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The Effect of Reconstruction and Volume Preset Parameters on Low-contrast Visibility for kV CBCT

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INTRODUCTION

The hypofractionated treatment of abdominal tumors using the Elekta VersaHD linear accelerator (Elekta, Crawley, UK) allows for clinically acceptable dose coverage for multiple simultaneous integrated boost (SIB) targets, while maintaining acceptable organs at risk (OAR) doses in agreement with RTOG and institutional protocols. However, the use of ultra-high-dose hypofractionated treatments require robust imaging and patient-positioning on a daily basis, with clear and concise triggers for an adaptive replan based on this daily kV CBCT imaging. Poor contrast between abdominal tumors and surrounding normal tissue limits this capability for dose escalation and adaptive re-planning and requires manual corrections to the automatic CBCT to planning CT registrations.

AIM

The aim of this study was to address the improvement of kV CBCT image quality for use in hypofractionated and ultra-high dose hypofractionated treatments of abdominal tumors using the Elekta VersaHD linear accelerator. The ability to delineate several different anatomical structures of similar densities on the CBCT image requires optimizing the standard scanning and reconstruction parameters. The aim of this study was to determine the optimal combination of imaging parameters to maximize the visibility of soft tissue contrast and OARs to improve confidence in treatment localization and quality of patient care.

METHOD

The Catphan phantom is a standard CBCT image quality phantom. The Catphan CTP 503 (Figure 1) was used in conjunction with the Elekta linear accelerator system to determine the optimal set of parameters to use in clinical imaging of SBRT abdominal patients. Using the onboard XVI system, image quality metric low contrast visibility % was analyzed for different combinations of volume and reconstruction CBCT presets. Higher low contrast visibility % corresponds to higher noise. Custom volume and reconstruction presets were used to compare the resulting images from varying mA, collimator, filter, slice averaging, and interpolation. Low contrast visibility % was assessed using the LDPE and polystyrene inserts in the CTP404 module illustrated below in Figure 2 with the following equation:

$$Low\ contrast\ visibility\ \% = \frac{(CT_{polystyrene} - CT_{LDPE})/10}{\{Mean_{polystyrene} - Mean_{LDPE}\}/\{(SD_{polystyrene} + SD_{LDPE})/2\}}.$$

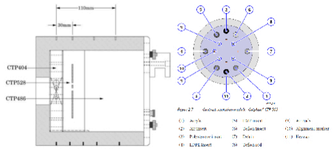

Figure 1

Figure 2

Figure 1: *Phantom model illustration from the Catphan 503 manual. The CTP404 module includes objects for measuring slide width, sensitometry and low contrast visibility %, and pixel size. The CTP528 module contains 21 line pairs as a measurement of high resolution. The CTP486 module allows for measurement of image uniformity.*

Figure 2: *CTP404 module details from the Elekta XVI R5.0 Customer Acceptance Tests.*

RESULTS

Increasing slice averaging from three to nine resulted in reduced low contrast visibility %. The highest low contrast visibility % was observed with the Bilinear interpolation (Recon 3) and lowest using the Partial2 interpolation (Recon 1 and 2) for varying mAs (Figure 3). Recon 1 corresponded to the smallest low-contrast visibility %, with less than 2% difference due to slice averaging, while keeping the collimator/filter (S20/F0) and mS (40) constant (Figure 3). Decreasing the collimator size and not using a bowtie filter in the volume presets also resulted in decreasing low contrast visibility % (Figure 4). Decreasing collimator size alone (S10 vs S20) demonstrated decreased low contrast visibility % (Figure 5). For the comparisons in Figures 4 and 5, Recon 3 corresponded to the smallest low-contrast visibility %. Reconstruction presets 1 and 2 utilized the same interpolation algorithm (Partial2) and pre-filter (Median9) but differed in scatter correction parameters, reconstruction voxel sizes, and projection down size factors. Additionally, reconstruction preset 3 used Bilinear interpolation while preset 2 used Partial2 interpolation. Reconstruction presets 3 and 2 used different scatter correction parameters, reconstruction filter parameters, and reconstruction data types (short vs float, respectively).

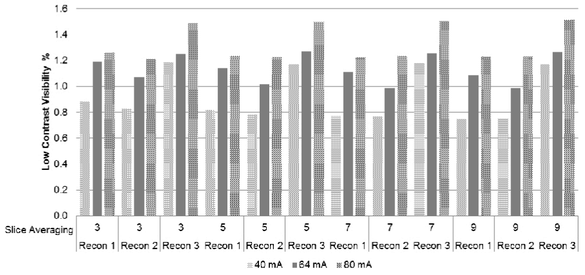

Figure 3: *Low contrast visibility % vs mA, slice averaging, and reconstruction presets. Volumes were acquired using 40 mS and S20/F0 collimator/filter.*

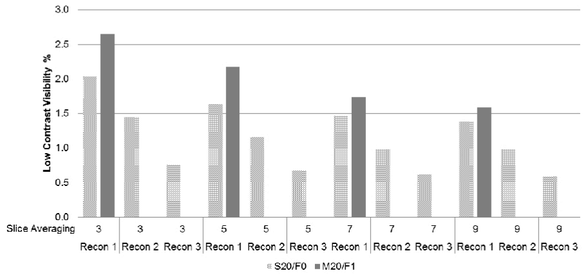

Figure 4: *Low contrast visibility % vs volume preset collimator/filter (F1 is a bowtie filter), slice averaging, and reconstruction presets. Volumes were acquired using 64 mA and 20 mS.*

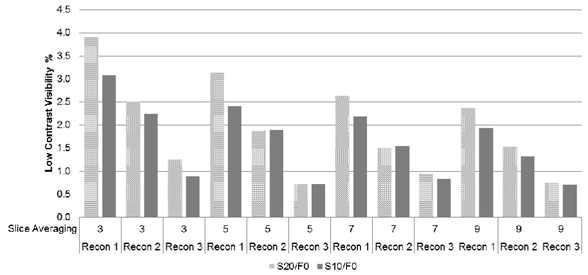

Figure 5: *Low contrast visibility % vs volume preset collimator, slice averaging, and reconstruction presets. Volumes were acquired using 20 mA and 20 mS.*

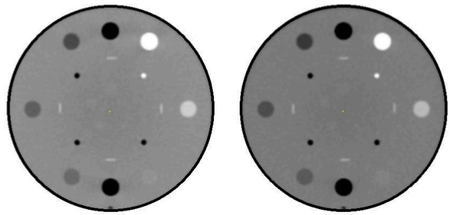

Figure 6

Figure 6: *Example images of the CTP404 module with the following presets: Left – S20/F0, Right – S10/F0 collimator/filter combinations. Both were reconstructed with Recon 3 and 3 slice averaging and captured with the same window/level.*

CONCLUSIONS

Using trends inferred from the study data, the recommended optimal combination should utilize the smallest collimator size and high slice averaging. The relative impact of the use a bowtie filter on low contrast visibility % may be decreased by increasing field size and needs further investigation. Further investigation is also needed to address the impact of the reconstruction algorithms for varying combinations with volume presets. This is necessary to identify a clear trend on the low contrast visibility % due to each parameter. Caution should be exercised with parameter changes that deviate significantly from clinical presets, especially when applied to a patient as opposed to this proof-of-concept phantom study. Further investigation is necessary with the proposed optimal combination with the Catphan phantom, other anatomically relevant phantoms, and patients with abdominal tumors.

REFERENCES

Catphan® 503 Manual, The Phantom Laboratory, 2017.
SVI R5.0 Customer Acceptance Tests, Elekta, Document ID 1503162 02, 2015.

CONTACT INFORMATION

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