

Dose Calculation on CBCT Datasets

Elekta System

Daniel Létourneau, PhD, DABR



Princess Margaret Hospital
University Health Network

Elekta Synergy - XVI

Cone-Beam CT for IGRT

- Field of View (FOV)
Sup-Inf: 12 and 26 cm
Axial: 27 to 50 cm
- Selectable mAs and kV
- Scatter correction in software
- Single Bowtie Filter
- No scatter rejection grid



Elekta Synergy - XVI

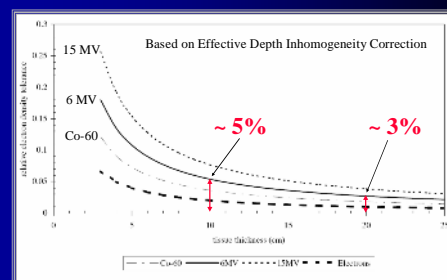
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Tolerance on Electron Density

Limiting Relative Dose Error to 2%

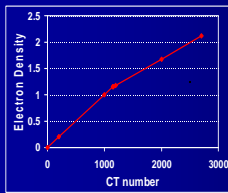


Kilby et al, PMB, 47: p.1485-92, 2002

Dose Calculation on CBCT Images

Key Requirements for Accurate Dose Calculation

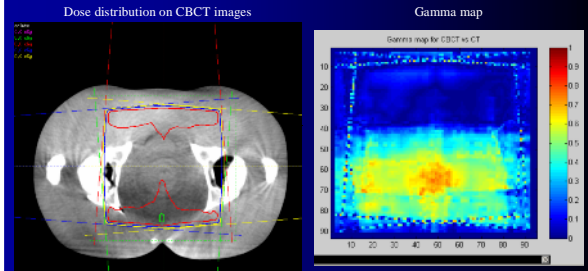
HU to ED conversion



- Image Geometric Integrity
 - Scale
 - No distortion
 - Skin-line
- Reproducible CBCT numbers
- Accurate CBCT numbers

Impact of Residual Artifacts

Result: 99.8% within 2% dose diff. and 3 mm DtoA



Letourneau et al, IJROBP, 67: p.1229-37, 2007

CBCT Image Artifacts

Three Categories:

- System
 - Panel and tube calibration
 - Post reconstruction processing

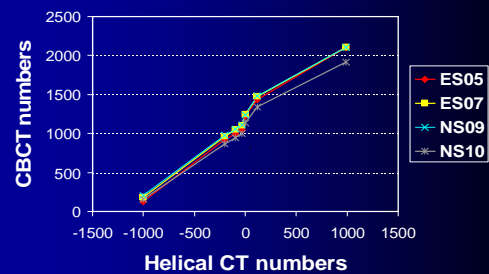
- Inter-system CBCT# variations
- Technique
 - kVp, FOV, Panel Offset, Bowtie filter, Grid, Pre-reconstruction processing

- Uniformity
- Lag/Skin-line
- CBCT# variation
- Patient
 - Size, prosthesis, intra-scan organ motion and truncation

- Uniformity
- Streaks

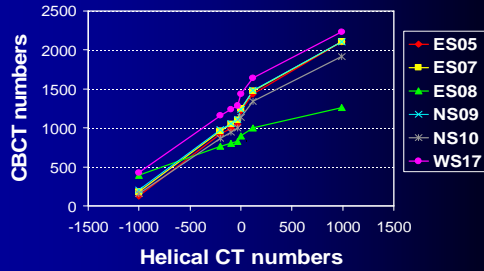
Inter-System CBCT# Variation

CBCT # from 4 Systems: Same phantom and imaging technique



Inter-System CBCT# Variation

CBCT # from 6 Systems: Same phantom and imaging technique



No Detector Calibration in Air?

Inter-System CBCT# Variation

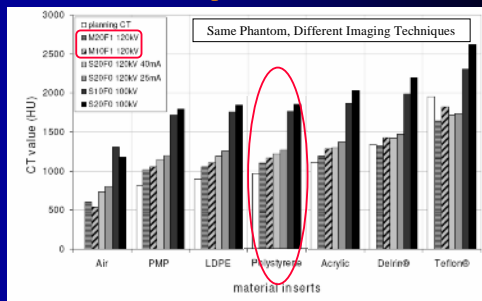
Potential Solutions:

- CBCT-to-ED table per machine
- Flood field calibration
 - Adjust the amount of water to compensate for tube output variation
- Post-Processing algorithm
 - User-defined linear CBCT number conversion

All these solutions require periodical QA!!!!

Inter-Technique CBCT# Variation

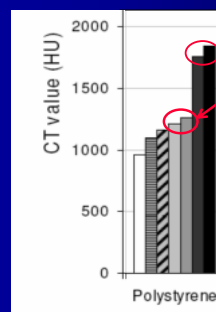
Variation in FOV, kVp, mAs and filter



Ritcher et al, Radiation Oncology, 3:42, 2008

Inter-Technique CBCT# Variation

Variation in FOV, kVp, mAs and filter



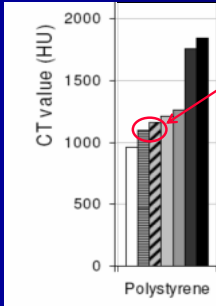
Change in kVp
(100 to 120 kVp) :

About 500 HU variation

Ritcher et al, Radiation Oncology, 3:42, 2008

Inter-Technique CBCT# Variation

Variation in FOV, kVp, mAs and filter



Change in Sup-Inf FOV
(12 to 25 cm) :
About 70 HU variation

Ritcher et al, Radiation Oncology, 3:42, 2008

Inter-Technique CBCT# Variation

CBCT-to-ED table per technique or per anatomic site

Dose on CT and CBCT for a pelvis patient

| Mean Difference | | IF | | patient plan | |
|---------------------|------------------------|--------------|--------------|--------------|--------------|
| Correction strategy | | 6 MV | 18 MV | dose plane | DVH |
| (a) Pelvis Patients | | | | | |
| standard | HU-D _{CT} | 21.6% ± 3.7% | 15.7% ± 3.4% | 8.0% ± 5.7% | 19.1% ± 3.4% |
| phantom based | HU-D _{H20R1} | 7.7% ± 5.2% | 5.6% ± 3.9% | 5.2% ± 3.7% | 12.7% ± 1.5% |
| group based | HU-D _{pelvis} | 2.7% ± 2.3% | 2.4% ± 2.0% | 0.9% ± 0.9% | 1.3% ± 1.0% |
| patient based | HU-D _{pelvL} | 2.4% ± 1.7% | 2.0% ± 1.4% | 0.9% ± 0.9% | 1.2% ± 0.9% |

Single CBCT Imaging Technique

Ritcher et al, Radiation Oncology, 3:42, 2008

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Using a technique-based CBCT-to-ED table

20 cm diameter phantom for pelvis!

Ritcher et al, Radiation Oncology, 3:42, 2008

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Using an anatomic-site-based CBCT-to-ED table

Ritcher et al, Radiation Oncology, 3:42, 2008

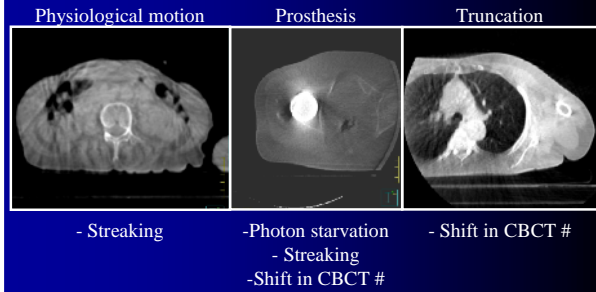
Inter-Technique CBCT# Variation

Summary:

- Dose accuracy within 2% is achievable
 - Multiple fields are more forgiving
- CBCT-to-ED table per technique and anatomic sites
 - Require maintenance
 - Risk of mismatch

Inter-Patient CBCT# Variation

Some cases:



Conclusion

Accurate dose calculation on CBCT is possible

- Inter-system CBCT# variation
- CBCT-to-ED table per technique and anatomic sites
- Periodical QA required