Introduction to Medical Imaging

CT Quality Considerations

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Factors Determining Image Quality

Acquisition

- focal spot, size of detector elements, table feed, interpolation method, sample distance, and others

Reconstruction

- reconstruction kernel (filter), interpolation process, voxel size

Noise

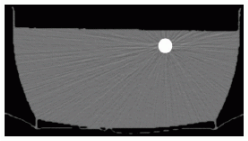
- quantum noise: due to statistical nature of X-rays
- increase of power reduces noise but increases dose
- image noise also dependent on reconstruction algorithm, interpolation filters, and interpolation methods
- greater Δz reduces noise, but lowers axial resolution

Contrast

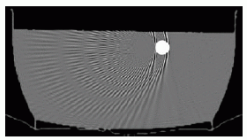
- depends on a number of physical factors (X-ray spectrum, beam-hardening, scatter)

Image Artifacts: Sampling

Normal phantom (simulated water with iron rod)



Adding noise to sinogram gives rise to streaks



Aliasing artifacts when the number of samples is too small (ringing at sharp edges)

Aliasing artifacts when the number of views is too small

Image Artifacts: Scatter

Normal phantom (plexiglas plate with three amalgam fillings)

Scatter (attenuation of beam is under-estimated)

- scattering in an object affects only detector bins near the orthogonal (target) bin, while remote detectors are protected by the collimators
- leads to an attenuation underestimation at the target bin and an overestimation at the nearby bins
- the larger the attenuation, the higher the percentage of scatter

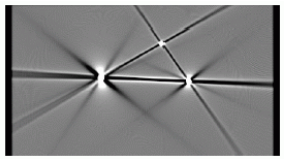
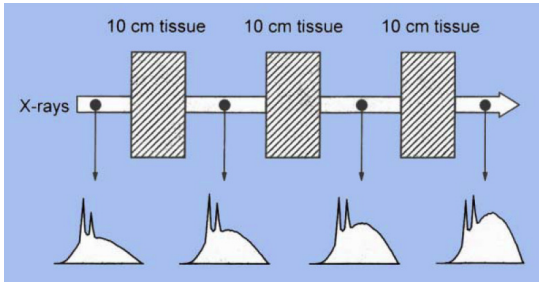
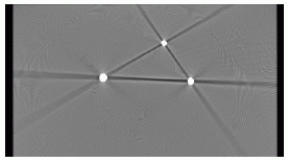


Image Artifacts: Beam Hardening

Beam hardening

- occurs when low energy photons are absorbed, while high energy photons still remain
- this leads to an increase of the mean energy of the beam → the beam becomes *harder*





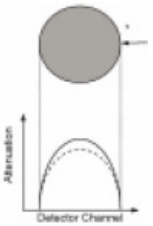
results in streaks and dark bands

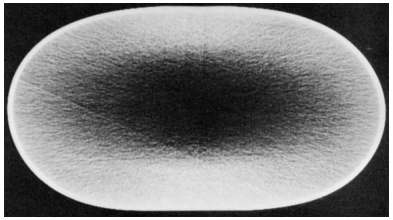
- the harder the beam the fewer photons are absorbed by a given density → the attenuation is under-estimated

Image Artifacts: Beam Hardening

Another effect: Cupping:

- X-ray passing through the center of a cylindrical object are hardened more than X-rays across the edges
- thus densities in the middle are underestimated





Measures to minimize beam hardening

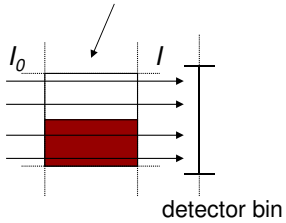
- filtration: put a flat piece of attenuating material (aluminum, copper) in front of the object to" pre-harden" the beam
- bowtie: hardens the beam more at the edges
- detector calibration via phantoms and correction with software

Image Artifacts: Partial Volume Effect

Partial volume artifact

- occurs when only part of the beam goes across an opaque structure and is attenuated
- most severe at sharp edges

single pixel traversed by individual rays:



- calculated attenuation: $-ln\ (\ avg(I / I_0))$
- true attenuation: $-avg\ (\ ln(I / I_0))$

$$-\ln\ (avg(I/I_0) < -avg(\ln(I/I_0))$$

- will underestimate the attenuation

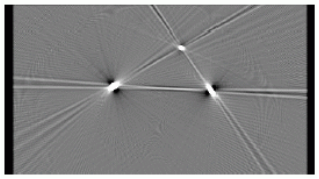


Image Artifacts: Motion and Helical

Motion artifacts

- rod moved during acquisition

Stair step artifacts:

- the helical acquisition path becomes visible in the reconstruction:

Many artifacts combined: