**Common Image Filters and Artifact Reduction Techniques**

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**Selecting the right imaging:**

dose, artifacts, resolution

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**No conflicts of interest to report**

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**2D or 3D?**

Ding et al., Radiat. 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

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**2D options**

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

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

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**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., Radiat. 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

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: rings

Radiopaedia.org
3D Artifacts: aliasing
Schube 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
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)

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Minor dose gains possible for kV from beam angle selection

2D or 3D?

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

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.