COMPUTED TOMOGRAPHY

Andrea De Bonis

DVM, MRVSC, MSc, PhD student, Resident ECVDI

Summary

1. History
2. Computed tomography physic and artefacts
3. CT Protocols
4. Cross section Anatomy
5. Pathological cases

1. History

History

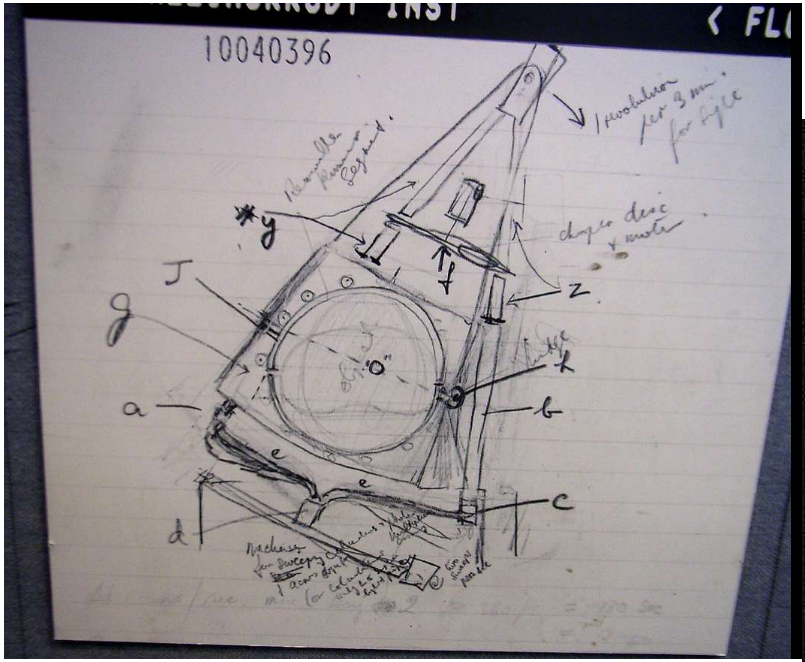
Sir Godfrey Hounsfield (UK)

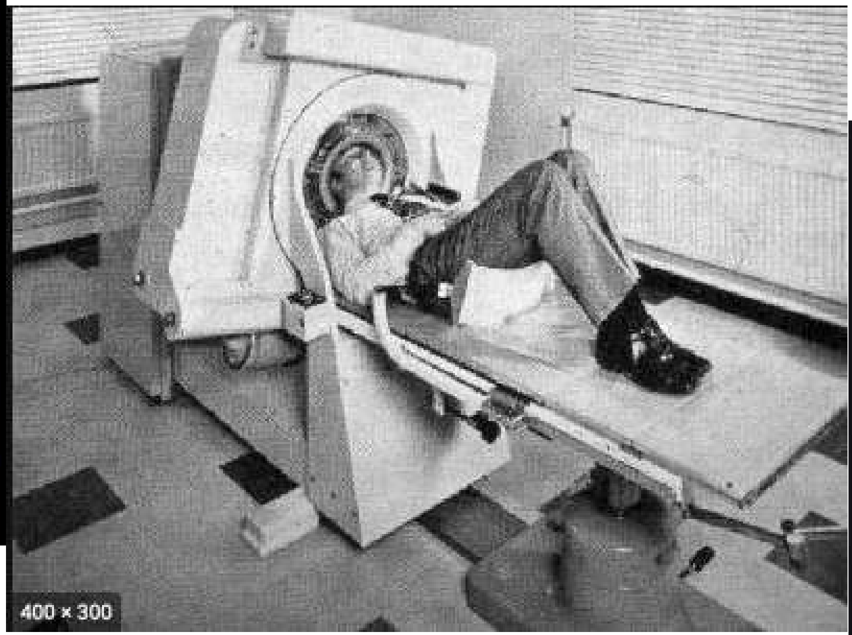
Shared Nobel Prize in Medicine in 1979

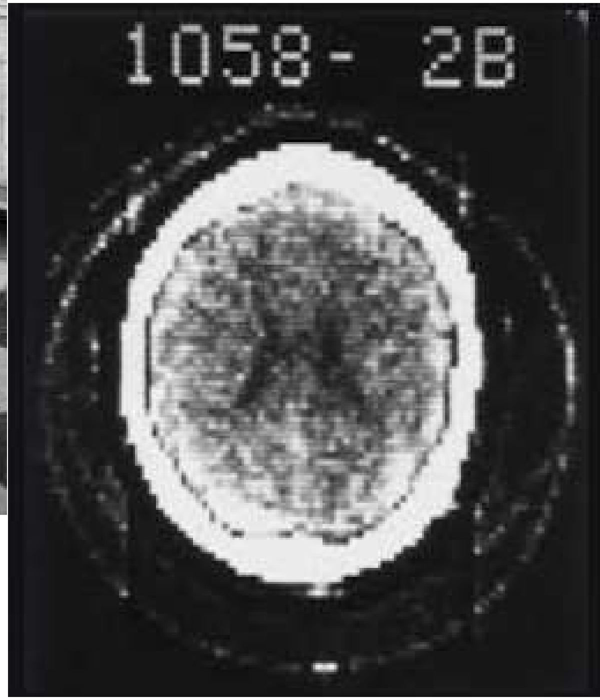
Allan McLeod Cormack (South African American)

Google

History







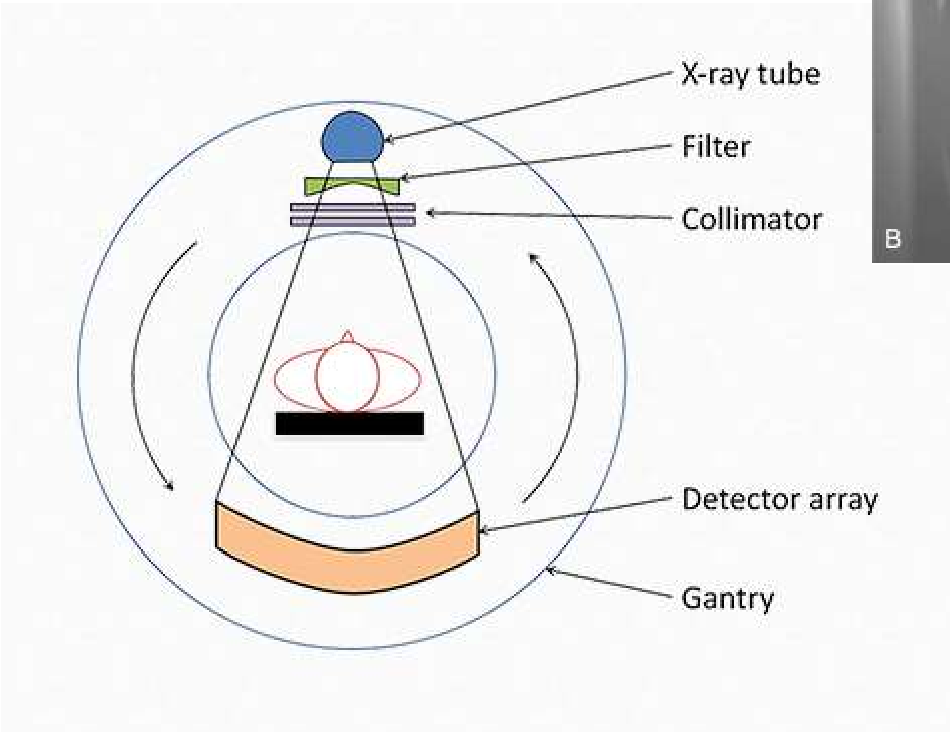
EMI MUSIC ad Abbey Road (Londra)

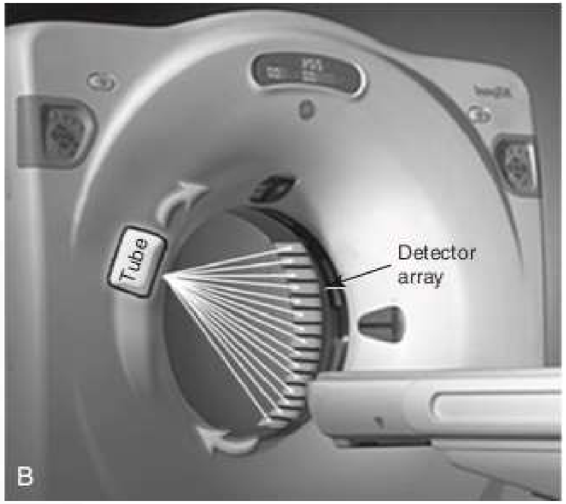
2. Physics and artefacts

Computed tomography physics

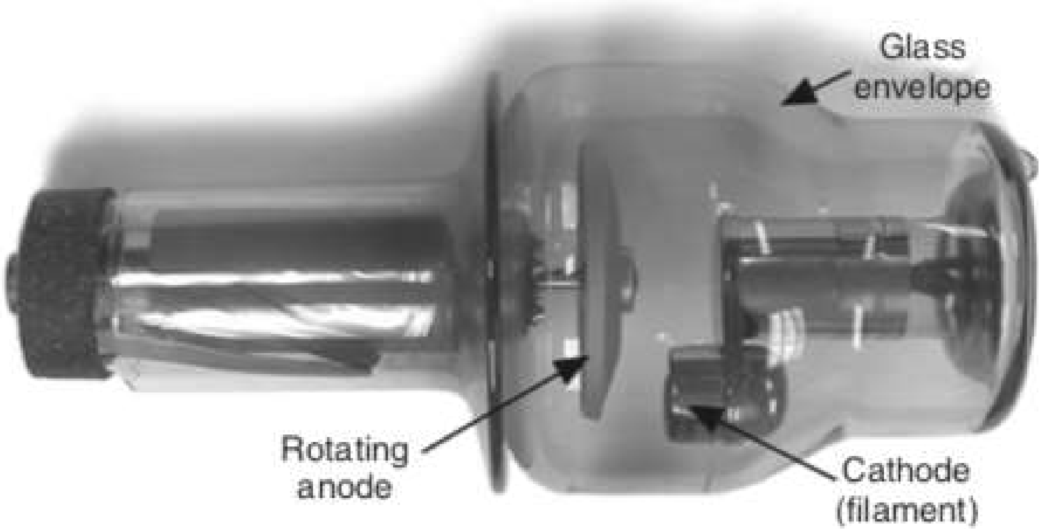
CT unit anatomy

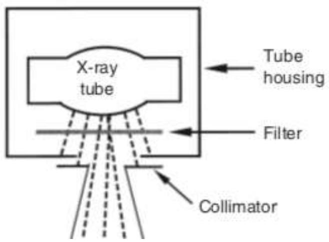
1. Gantry
   - 1.1 X-ray tube.
   - 1.2 Filter.
   - 1.3 Collimator.
   - 1.4 Detector array.
2. Patient bed
3. Work station





X-ray Tube

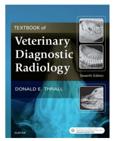




1. Electric current (mA) heat the cathode(-)/filament –> electrons are produced.
2. Those electrons are accelerated to the metallic target (anode(+) by applying a voltage differential (kV).
3. About 1% of this energy is converted into X-rays.

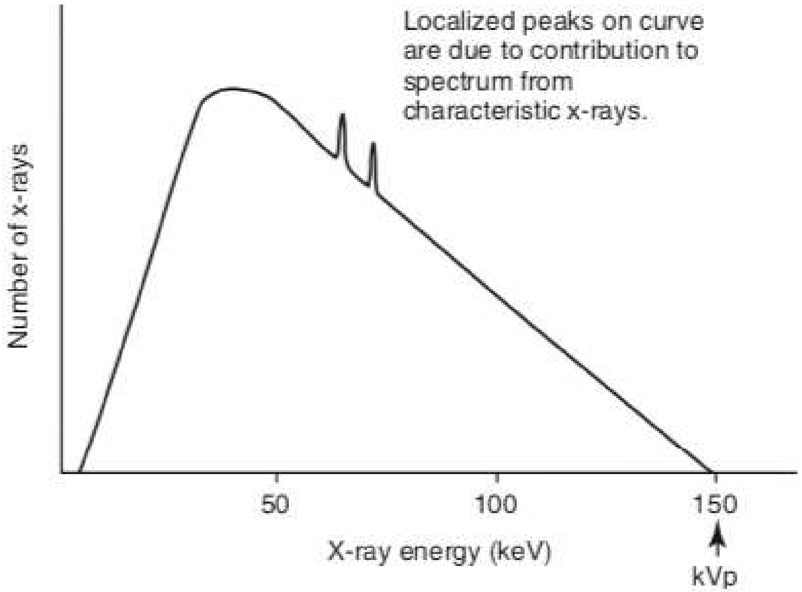
kV Energy of the x-rays

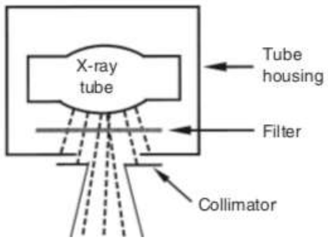
mA Number of x-rays produced



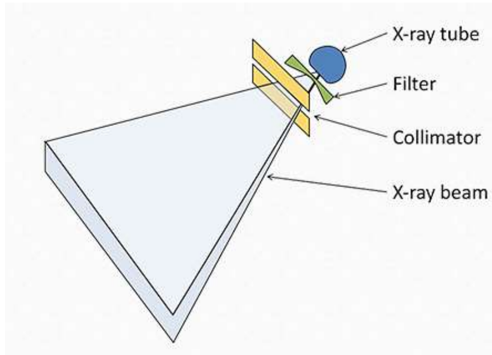
Filter and collimator

A wide spectrum of x-ray energies

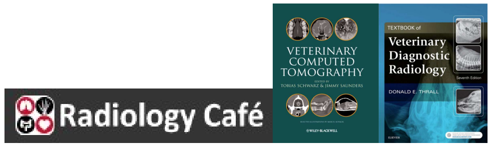




1. The filter remove low energy x-rays that don’t contribute to imagen formation but increase patient dose and scatter.

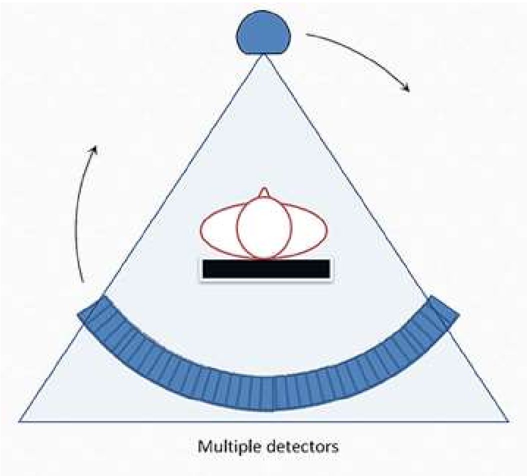


2. The collimator shapes the x-ray fan beam (slide width), lowers radiation dose, restricts scatter.



Detector

3rd Generation CT

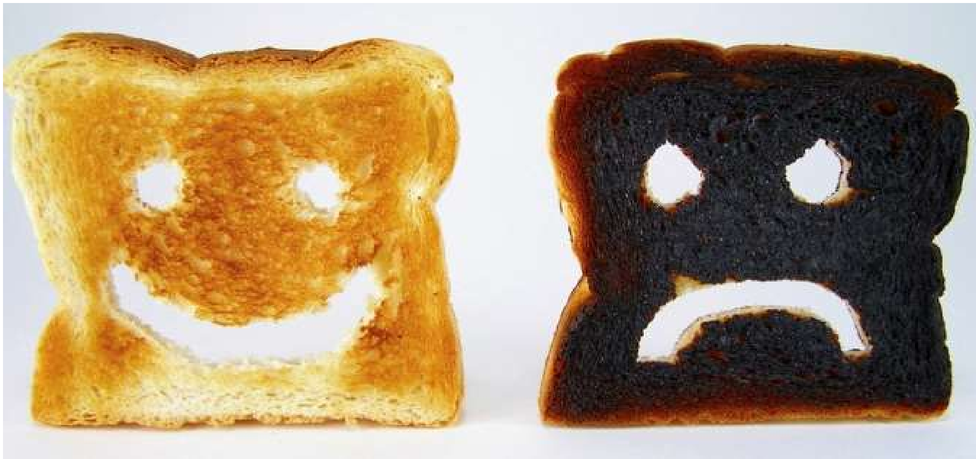


1. The x-ray tube and the detectors rotate together within the gantry.
2. The x-ray pass through the patient, hits the detector and produces different shades of grey depending the tissue.

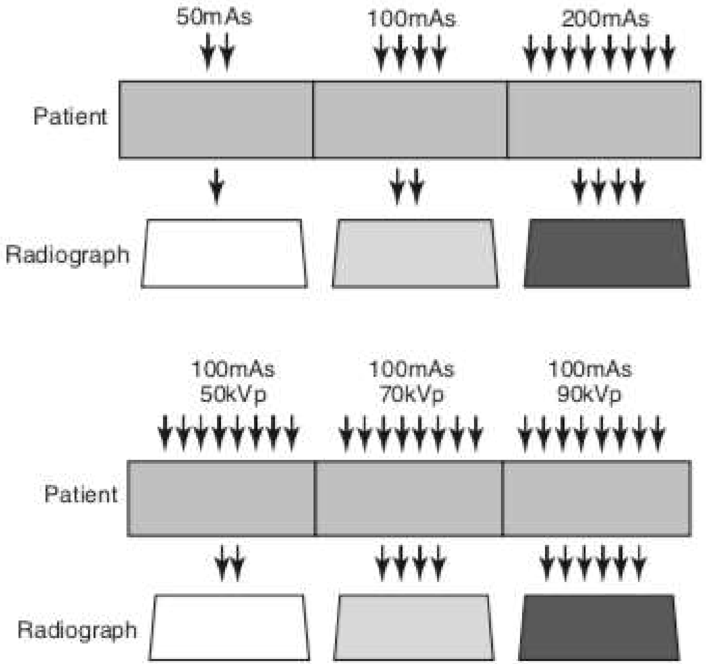
Interaction of radiation with matter - Image formation

- Same principle as radiography:

X-ray hit the patient then part of it gets absorbed then hits the detector and produces a shade of grey.



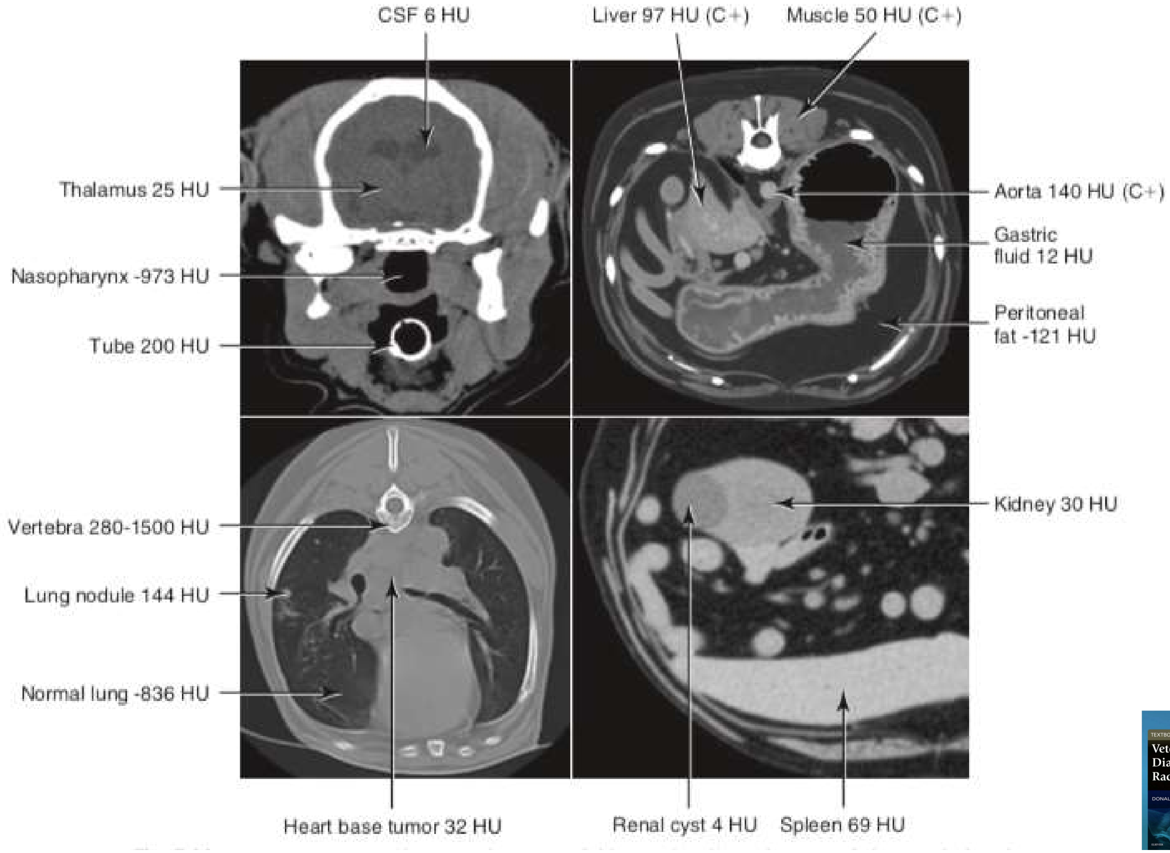
Kindness Blog



Hounsfield Units (HU)

CT numbers for various Tissues in Hounsfield units (HU)

Air	- 1000
Lung	- 830 to – 200
Fat	-30 to –250
Water	0
Heart	10 to 60
Brain	20 to 40
Blood	20 to 80
Liver	20 to 80
Muscle	35 to 50
Spleen	40 to 60
Bone	150 to 500
Bone (dense)	350 to 1000
Metal	>2000



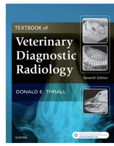
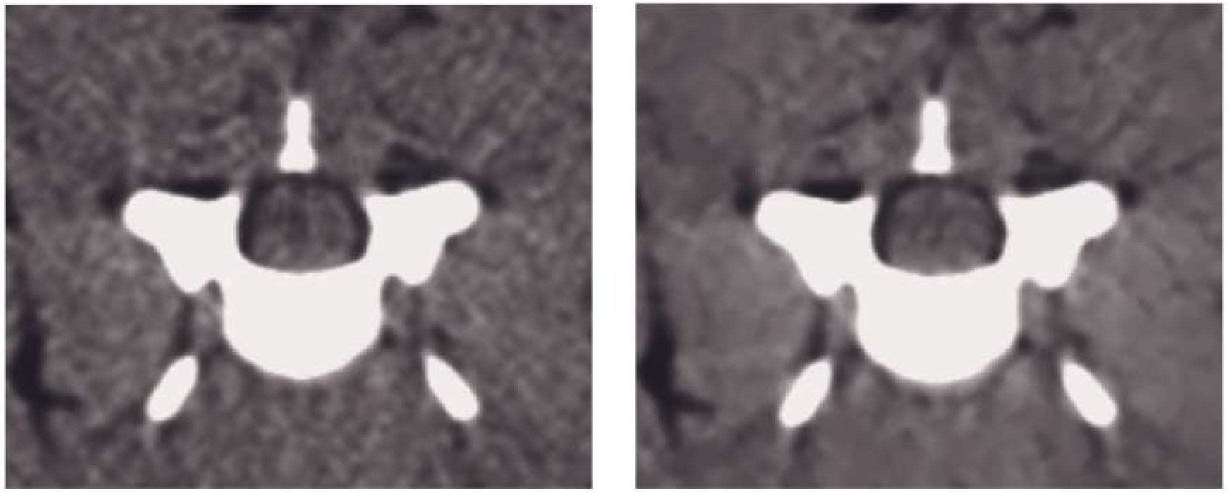


Image parameter selection –
What can we do to optimize our images?

- 1. Tube rotation time: short for body parts with movement, increase rotation decrease aliasing artefact and improve image quality. Usually between 0.5-2s.
- 2. mAs: There is an inverse proportional relationship between mAs and image noise. Thus higher mAs settings will reduce noise. Small slice thickness increases image noise. Therefore if a small slice thickness is selected (2 mm or less) the mAs should be increased to keep the noise at an acceptable level.

↑ mA ↑ Number of x-rays produced



A B

Figure 2.1 CT images of a canine cervical spine acquired with (A) 100 mAs and (B) 200 mAs, and otherwise identical settings. The image noise is represented by the general graininess of the image, which is reduced in (B).

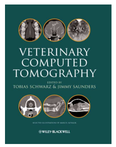
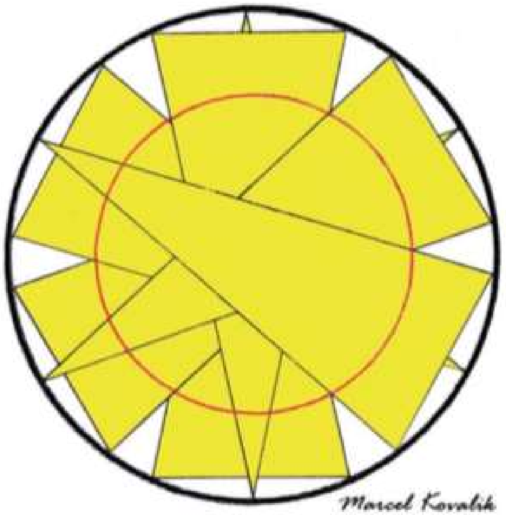


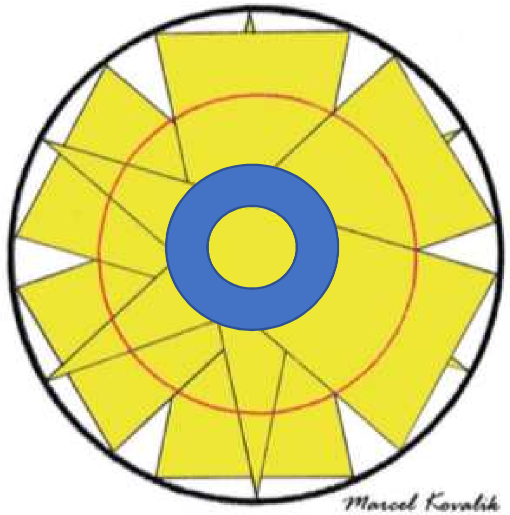
Image parameter selection

- 3. Kilovoltage: Usually limited number of choices 80-140kV. Usually 120kV is adequate for most of the patients. In large patients can be increased to ensure adequate penetration.

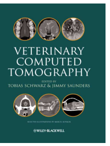
↑ kV ↑ Energy of the x-rays

- 4. Scan Field of View (SFOV) vs display field of view (DFOV)





→ As small as possible



- 5. Gantry tilt

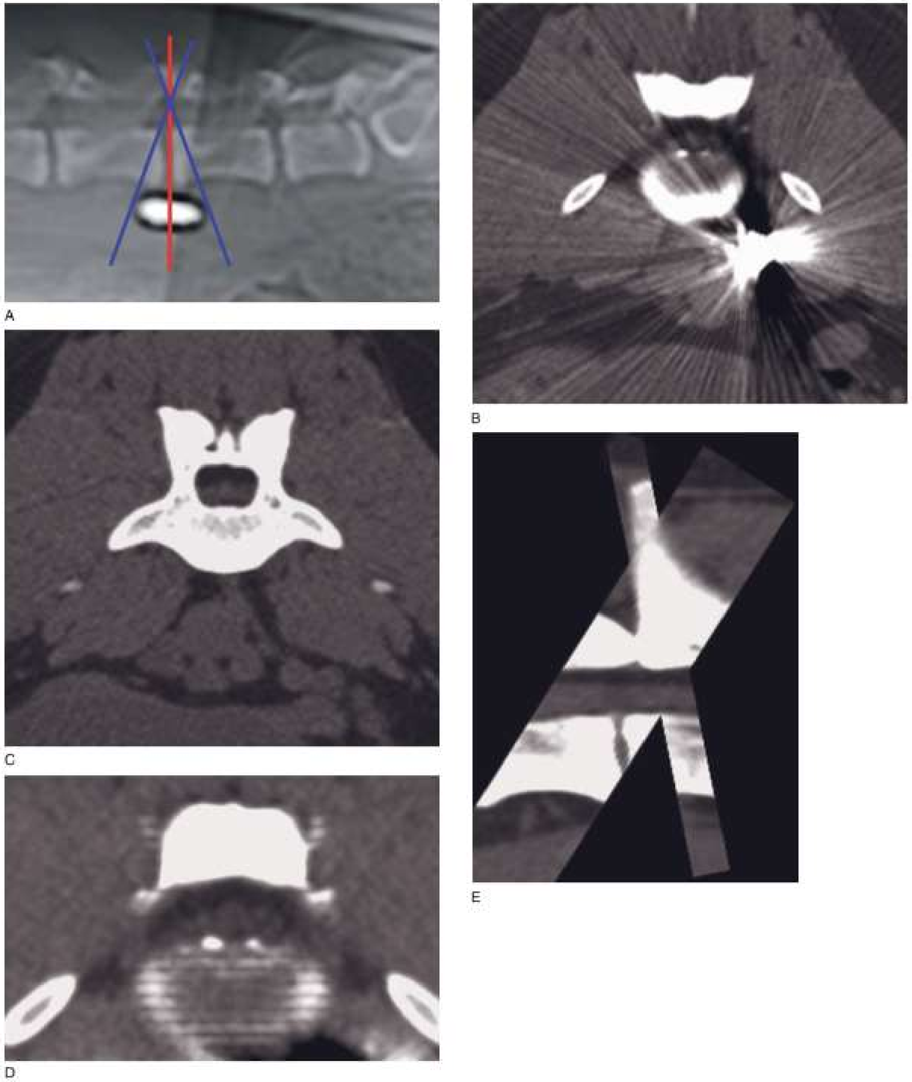
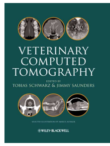
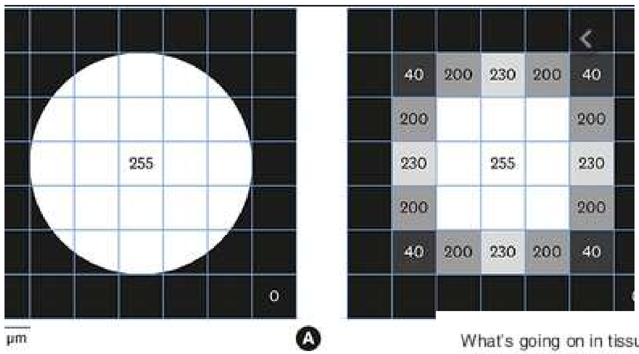
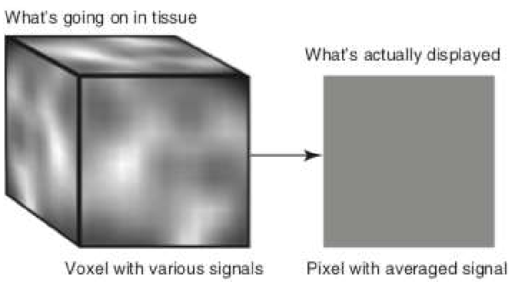


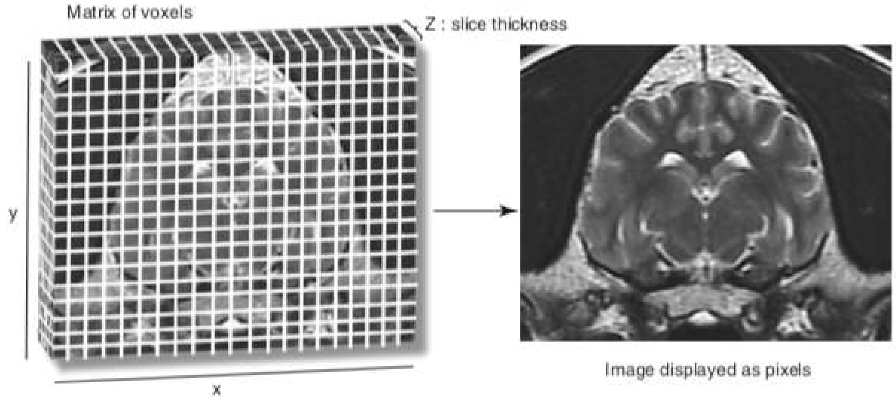
Figure 2.4 The creative use of gantry tilt can facilitate diagnostic images in challenging patients, such as in this dog with a paraspinal bullet seen on the topogram in (A). The transverse scan plane (red line) results in a non-diagnostic transverse CT image (B) for the area of interest due to the strong metallic artifact. The tilted (blue line in A) CT image (C) eliminates the artifact. These images can be retrospectively reconstructed into a transverse aligned CT image (D). A combination of the sagittal reconstructions from both tilted acquisitions (E) displays the diagnostic information from almost all areas obtained with this strategy.

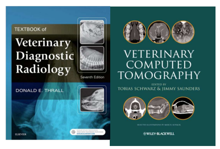


- 6. Slide thickness: Probably the single most important setting
    - - Thin-slice images should be obtained with highest mAs to keep the noise low.
    - - Slice thickness is directly proportional to the magnitude of volume averaging and inversely proportional to the magnitude of image noise.



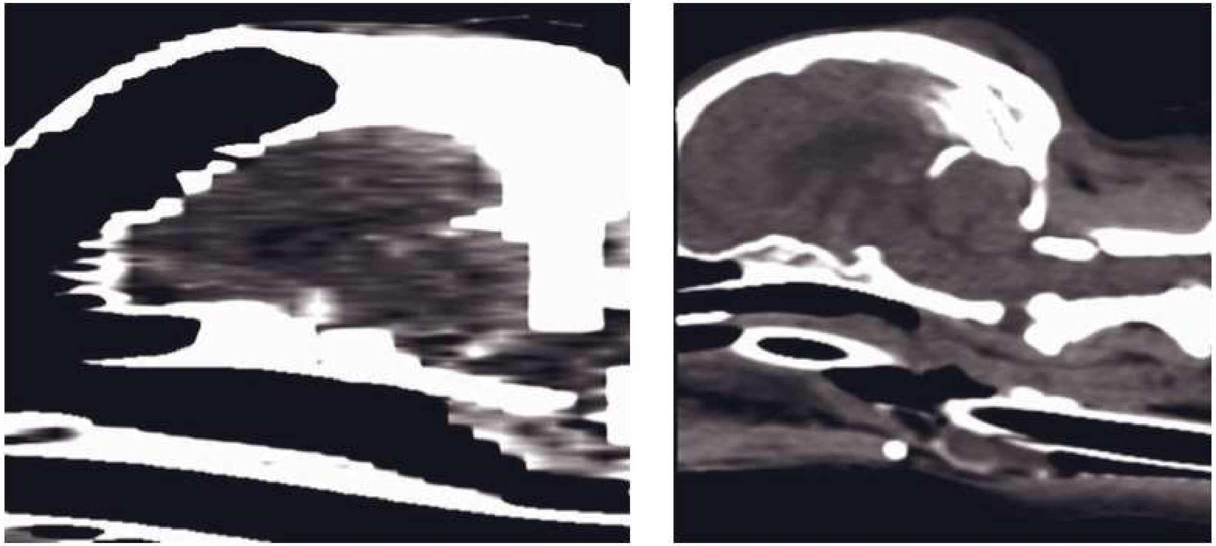






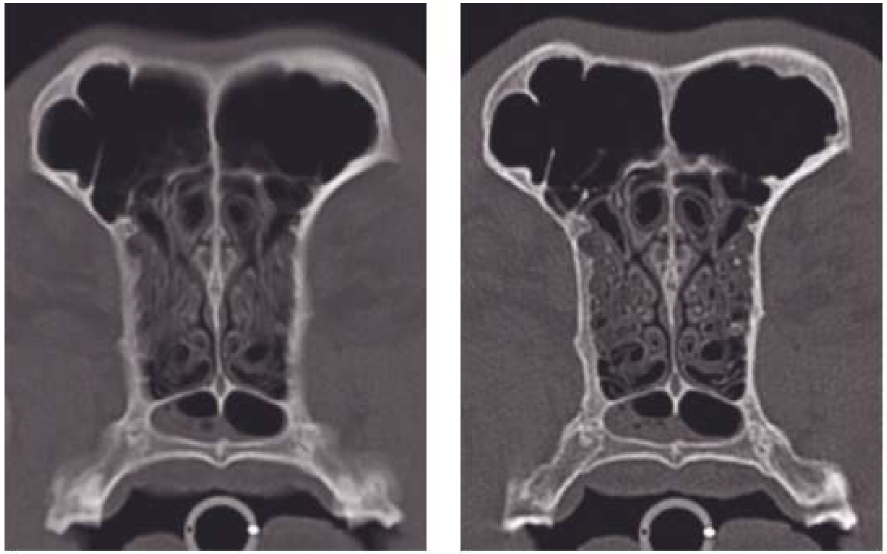
Google

Voxel To pixel

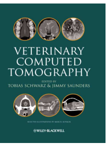


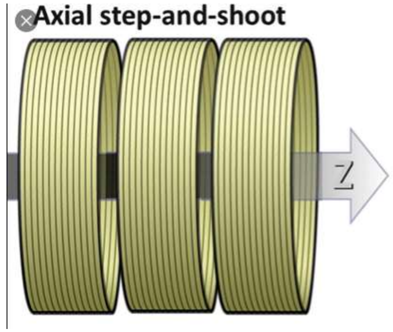
A B

Figure 4.9 (A) Sagittal reconstruction of a canine head obtained with 5 mm slice width and interval. All anatomic margins have a large step-like contour. (B) Sagittal reconstruction of another canine head with 1 mm slice width and interval has minimal stair step artifact.



A B





- 7. Pitch = table increments per 360 degree rotation/detector width (usually 0.5 - 1.5)

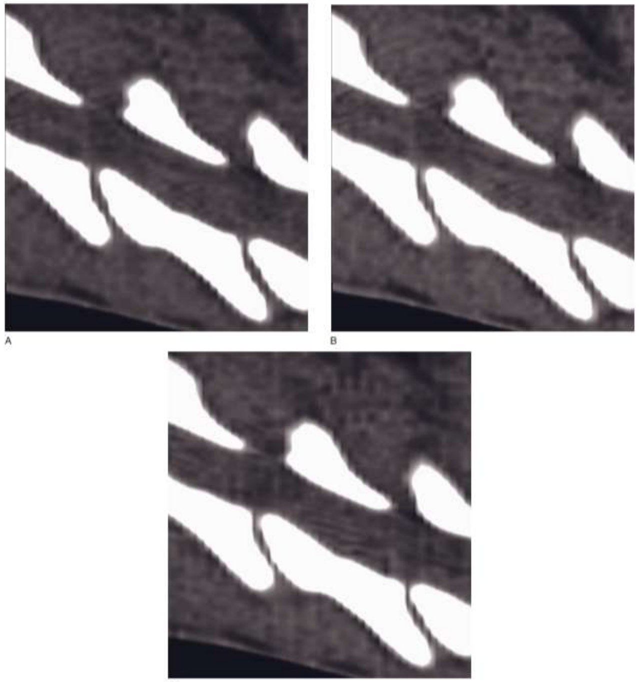
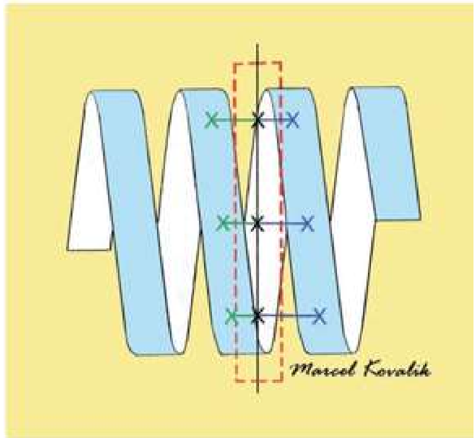
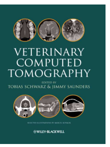


Figure 2.11 Examples of different pitch selections (otherwise identical settings) and their effect on image quality of sagittally reconstructed cervical spinal CT images acquired with a single-slice CT unit. (A) Sequential CT scan (pitch = 0). (B) Helical series with a pitch of 1 introduces slight image blur, reducing the visibility of the intervertebral disk. (C) Helical series with a pitch of 2 results in further blurring and loss of intervertebral disk definition.

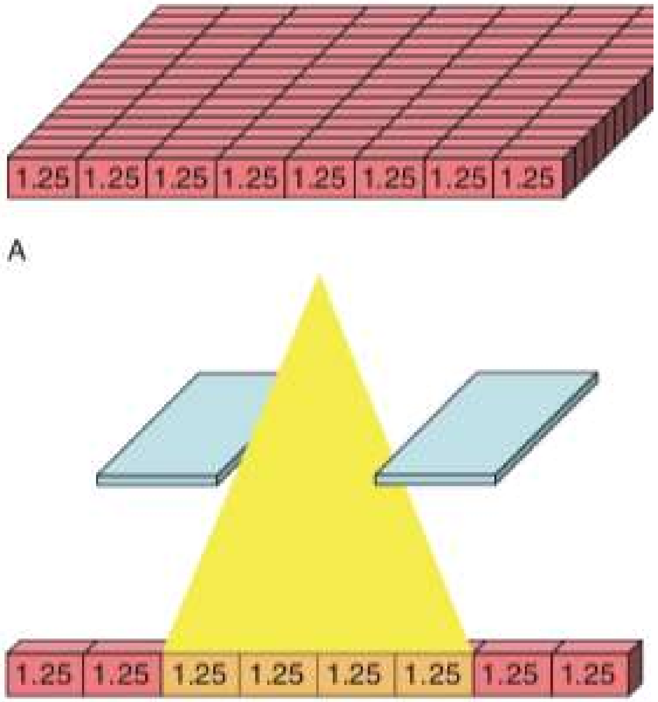


1. Data redundancy is used to make more accurate interpolations during the image reconstruction.

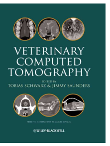
2. Low pitch produces blurring and poor images.



Multi-slice CT



Example of 8 slice 1.25mm detector



- 8. Reconstruction interval

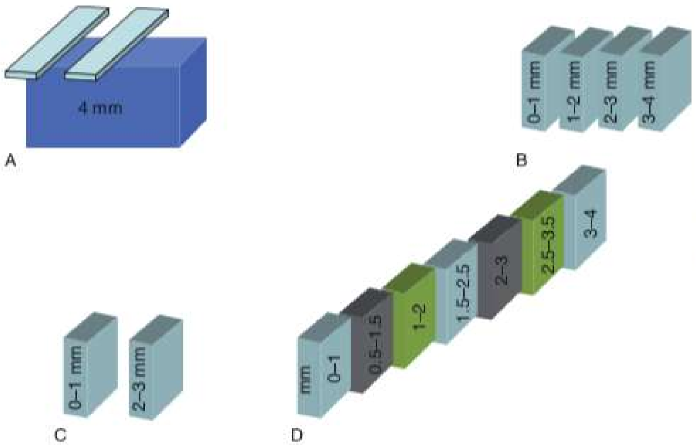


Figure 2.12 Illustration of the helical image reconstruction interval (HIRI). (A) A 4mm long patient volume set of data has been acquired with a helical CT scan and a 1mm slice collimation. (B) The default option on most CT scanners is to reconstruct images with a HIRI equal to the selected slice width. In this example this results in four 1mm thick slice images spaced 1mm apart, which is continuous image reconstruction. (C) Another option is to leave gaps between images, resulting in this example in two 1mm thick images spaced 2mm apart. (D) With interleaved reconstruction, images are reconstructed at an interval smaller than the slice width, in this example resulting in seven 1mm thick images, spaced 0.5mm apart. Interleaved image reconstruction increases image resolution for several reasons.

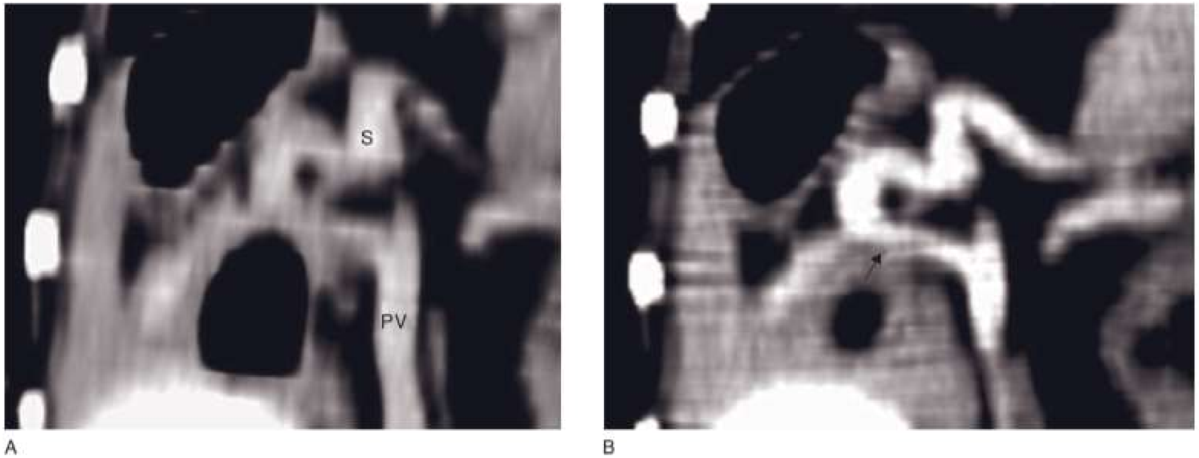
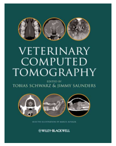
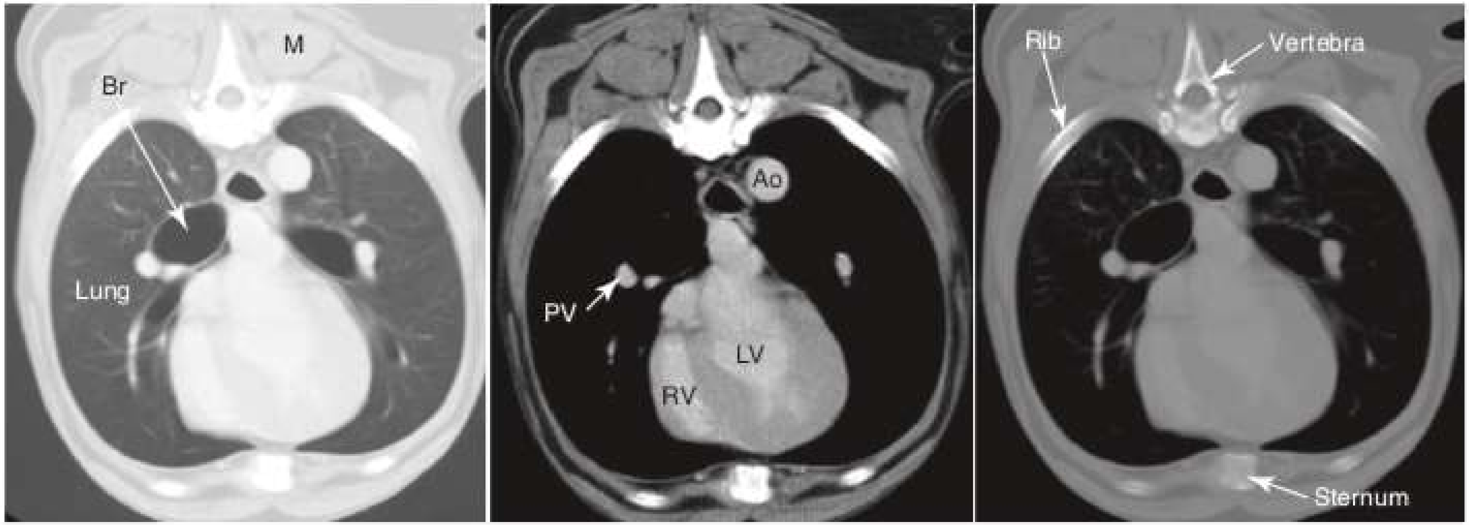


Figure 2.13 Two dorsal reconstructions of an abdominal vascular CT study with different HIRI and otherwise identical settings (3mm slice width). (A) With a 3mm HIRI the connection between the portal vein (PV) and the shunt vessel (S) is ambiguous. (B) With a 0.3mm HIRI the connecting branch of the shunt vessel (arrow) is clearly visible.



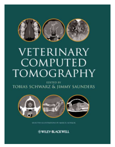
Reconstruction algorithms



W 1600 L −600 | W 400 L 40 | W 2000 L 300

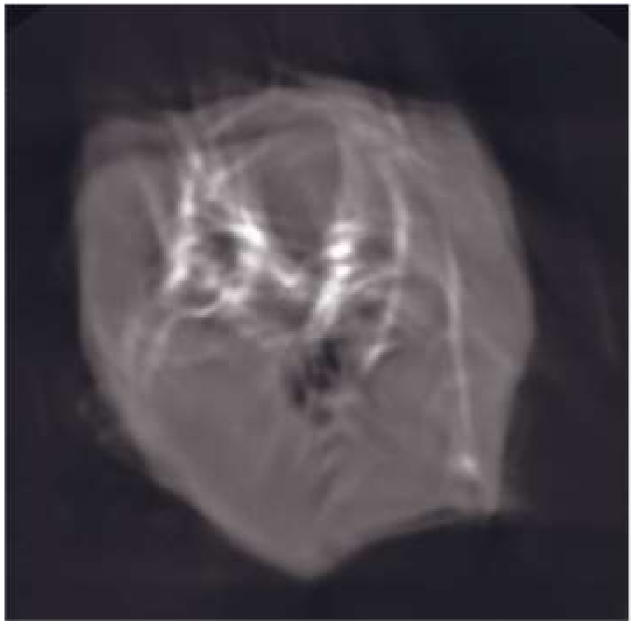
Window width: how many shades of grey

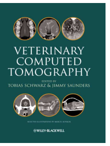
Window level: center of on the grey scale



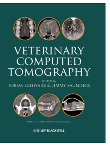
Quick overview on Artefacts

- 1) Aliasing= undersampling: caused by insufficient data sampling of a wave leading to data ambiguity.
- 2) Movement artefact

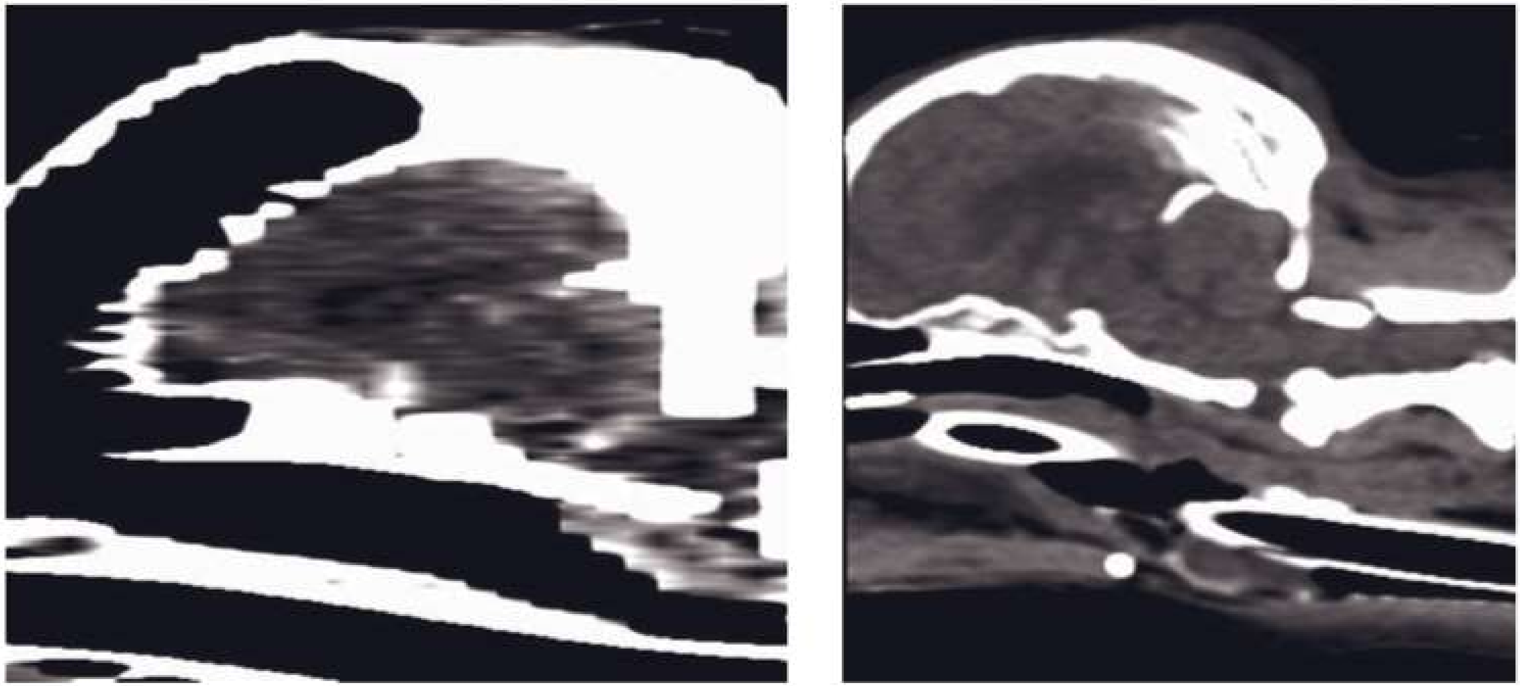


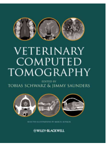


3) High pitch blurring

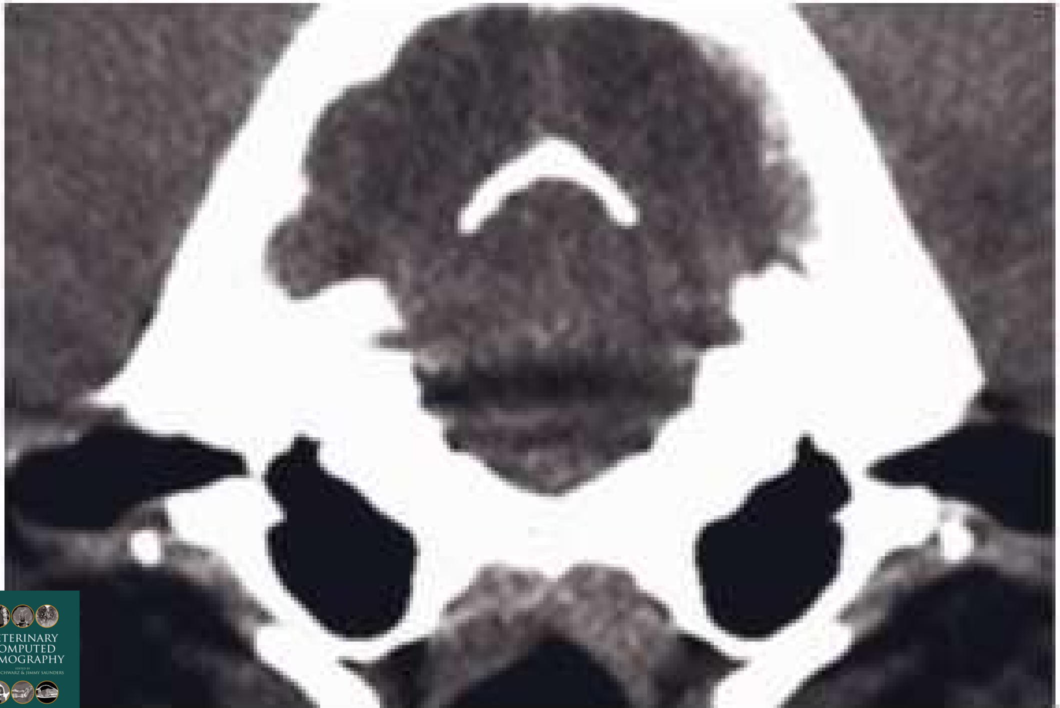


4) Stair step artefact: Due to wide slice collimation and/or interval

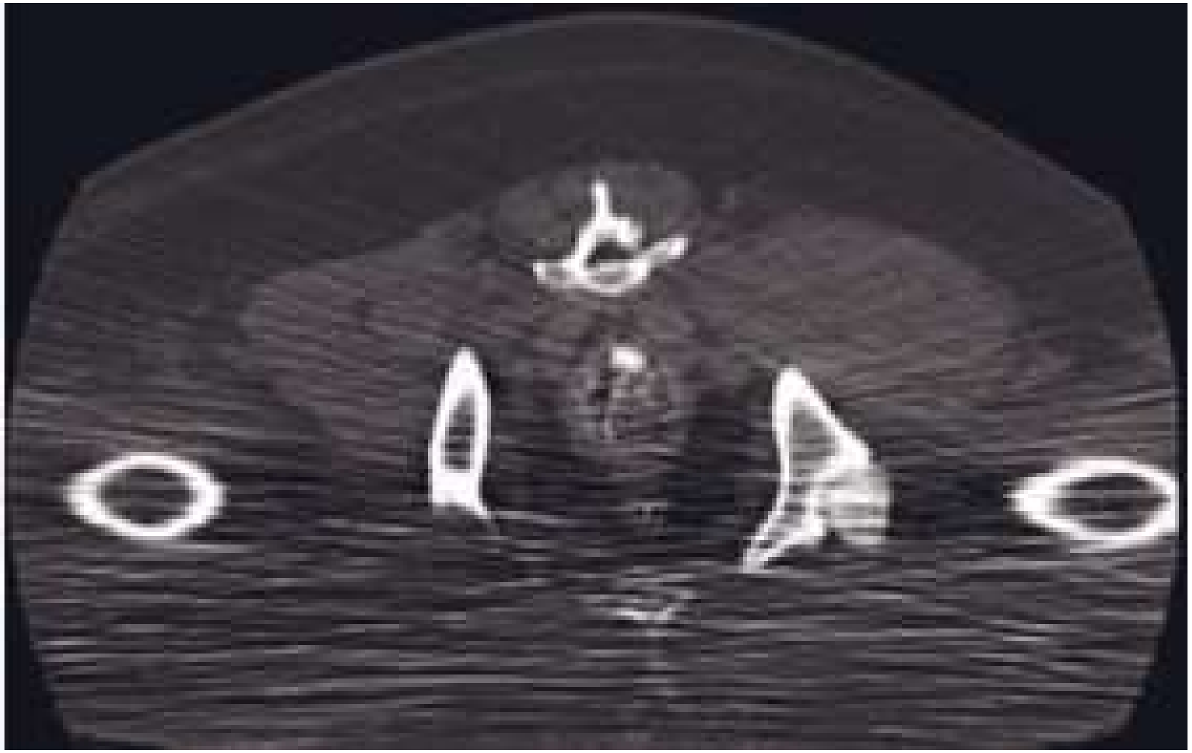


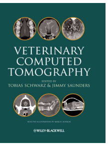


5) Beam hardening:

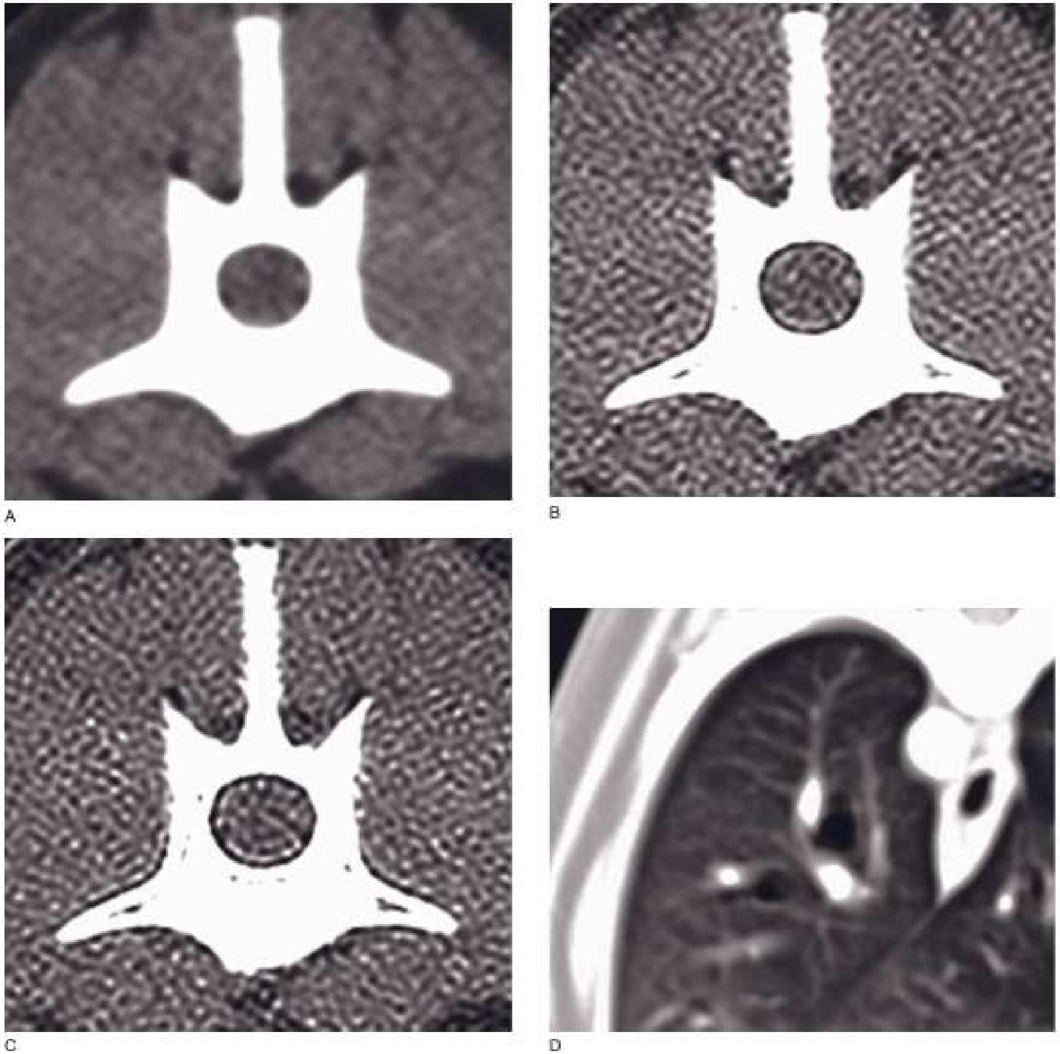


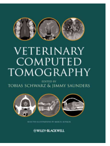
6) Photon starvation





7) Edge enhancement and rebound artefact





Thank you very much