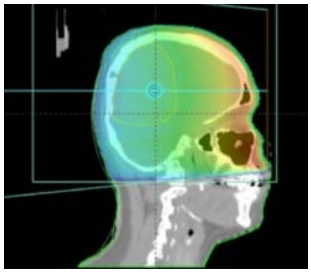
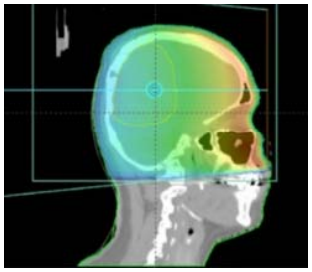
Common Image Filters and Artifact Reduction Techniques



Jussi Sillanpaa

Memorial Sloan Kettering Cancer Center

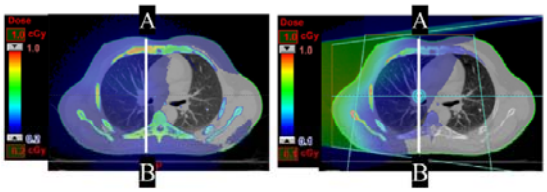
Common Image Filters and Artifact Reduction Techniques



Selecting the right imaging: dose, artifacts, resolution

No conflicts of interest to report

2D or 3D?

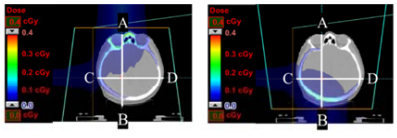


Ding et al., Radiot. Oncol. 97 91-98

Considerations include imaging dose, time, target of match, motion management

3D may not be possible for difficult setups (e.g., couch kicks) or during treatment

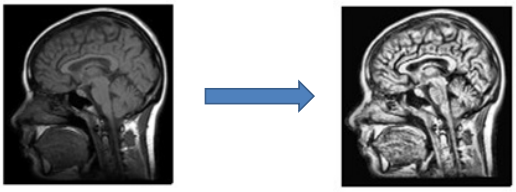
2D options



Ding et al., Radiot. Oncol. 97 91-98

Technique can be adjusted: energy, mA / MU, image filter, beam angle, sometimes beam filter

2D Image Filters

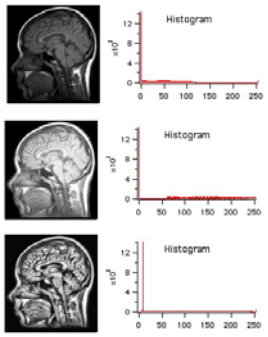


Improve contrast: Histogram equalization

Reduce noise: Median, Wiener, Gaussian filter

Improve sharpness: Edge enhancement filters

Histogram equalization



Original

Equalized

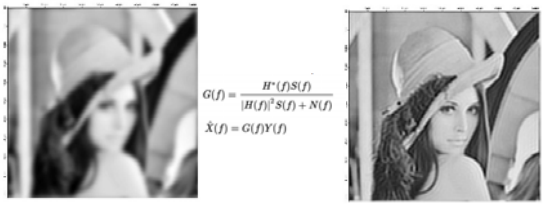
AHE

Igor Pro manual

Noise reduction – Wiener filter

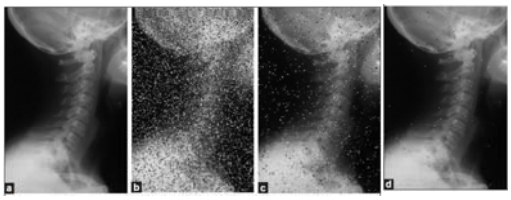
Original, with Gaussian noise

Filtered



Igor Pro manual

Noise reduction – median filter



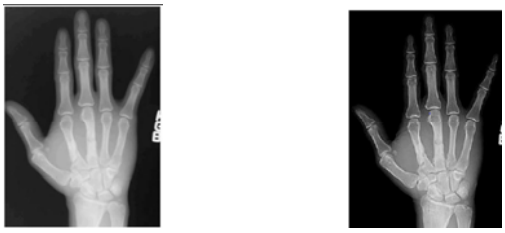
Sadri et al., J Med Signals Sens. 2 25-37

a – original, b – corrupted by Poisson noise, c – vector median filtered, d – adaptive median filtered

Edge enhancement

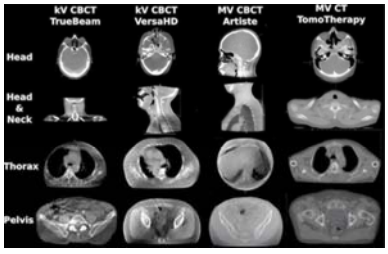
Original

After Scalable Edge Enhancement (SEE) filter



Yin et al., Pattern Recognition 37 1407-1422

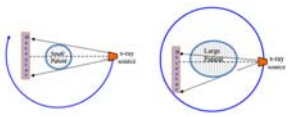
3D



Held et al., J Appl Clin Med Phys 17 279-290

A wide variety of kV and MV volumetric imaging systems available

3D options



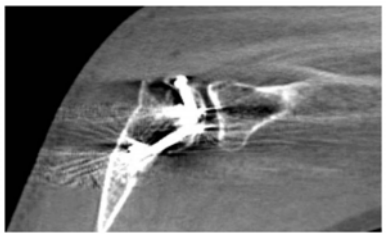
Ding et al., Radiot. Oncol. 97 91-98

CBCT often has limited (or no) choice of kVp, mA -> not much control over noise or dose

Slice thickness, pixel size, reconstruction filter can be customized

Full vs. Half fan CBCT – for Full, selection of start and stop angles

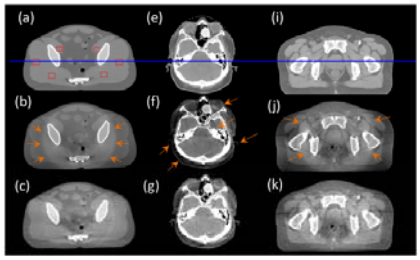
CT Artifacts



Meilinger et al., Z. Med. Phys. 21 174-182

Common artifacts include motion, bowtie/crescent, beam hardening, ring, aliasing
Typically more severe in CBCT than diagnostic CT

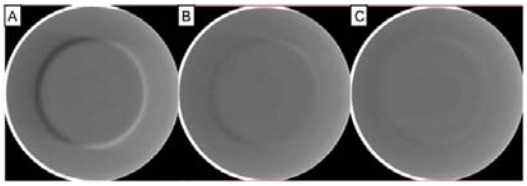
3D Artifacts: scatter



Xu et al., Phys Med Biol 60 3567-3587

Top: Diagnostic CT, Middle: CBCT, Bottom: CBCT with scatter correction

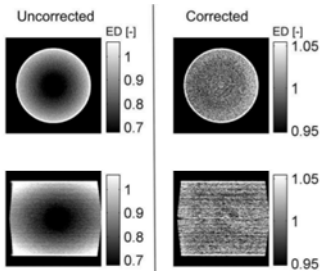
3D Artifacts: bowtie / crescent



Zhang et al., Technol Cancer Res Treat 16 81-91

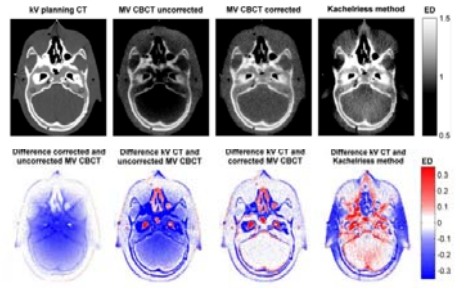
Left: no correction, Middle: correction with predicted BF shift, Right: correction with in-air projections

3D Artifacts: beam hardening



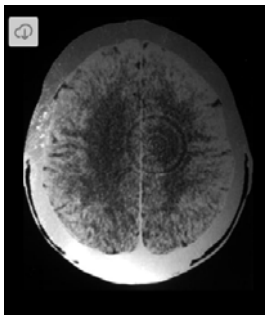
Petit et al., Med Phys 35 849-65

3D Artifacts: beam hardening



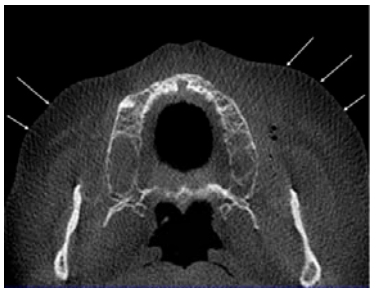
Petit et al., Med Phys 35 849-65

3D Artifacts: rings



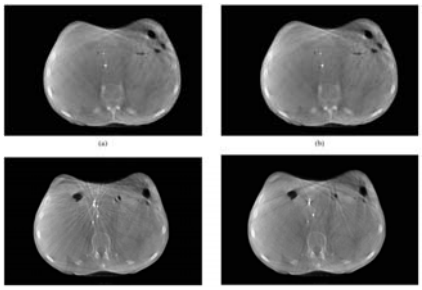
Radiopaedia.org

3D Artifacts: aliasing



Schulze et al., Dentomaxillofac. Radiology 40, 265-273

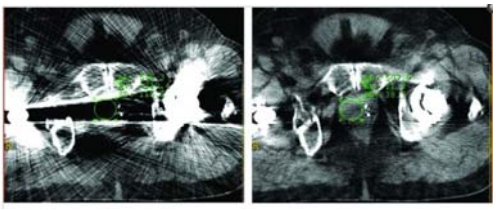
3D Artifacts: motion



Marchant et al., BJR 84 251-264

Left: no motion correction, Right: projection warping based motion correction

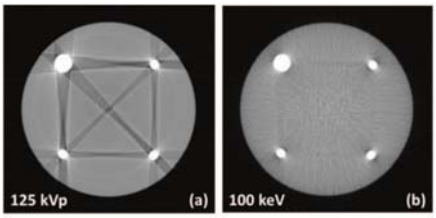
3D Artifacts: metal



Hua et al., Med Phys 39 7507-7012

Metal artifact reduction algorithms commercially available for CT, investigational for CBCT

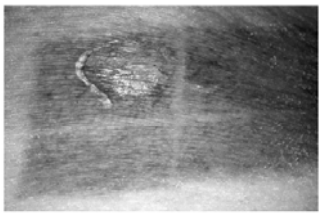
3D Artifacts: metal



Hao et al., Med Phys 39 6056-6064

Metal artifact reduction for CBCT accomplished with dual-energy imaging and a virtual 100 keV image

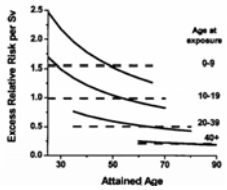
IGRT Dose – Deterministic effects



Thomadsen et al., Med. Phys. 27 1681-1684

Very low risk of deterministic effects

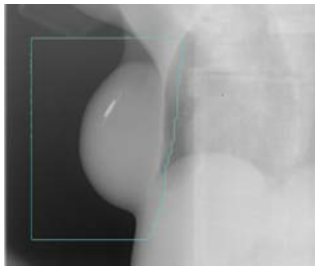
IGRT Dose - secondary cancers



Beir VII

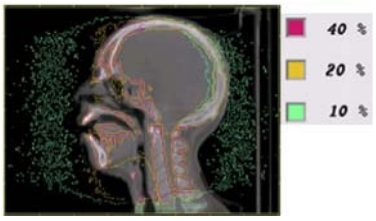
Little hard data – considering the latency period and reduced sensitivity of older patients, many patients have low risk of developing a radiation-induced cancer in their lifetime

IGRT Dose - MV



MV dose easy to sum up, generally no longer subtracted from MU, could in principle be used as a base dose for optimization, sometimes limiting factor

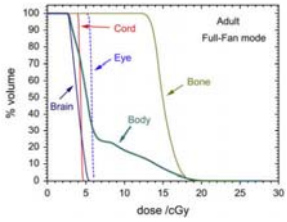
IGRT Dose - kV



Ding et al., Int J Rad Onc Biol Phys 73, 610-617. Full Fan, 125 kVp, 2000 mAs.

kV dose difficult to sum – not modeled by TX planning system, significant dose enhancement in bone (Monte Carlo methods useful)

IGRT Dose - kV



Ding et al., Int J Rad Onc Biol Phys 73, 610-617. Full Fan, 125 kVp, 2000 mAs.

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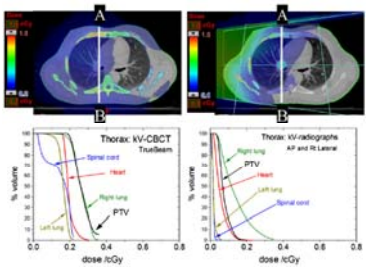
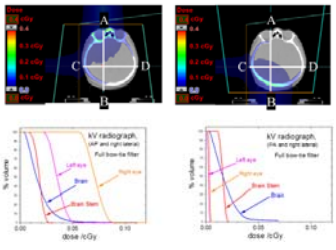
2D or 3D?



Ding et al., Radiot. Oncol. 97 91-98

Implanted fiducials may make soft tissue targets amenable to 2D imaging. For either 2D / 3D, try to limit imaged volume.

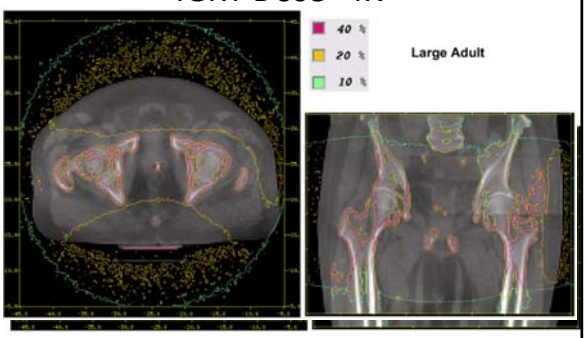
2D options



Ding et al., Radiot. Oncol. 97 91-98

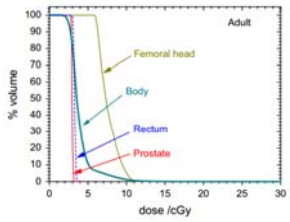
Minor dose gains possible for kV from beam angle selection

IGRT Dose - kV



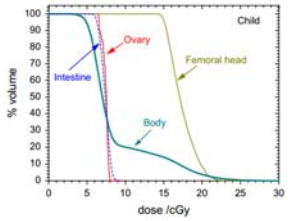
Ding et al., Int J Rad Onc Biol Phys 73, 610-617. Half Fan, 125 kVp, 2000 mAs.

IGRT Dose - kV



Ding et al., Int J Rad Onc Biol Phys 73, 610-617. Half Fan, 125 kVp, 2000 mAs.

IGRT Dose – pediatric patients



Ding et al., Int J Rad Onc Biol Phys 73, 610-617. Half Fan, 125 kVp, 2000 mAs.

If the same technique is used, doses are significantly higher than in adult patients

IGRT Dose – conclusions

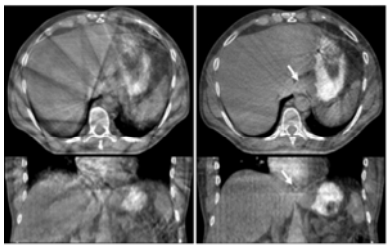
- Essentially no deterministic effects, but the potential for secondary cancers, especially in pediatric patients
- kV doses generally lower than MV ones for the same image quality, but CBCT can add up to 3 Gy over the TX course
- Due to limited choice of technique, CBCT doses high for children
- kV beams have 2-4 X dose enhancement in bone

Imaging & motion management

Both 2D and 3D imaging can be integrated with respiratory motion

Popular CT strategies include 4D CT, gating, slow 3D CT

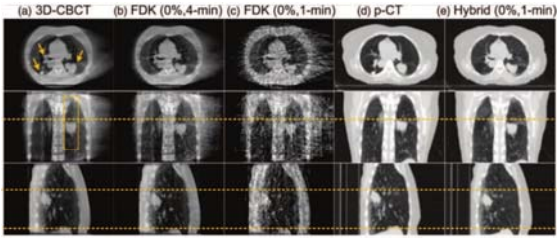
Gating



Kincaid et al., Med Phys 40 041717

Projection images only acquired during the selected respiratory phase. Left: nongated, Right: gated CBCT

Slow CT / 4D CT



Yan et al., Med Phys 41 071903

Projection images acquired in all phases, sorted according to breathing phase or amplitude, separate reconstruction for different phases. May result in few / unevenly spaced projections for some phases.