x-rays permits detailed images of body organs and pathologic conditions that can occur. It can be used to determine the extent of trauma, location of tumors, the status of blood vessels, and pre-surgical planning.
CT Scanner
This open gantry contains some of the most important components of the scanner including the detector array, x-ray tube, data acquisition system, slip rings, and other components.

Detectors          X-ray tube                      Closed gantry cover

The picture included above, happens to be a Toshiba Aquilion CT. There are other CT scanners made by GE, Picker, and Siemens.

The black bar on the floor in front of the gantry is for attaching a large animal table, used for scanning horses. The monitor on the upper right is for fluoroscopy which is included on some systems.

The Table or Couch

View looking at gantry with RT top          View with RT top and white pad

Below left, from the back of the scanner, the RT (Radiation Therapy) top is off and the white foam pad that comes with the scanner is in place on the concave couch. The
concave surface may not be suitable for scanning animals. On the right, RT top is on for comparison.

Side view of couch with assorted wedge foam positioners. Velcro straps and flat RT top with white pad. The couch was modified, to allow Velcro straps to be attached for the different anatomical sizes of animals.

Below is an assortment of Velcro straps, which are made from washable material, to secure a variety of animals to the couch in various positions.
We also use RT cushion positioners for all head scans, using suction to make it form to the head for straightness.

A small cushion is displayed

Cat on a RT cushion under anesthesia

(Courtesy to CIVCO Radiotherapy VAC-LOK™ Cushion)

Patients come from all areas of the hospital in a referral facility:

1. anesthesia – from induction, already induced or pre-meded, due to difficult intubation or oral exams
2. wards- small, large, exotic, wildlife – some walk over and get induced or sedated in the CT room
3. ER/ICU – critical trauma, transported with rolling gurneys, lift gurneys, and soft-sided stretchers.

Other equipment needed in the CT room for the anesthesia technologist and the anesthesiologist:

1. IV pole and fluids
2. blood pressure cuffs
3. infusion pumps
4. anesthesia monitor –which displays waveforms for ECG, Resp, SP02, C02, temp, and a pulse oximeter
5. convective air warming blankets or warming pads

Keeping patients warm is always a challenge. Electric pads have a risk of overheating and circulating water pads are easily damaged. The convective warm air blankets are a safe, economical solution to this problem. They are made of a silky polyester fabric with an inlay of nylon, waterproof material to keep airflow circulating toward the patient. These blankets are machine washable and there is a 5” diameter round opening with a nylon cord to secure the blanket to the warm air convection units.
Below is an example.

Cat on table, head towards gantry opening, with Baja convection air warming blanket.

The X-Ray Tube

CT scanners have x-ray tubes that have to be warmed up like conventional x-ray tubes. Warm up of the tube is very important, since it has high heat loading and heat dissipating capacities. It is normally done first thing in the morning when the scanner is turned on or before a patient, if there has been a long delay between patients. The x-ray beam is collimated in two places (at the x-ray tube and at each detector) and is the sole means of reducing scatter radiation and regulating slice thickness. The x-ray tube and the detectors may rotate together around the patient and a fan beam is directed into a localized section of the patient. The advantage of the fan beam/multiple detector array is speed of scanning.

While warming up, no one should be in the room, the x-ray tube is exposing and producing radiation.
Detector Array

A detector measures the transmitted photons from each x-ray or projection that completely passes through the patient. The value is known as the CT number or Hounsfield unit (HU). The detector doesn’t form the image, it merely adds up the energy of the transmitted photons and converts them into tiny electrical signals which pass through an amplifier to increase their strength. Then the signals go to a sample and hold component and get digitized by the analog/digital converter. It can be quite obvious when there are problems with the detectors.

Operator Console

CT units have computer interfaces that are menu-driven and user friendly. When requesting a CT, it is important to supply a good clinical history of the animal because it allows the operator to select the appropriate protocol to acquire the diagnostic study. The acquisition monitor (right) allows for protocol creation, protocol selection, selection of specific parameters (kVp, Ma, rotation time, algorithms, filters) and transferring of studies to the display monitor (left). The image display / reprocessing monitor, displays the images being scanned, allows for changes in window / gray scale to be applied, application of different filters, measurements to be taken, reconstruction of raw data, 3D reconstructions, multi-planar reconstructions (MPR’s), and archiving/transferring of patient studies to a digital storage computer system (PACS).
Toshiba Aquilion Console

**Quality Assurance**

After the x-ray tube is warmed up, a QA procedure is performed daily, weekly, or during a preventive maintenance visit by a service representative. It is a procedure of performing specified tests and measurements on a periodic basis in order to assure that a level of quality, as specified by the system manufacturer, has not been compromised.

The typical daily QA is done with a water phantom where ROI’s are placed on the different density knobs in the image and the measurement is recorded. This QA checks the CT number or Hounsfield unit which must stay consistent from day to day, because it reflects the different anatomical tissues, fluids, or air. The manufacturer will give the operator a range that the data must fall inside. If the values fall outside this data, a service representative must be called.

**Depending on the CT scanner, QA tests that can be performed:**

1. Linearity of the gray scale of the CT image, relates to the actual density of the tissue measured
2. Table accuracy
3. Slice thickness accuracy
4. Measurements of spatial resolution
5. Consistency of CT numbers across the image
6. Radiation scatter and leakage
7. Contrast resolution
8. Fidelity of the video monitor

QA water phantom with density knobs on positional holder attached to the CT couch.

By looking at your QA, you are able to recognize when there are problems with the electronic parts of the scanner and to place a call for service. Service will image other water phantoms to determine the problem. Anesthesia, clinicians, and the radiologist must be informed that the system is down.

Acquisition Monitor

Normal QA Image
Hounsfield Density Scale

In CT, depending on the radiation of the scanning device, the density values of different tissue types and their relationship to water, a fixed point of zero, are represented on the scale with their associated CT number (HU). They are used as measurable guidelines as to tissue type. A basic scale is displayed below.
Windowing

Windowing refers to a method by which a CT image gray scale can be manipulated using the CT number (HU) of the image. The operator (viewer) can alter these numbers to provide optimum demonstration of the different structures. Through the manipulation of the CT numbers of the various tissues, the image can be changed to show soft tissue (muscle, organs) and dense structures (bone).

The HU scale extends from +3,000 to –1,000, which is the range for most tissues in the body. However, the monitor only displays 256 shades of gray and the human eye can only distinguish approximately 30 shades of gray. Windowing allows one to focus on the tissues of interest by spreading those 30 shades of gray over a selected range.

**HIGHER CT NUMBERS** are assigned lighter shades of gray. (Bone is white).

**LOWER CT NUMBERS** are assigned darker shades of gray (Soft tissue is gray).

The image contrast is easily changed with two control mechanisms: the window width (WW) and the window level (WL).

**Width** - The window width (WW) is the absorption measurement range and it determines the maximum number of shades of gray displayed on the monitor. Within the range, the CT numbers are equally distributed from black to white. A wide range of tissues on the image, but less displayed contrast between tissues of similar density.

**Level** - The window level (WL) is the center midpoint of the range of CT numbers and can be positioned anywhere on the (WW), usually it is set equal to the CT number of the tissue of interest.
WL 40   set for soft tissue
WL 300   set for bone
WL -600   set for lung
WW 150   Narrow,  
WW 1,500  Wide,  
WW 1,600 Wide,  
increases contrast of tissues  
decreases contrast in tissues  
decreases contrast in tissues  
with similar densities  
with similar densities  
with similar densities

Scan Types

There are several different types of scans.

Axial scanning – this refers to “take an image-move the couch-take another image” type of scanning. You use this type of scan to take a single slice for a biopsy, straightness for a RT treatment scan, to set an ROI on a special study (like a portosystemic scan), or for needle placement for a myelogram. Reconstructions speeds on single slice scanners for a whole study are considerably slower.

Helical or spiral – this is the most common scan performed now because it is faster.
You start the scan, the table moves in the z-axis for the entire plan, then stops. It covers anatomical areas in seconds. Reconstructed images are processed from the data collected, which can take a while, depending on the thickness of the slices and the processors on the machine, ie: 16 or 64.

Dynamic – this scan is usually done with sequential scans at only one location or multiple locations without reconstructions. The data collected is processed later. Often used with contrast injection for timed protocols, like pulmonary angiograms.

**Set up for scanning a Patient**

The animal is placed on the couch and Velcro straps and foam wedges assist in securing the animal on the table, as well as, keeping the animals body straight. A RT cushion may be used to straighten the head. EKG leads and IV lines are placed away from the scan area and the anesthesia machine is placed on the same side as the head.

**Please see the following guides for specific setup of anatomical areas for typical scans on dogs and cats:**

- CT Scan for Dog, Cat, or Exotic Head
- CT Thorax
- CT Head Thorax
- CT Abdomen
- CT Thorax Abdomen
- CT TL Spine
- CT Dog Elbows
- CT Orthopedic Scan for Hind Limbs

The patient table is inserted through the opening in the gantry. The CT table may have a weight limit of 450 lbs., referral centers also have large animal tables that will support
2,000 lbs. General anesthesia or sedation is necessary for complete immobilization of the patient, because patient motion will cause severe image degradation.

Considerations for CT are largely based on economics and availability. X-ray factors are selected relative to the body region and the tissue being imaged. Images are usually acquired pre- and post-contrast. The label, is displayed on the left of the images, reflecting the right of the patient on transverse and dorsal/sagittal images. The contrast is used to enhance various parts of the body under exam for vascular abnormalities, masses, and inflammation. The contrast injected is Iohexol 300mg/ml given at 2cc/kg. through an indwelling catheter, most often in a front leg, but a hind leg can also be used. If hand injecting, the contrast should be given slowly to watch for any changes in the patient because it can sometimes cause an allergic reaction and the injection should be immediately stopped. An injector is used for special studies, such as, pulmonary angiograms and portosystemic shunts, because these are timed studies with multiple series, acquired in secession.

**Scan**

The **Localizer Radiograph** is acquired at the beginning of a CT study with a stationary x-ray tube and detector array where the patient table moves continuously. The length of anatomical coverage is dependent upon the speed of the patient table and the amount the x-ray tube is on which is set by the operator. The image is used to determine the scan location. Only a single projection is used. The position of the tube to the patient determines the orientation of the localizer image, DV/VD or Lateral. The localizer radiograph produces an image similar to a conventional high detail x-ray from a relatively large field of view.

Take a look at the localizer radiograph because an abnormal image may indicate where a lesion or mass may be located and the need to extend your plan for scanning, as well
as, watching this area for asymmetrical anatomical changes on the transverse slices. The localizer radiograph is the image displaying the prescribed slices in a CT study, allowing us to align the cross-sectional slices with specific anatomical structures. Each line on this plan represents a slice or transverse image in the study in a numerical order.

Normal Dog Localizer Radiographs

Digital images are numerical representations of an object that can be recognized by a computer. These images can be displayed on the monitor, previously printed on film, or archived to permanent digital storage system (PACS) for interpretation. Multi-planar reconstructed images (MPR’s) are volume images displayed in the dorsal, sagittal, and oblique planes of the body. Interpretation requires an appreciation of how the anatomy appears in each of these planes.
Imaging planes, terminology, and the appearance of the brain of a human being and a dog in each plane. The sagittal plane transects the subject into the left and right portions. The trans-axial (human) or transverse (dog) plane is perpendicular to the plane of the CT table and transects the subject into superior/cranial and inferior/caudal portions. The coronal (human) or dorsal (dog) plane transects the subject into anterior/ventral and posterior/dorsal portions. Because the brain of a human being is situated within the skull perpendicular to the long axis of the body, compared with that of the dog, whose brain is aligned with the axis, the corresponding views appear to be opposite. That is, the trans-axial image of the human brain appears more like the dorsal
image of the dog; likewise, the coronal image of the human is more like the transverse image of the dog.

**Tomographic Imaging**

Understanding a transverse slice in CT

Dog laying on its back, VD

Pelvis

Shoulders

CT planning image showing location of a transverse slice

Bread images courtesy of Dr. Amy S. Tidwell

Transverse image of a dog's spine

**Image Artifacts**

Artifacts can degrade image quality, affect the perceptibility of details, or even lead to a miss diagnosis. An artifact is a distortion or error in an image which can make it unreadable. CT artifacts can arise from a number of sources, either from patient positioning (limbs not included in the calibrated field (CFOV)) or equipment used in or outside the field of view (FOV).
**EDGE GRADIENT and BEAM HARDENING** – These two artifacts often occur together. Edge gradient appears as dark streaks or multiple dark streaks, which emanate from structures that have sharp edges and great density differences from neighboring tissues. Beam hardening results due to the selective attenuation of photons of lower energy and only high energy photons are left to contribute to the beam and thus the beam energy is increased or “hardened”. May be seen at the interface of soft tissue and bone, air and contrast media. The attenuation is inconsistent, causing an uncertainty in the CT numbers assigned during the image reconstruction.

Dog frontal sinus, vertical ramus

![Image of a dog frontal sinus and vertical ramus](image1)

Equine teeth, paranasal cyst

![Image of equine teeth and paranasal cyst](image2)

**PARIAL VOLUME** – results from the mathematical averaging of various attenuation coefficients from several mm’s of different tissue types. High / low tissue densities get averaged together as a single shade of gray in the image, especially with thick slices in a region. Blurring of the object, where the object curves out of the slice plane, falsely gives the impression of pathology in which vague opacities are the result of a slice through the top or bottom of a rounded structure. Causes: lung, liver, kidney, and heart.
**MOTION**- Patient motion (voluntary) has devastating effects on image quality. The reconstruction program has no ability to make appropriate corrections because motion is random and unpredictable. The image can have the appearance of streak artifacts, blurring of the tissue, and ghosting (double edge). The results are inaccurate CT numbers through the tissues displayed. Causes: breathing and heart beating (involuntary), light anesthesia, and a moving patient.

**METAL**- Metal is a very dense material that x-rays cannot penetrate and areas around the metal can be unreadable. Streaks emanating from the metal object is caused by a combination of beam hardening, edge gradient, partial volume, and motion. Causes:
surgical clips, staples, microchips, prosthesis, fiducial markers, EKG & pulse oximeter clips, pacemakers, plates and screws, and foreign bodies.

Wire in dog head  Pulse oximeter clip  Prosthesis in dog pelvis VD

OUT OF FIELD ARTIFACTS – dependent on the field of view or size of the calibrated field. Occurs because the anatomy outside the scan field of view contributes toward the attenuation and hardening of the x-ray beam. Result is inaccurate CT numbers of the tissues in the reconstructed images. Presented on the image as streaks and shading. Causes: Limbs and heads, EKG leads, and needles into IV lines.

Head out of field  EKG lead out of field  Pacemaker – out of field

RING ARTIFACTS – common with third generation scanners, usually the result of a mis-calibrated or defective detector element of detector row or scanner based artifact.
Appears as a black ring or multiple black concentric rings on the image.

Endotracheal tubes with dense barium stripes causing rings  

![Image of endotracheal tubes with dense barium stripes causing rings]

Tube arc with ring

![Image of tube arc with ring]

**NOISE** - Photon Starvation – results in random dark and light streaks that appear, all in a horizontal direction of the greatest attenuation, usually seen through shoulders or hip anatomy. It is due to a low Kvp for the area and not enough penetration or routine use of thin slices where insufficient photons are reaching the detectors.

When the image is reconstructed, the noise is magnified, resulting in the streaks.

![Image of NOISE - Photon Starvation]

**Acknowledgements**

Toshiba Aquilion 16 slice CT Scanner- Cannon Medical Systems, USA Inc., 2441 Michelle Dr., Tustin, Ca. 92780

RT Radiotherapy cushions- CIVCO Global Sales and Operations, 1401 8th Street SE, Orange City, Iowa 51041
Tidwell DVM, Dr. Amy S., “Updates in CT and MRI, Part 1”, CLINICAL TECHNIQUES IN SMALL ANIMAL PRACTICE Vol 14, Number 2, W.B. Saunders Co., (May 1999) Fig2, P66.

Baja Convective Air Blankets – Animal Hospital Supply, Inc., 4142 Industry Way, Flowery Branch, Ga. 30542

Advanced Locking Plate System - Kyon Veterinary Surgical Products, 156 Porter St. Unit 249, Boston, Ma. 02128