KiloVoltage Cone Beam CT Image Quality for Adaptive Radiotherapy

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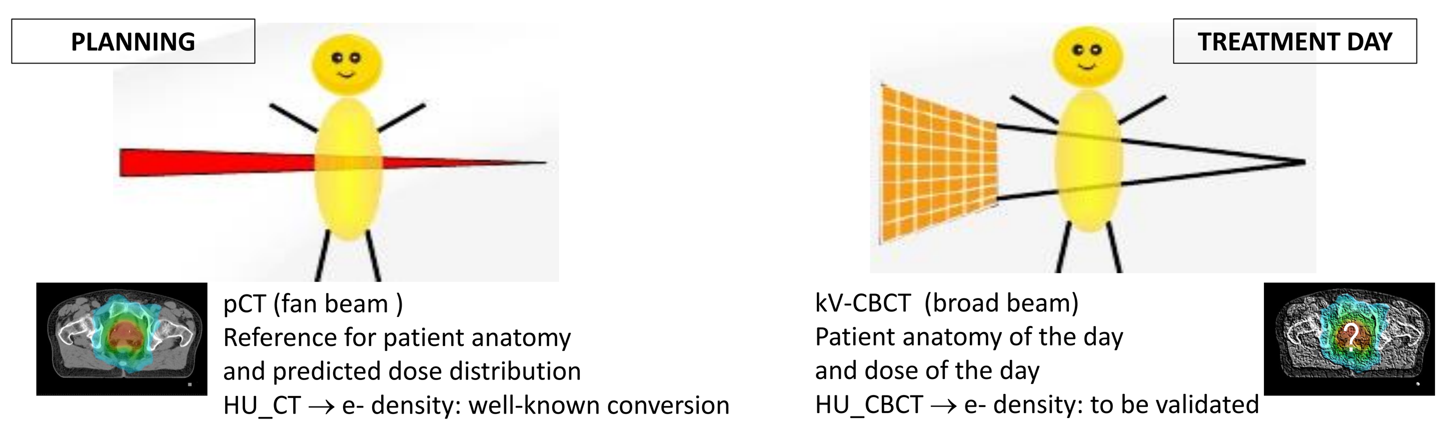
INTRODUCTION

The quantitative comparison of planned and actual delivered doses is a new concern in External Beam RadioTherapy. KiloVoltage Cone-Beam CT (kV-CBCT) allows highlighting daily anatomical and morphological changes by comparing with the pCT images used for the treatment planning (reference for dose calculation). Thus, kV-CBCT is potentially the reference data for the calculation of the *dose of the day*. However, kV-CBCT beam geometry is different from FBCT, introducing well known artefacts and leading to Hounsfield Units (HU) inaccuracies. Image quantification in term of relative electron density (RED) to water in regards to Fan Beam CT (FBCT) is essential to save calculation accuracy.



AIM

The scope of this study is to review and compare the main issues of kV-CBCT imaging highlighted from different generation systems and their respective image quality in regards to CT (FBCT technology). This approach includes analyzing image quality, Hounsfield units (HU) consistency and noise evaluation. To compare performance, this work used a new metric based on HU differential histogram of the image set.

MATERIALS & METHODS

Treatment units, Imaging System and acquisition parameters (Table 1):

- **unit 1:** Varian Truebeam, 4D v2.5
- **unit 2:** Varian Truebeam, 4D v2.5
- **unit 3**: Varian Clinac 2100CD, OBI v1.6

- Reconstruction and ring artefact correction method: Auto

- **FBCT technologies:** Toshiba AquilonLB and Siemens SOMATOM Definition AS

Image registration & Numerical analysis:

- ISOgray TPS (DOSIsoft, Cachan, France)
- Matlab2017R (The MathWorks®, Inc)

Water phantom:
NEMA IEC body water phantom (Data Spectrum Corp.) for image quality, HU uniformity, noise (Figure 1)

Heterogeneous phantom:
Cheese phantom (Gammex RMI, Middleton, WI) for HU to electron density (de-) calibration curve (Figure 2 and Table 2)

FBCT Toshiba AquilonLB	**Tube Voltage (kV)**	**Tube current (mA)**	**Resolution (pixel/mm)**	**Voxel size (mm³)**
Pelvis standard	120	100	0.9331	1.0740x1.0740 x3
FBCT Siemens SOMATOM Definition AS	**Tube Voltage (kV)**	**Tube current (mA)**	**Resolution (pixel/mm)**	**Voxel size (mm³)**
Pelvis standard	225	250	1,4629	0,6836x0,6836 x3
Unit 1 and 2 (Half Fan bowtie filter)	**Tube Voltage (kV)**	**Tube current (mA)**	**Resolution (pixel/mm)**	**Voxel size (mm³)**
Pelvis	125	80		
Pelvis obese	140	100	1,1013	0.9080x0.9080 x2
Thorax	125	20		
Unit 3 (Half Fan bowtie filter)	**Tube Voltage (kV)**	**Tube current (mA)**	**Resolution (pixel/mm)**	**Voxel size (mm³)**
Pelvis	125	80	1,1318	0,8780x0,8780 x2
Low dose thorax	110	20		

Table1: Acquisition parameters

	Inserts name	Mass Density		Inserts name	Mass Density
9	Lung 300	0.27	11	Liver	1.094
10	Lung 450	0.45	6	B200 Bone	1.145
1	Adipose	0.943	7	Inner Bone	1.152
2	Breast	0.98	8	CB2 30%	1.333
4	Solid Water	1.017	5	CB2 50%	1.559
12	Brain	1.051	3	Cortical Bone	1.822

Table 2: Inserts of human tissue equivalent material

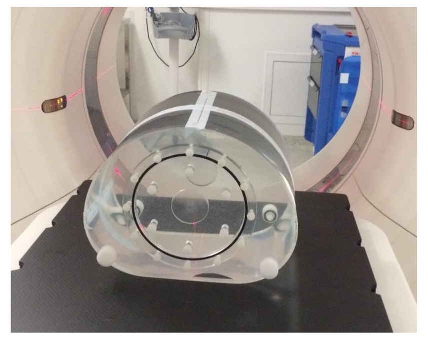


Figure 1: Phantom without multiple fillable spheres and cylindric inserts and fill with water

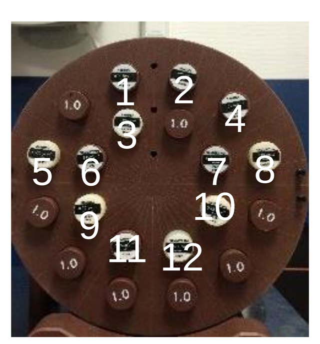


Figure 2: « Cheese » phantom with inserts

RESULTS

Water phantom

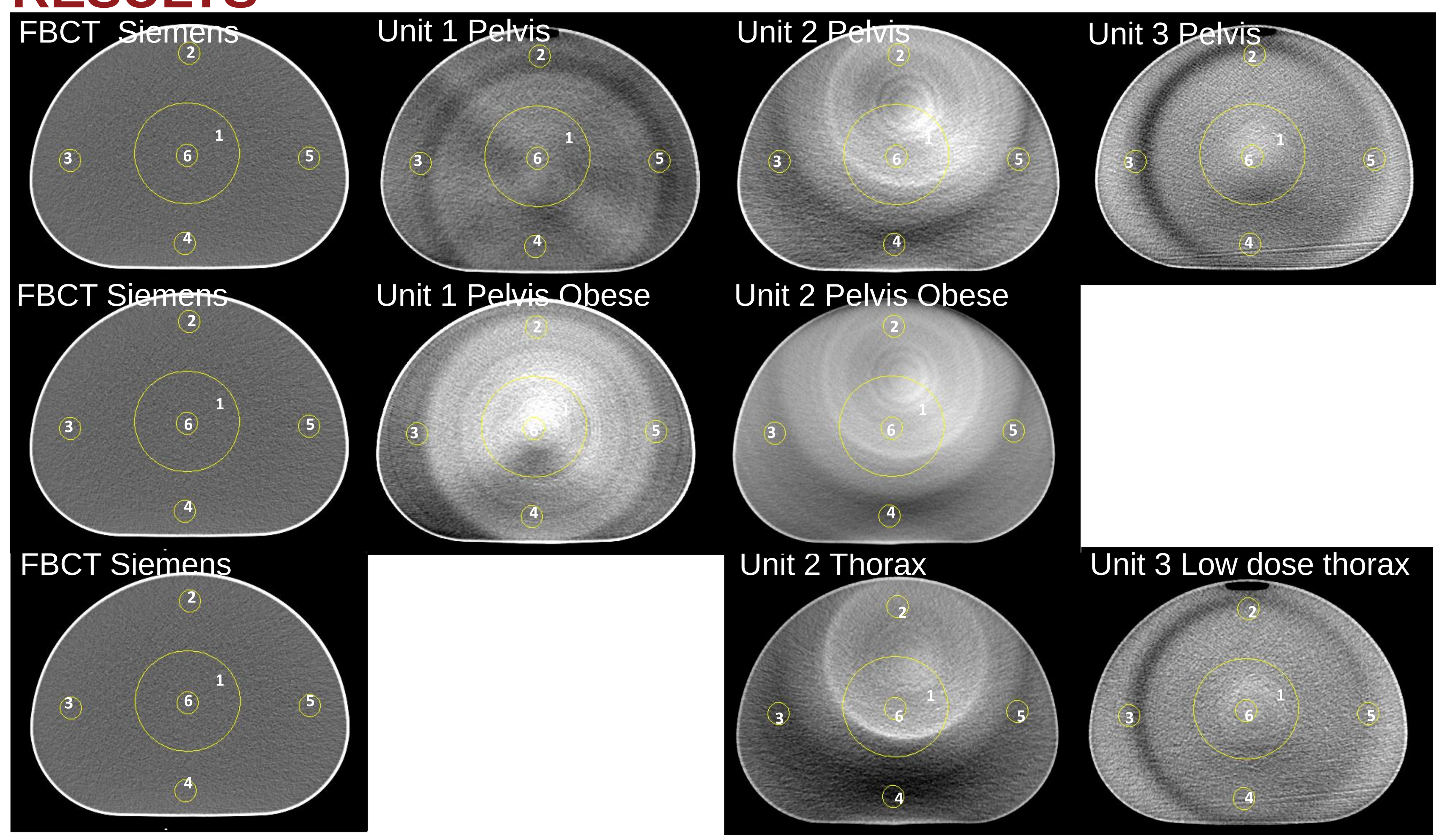


Figure 3: Image quality of the homogeneous water phantom.

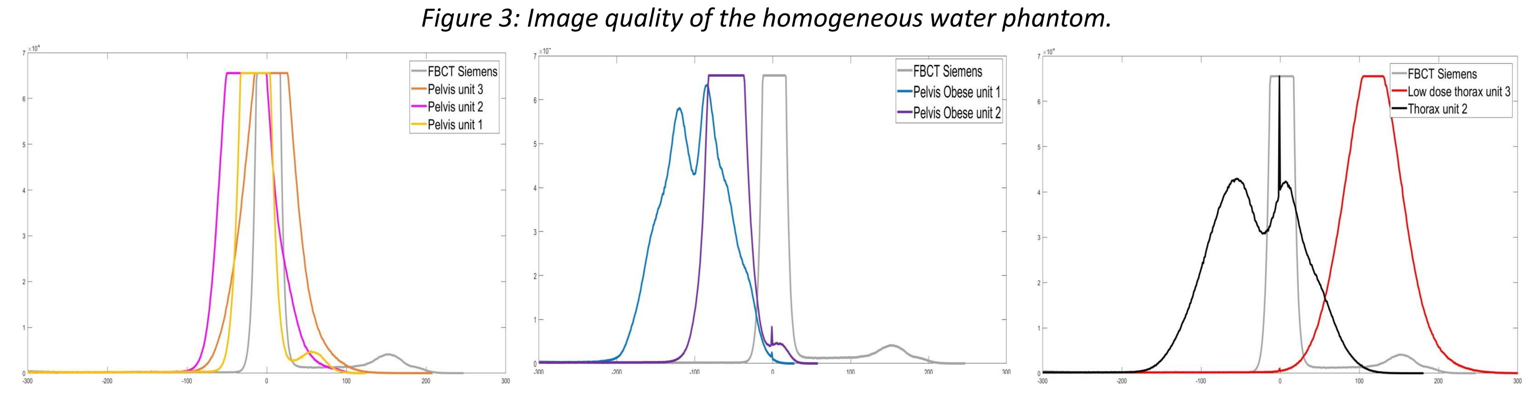


Figure 4: Hounsfield units differential histogram representing HU distribution of the water phantom

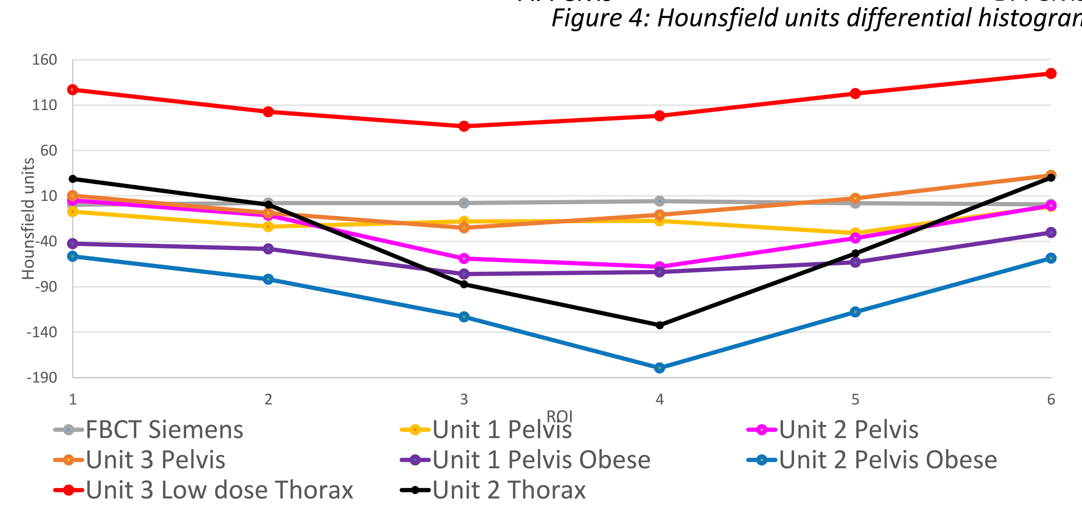


Figure 5: Measured HU number accuracy for the homogeneous water phantom

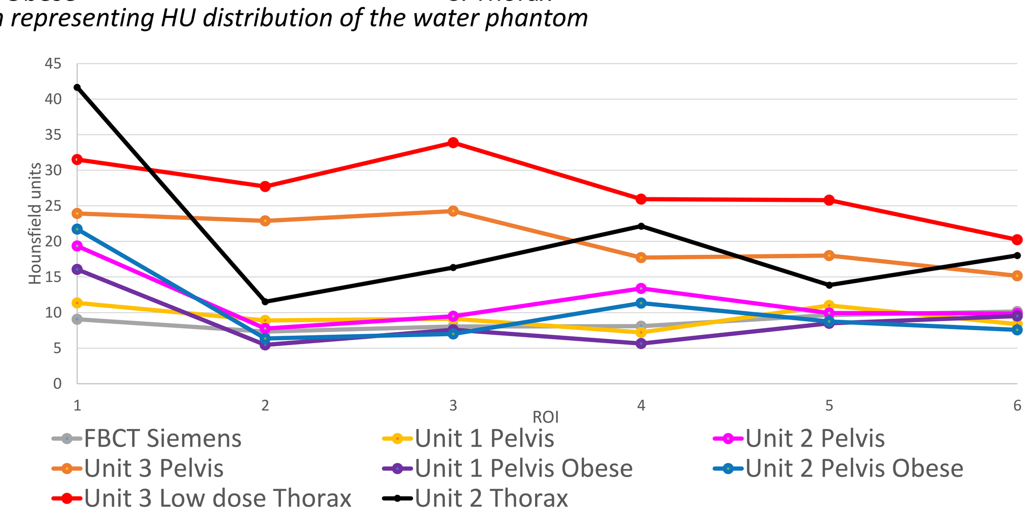


Figure 6: Measured noise for the homogeneous water phantom

Heterogenous phantom

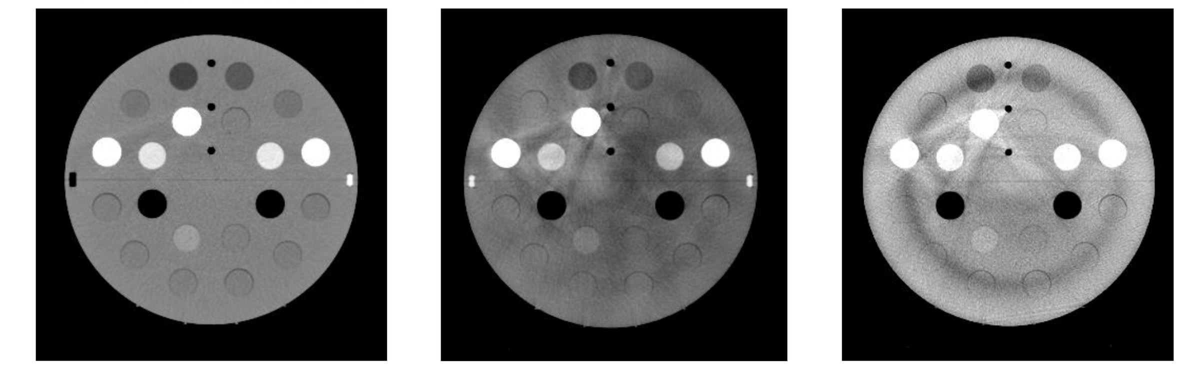


Figure 7: Image quality of the "Cheese" phantom for different units

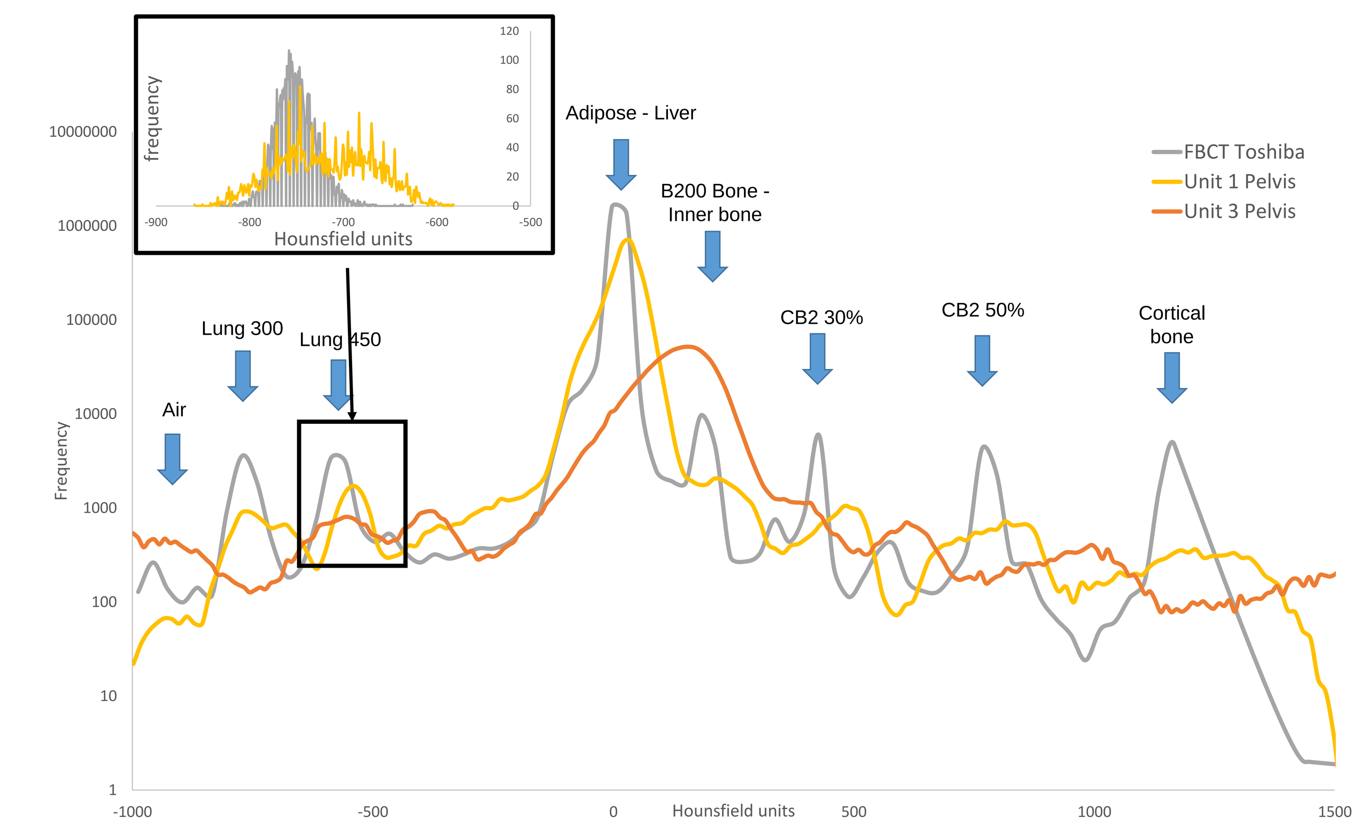


Figure 8: Hounsfield units differential histogram representing HU distribution for each insert on different units and same protocol

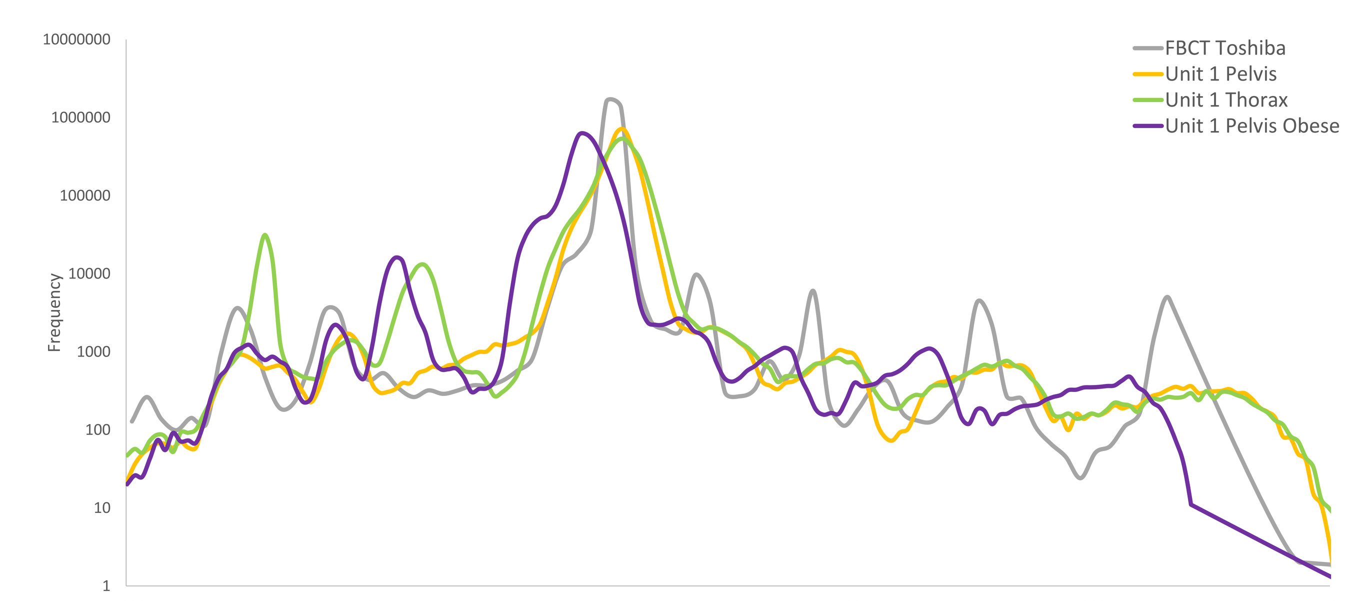


Figure 9: Hounsfield units differential histogram representing HU distribution for each insert on same unit and different protocols

CONCLUSION

In this work, the three commercial kV-CBCT systems studied demonstrate different noticeable performances:

- ✓ Offset of HU water peaks (calibration processed by the vendor)
- ✓ Artefacts are much more noticeable in Unit 3 as its an oldest technology compared to unit 1 & 2

For the same machine: we observed different HU distribution from one protocol to another as well as across the entire imaged volume.

The kV-CBCT HU calibration into electron density is disturbed by the broader HU peaks in comparison to the standard unique HU relationship achieved with FB Computed Tomography. Alternative strategies to quantify kV-CBCT images have to be considered in order to limit inaccuracy to calculate "the dose of the day".

REFERENCES

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