

Truebeam Hypersight Hounsfield Unit Accuracy for Dose Calculation

Bradford Vecchione¹, Nick Lowther, PhD¹, Matthew W. Jacobson¹, Thomas C. Harris, PhD¹, Marios Myronakis, PhD², Dianne M. Ferguson, PhD¹, Francois de Kermenguy, PhD¹, Ross I. Berbeco, PhD¹, Yue-Houng Hu, PhD¹

(1) Brigham and Women’s Hospital, Dana-Farber Cancer Institute, Harvard Medical School (2) Medical Physics Department, Medical School, University of Thessaly, Larissa, Thessaly, Greece

Introduction

- Cone Beam CT imaging with the TrueBeam HyperSight imager advertises image quality with Hounsfield Unit accuracy comparable to traditional fan beam simulation CT imagers.
- An improved scatter rejection model is suggested to increase dosimetric accuracy to be comparable with fan beam CT imaging.
- Improved daily imager accuracy could avail the development of online adaptive radiotherapy directly utilizing CBCT imaging.

Methods and Materials

- The HyperSight imager was calibrated and evaluated at 125 and 140 kVp scan potentials. A Gammex model 467 plug phantom was used for calibration.
- Treatment plans calculated on HyperSight and Simulation CT image volumes were compared using a range of gamma analysis criteria (Eq. 1) from 3%/2mm to 1%/1mm. Planning was done in Eclipse treatment planning software.

$$\gamma = \min\left(\sqrt{\frac{DTA^2}{\Delta DTA^2} + \frac{\%DD^2}{\Delta\%DD^2}}\right) \quad (1)$$

Results

- Phantom measurements yielded a gamma pass rate of 99.97% and 99.95% for 1%/1mm criteria.
- Patient measurements averaged a pass rate of 98.94% for 1%/1mm criteria for a current group size of 10 patients.

Conclusions

- Dose calculated directly on a HyperSight CBCT imager is comparable to that done traditionally on simulation CT. This could direct new workflows for online adapative radiotherapy, where up-to-date patient anatomy has accurate density reconstruction in the daily CBCT.

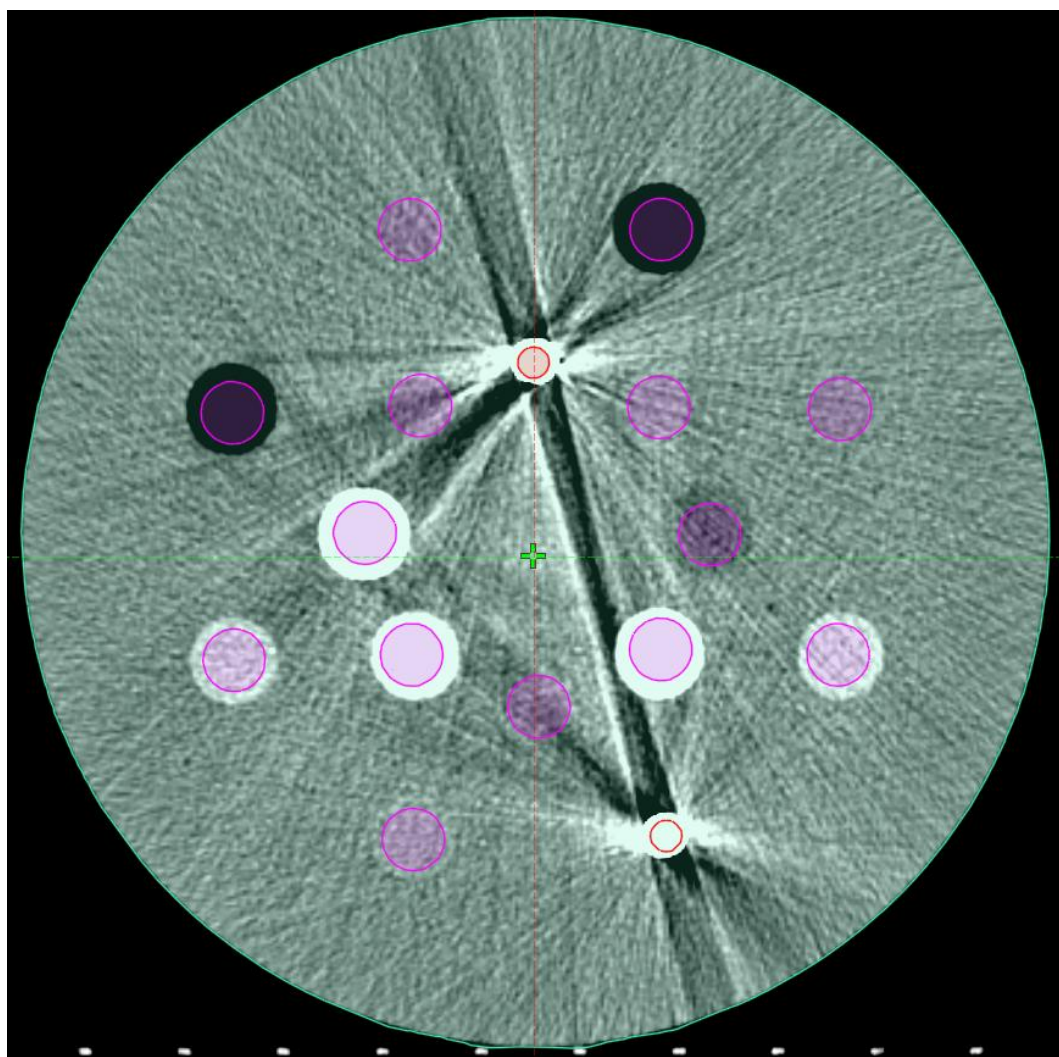


Fig 1: TrueBeam Calibration setup (Left) utilizing Gammex model 467 plug phantom (Middle). 125 kVp image shown (Right) containing high density core and titanium plugs and tissue plugs ranging from 0.28 to 1.69 relative electron densities.

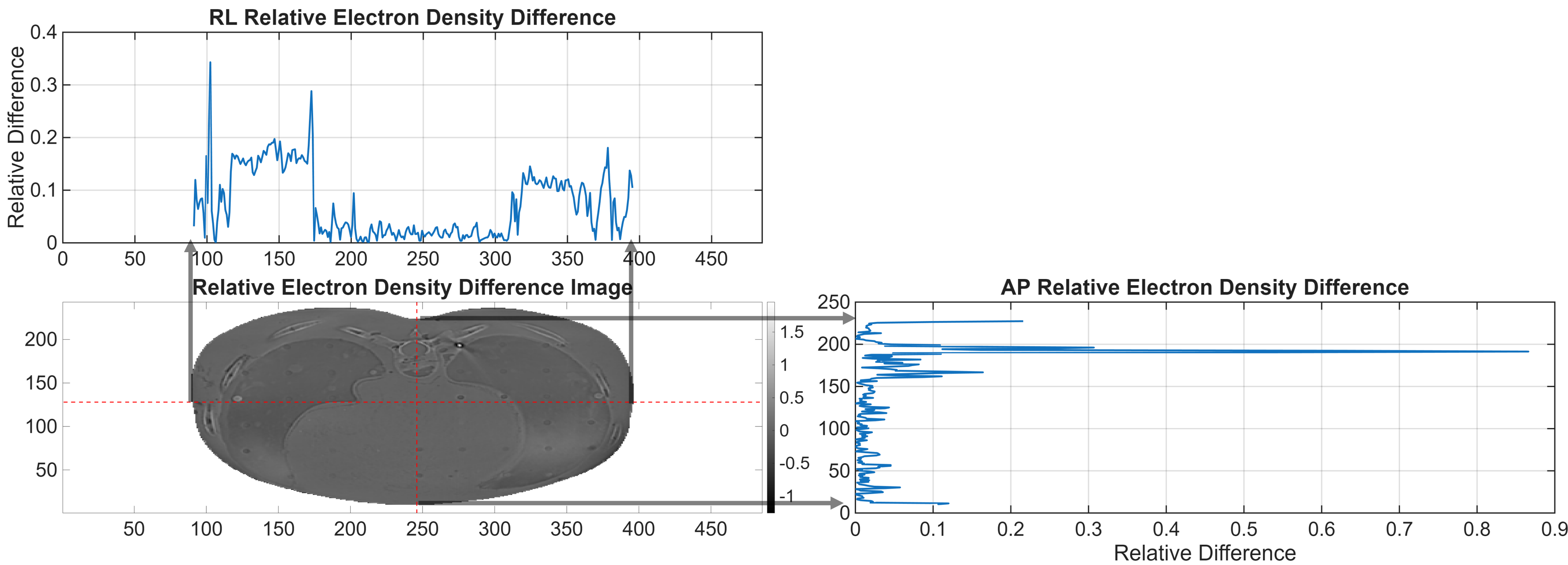


Fig 3: Phantom relative electron density difference plot imaged at 125 kVp HS showing the magnitude of the subtraction map between HyperSight and simulation CT image volumes. Bony structures prove most difficult for this comparison due to registration imperfections magnified. Phantom measurements yield a RMSE of 0.055 and 0.054 relative electron densities for 125 and 140 kVp respectively. Patient measurement gave a RMSE of 0.084 relative electron density.

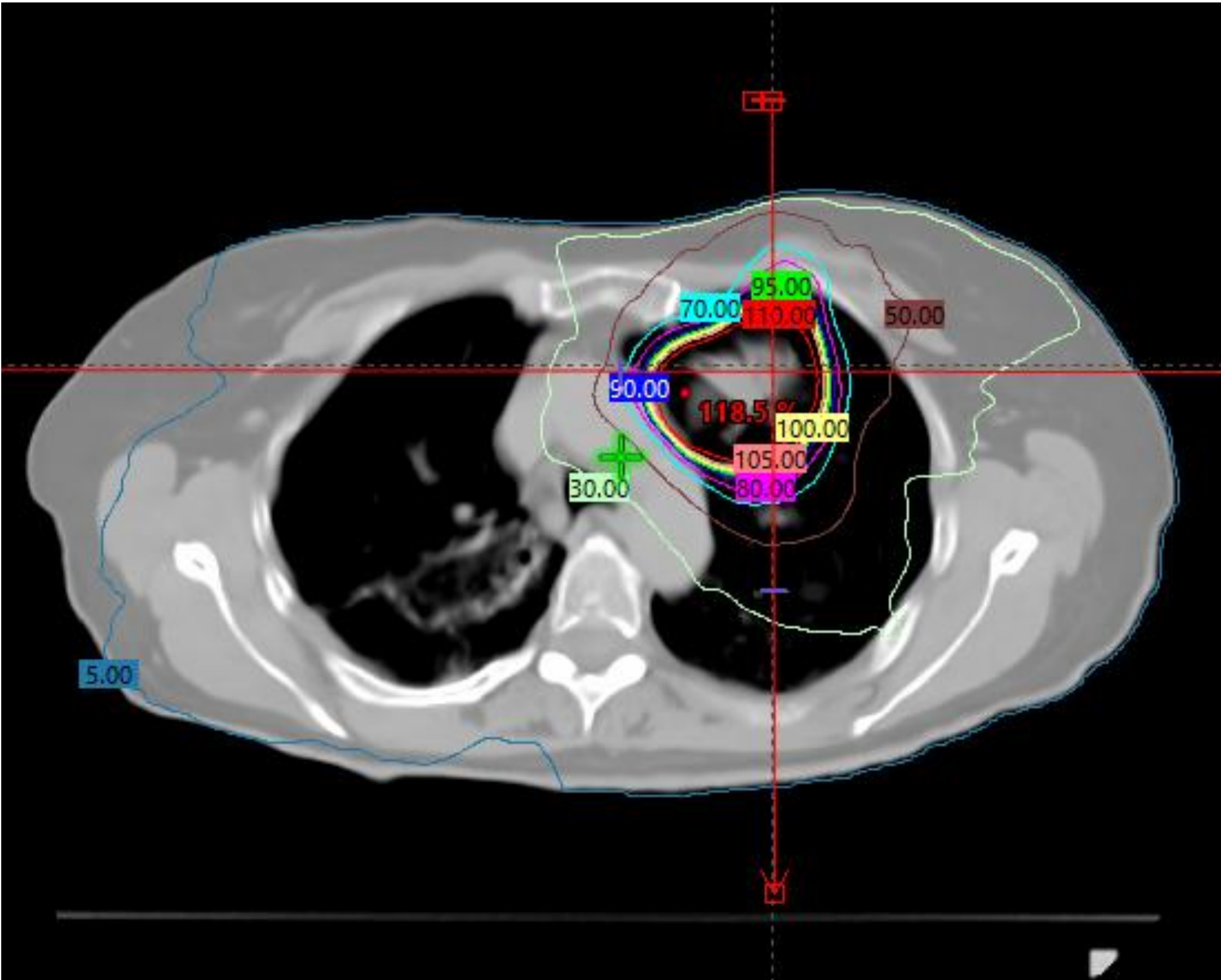
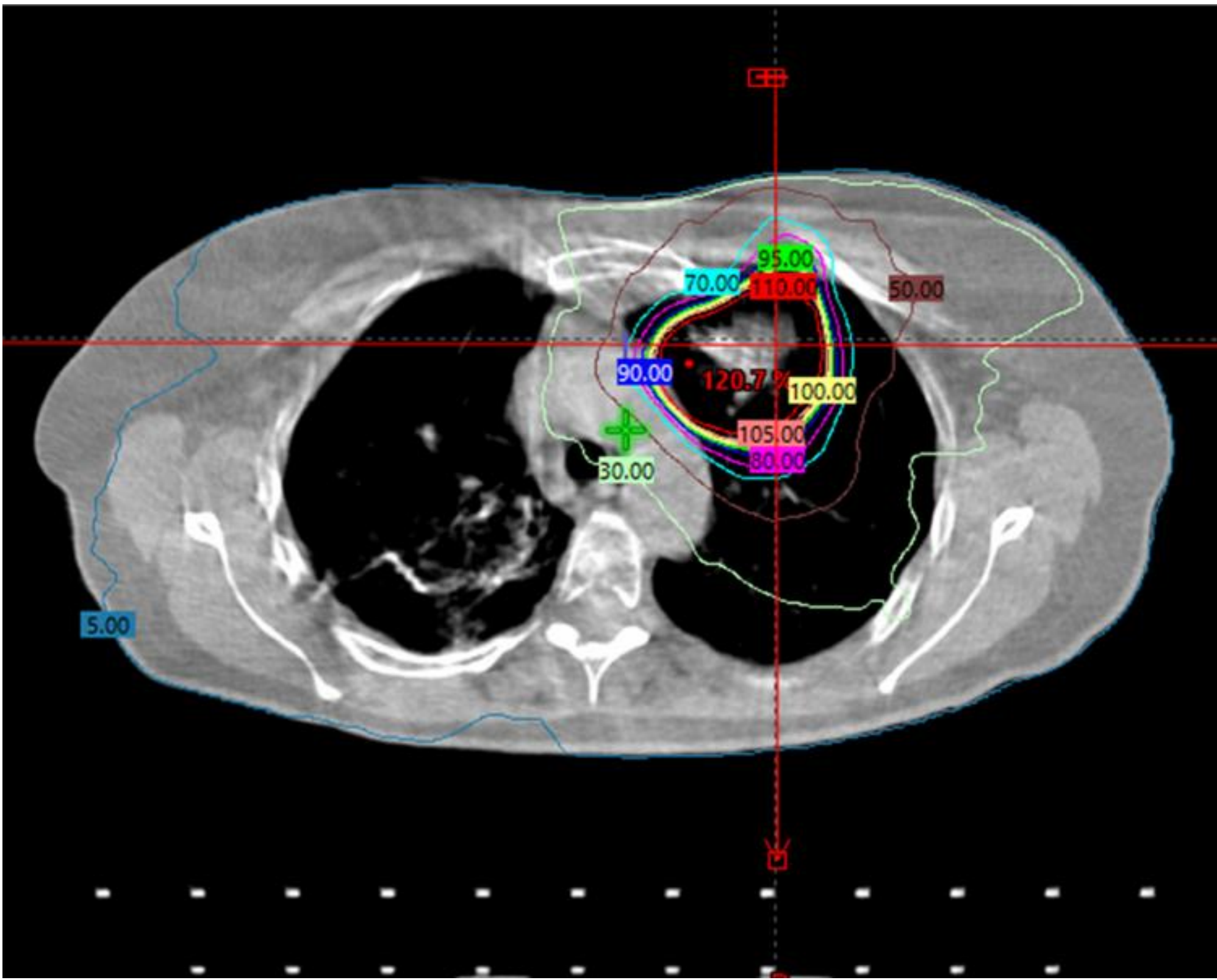


Fig 4: Deformed CBCT image (Left) and reference CT Simulation (Right) dose volumes (Typ.) used for DVH and Gamma analysis

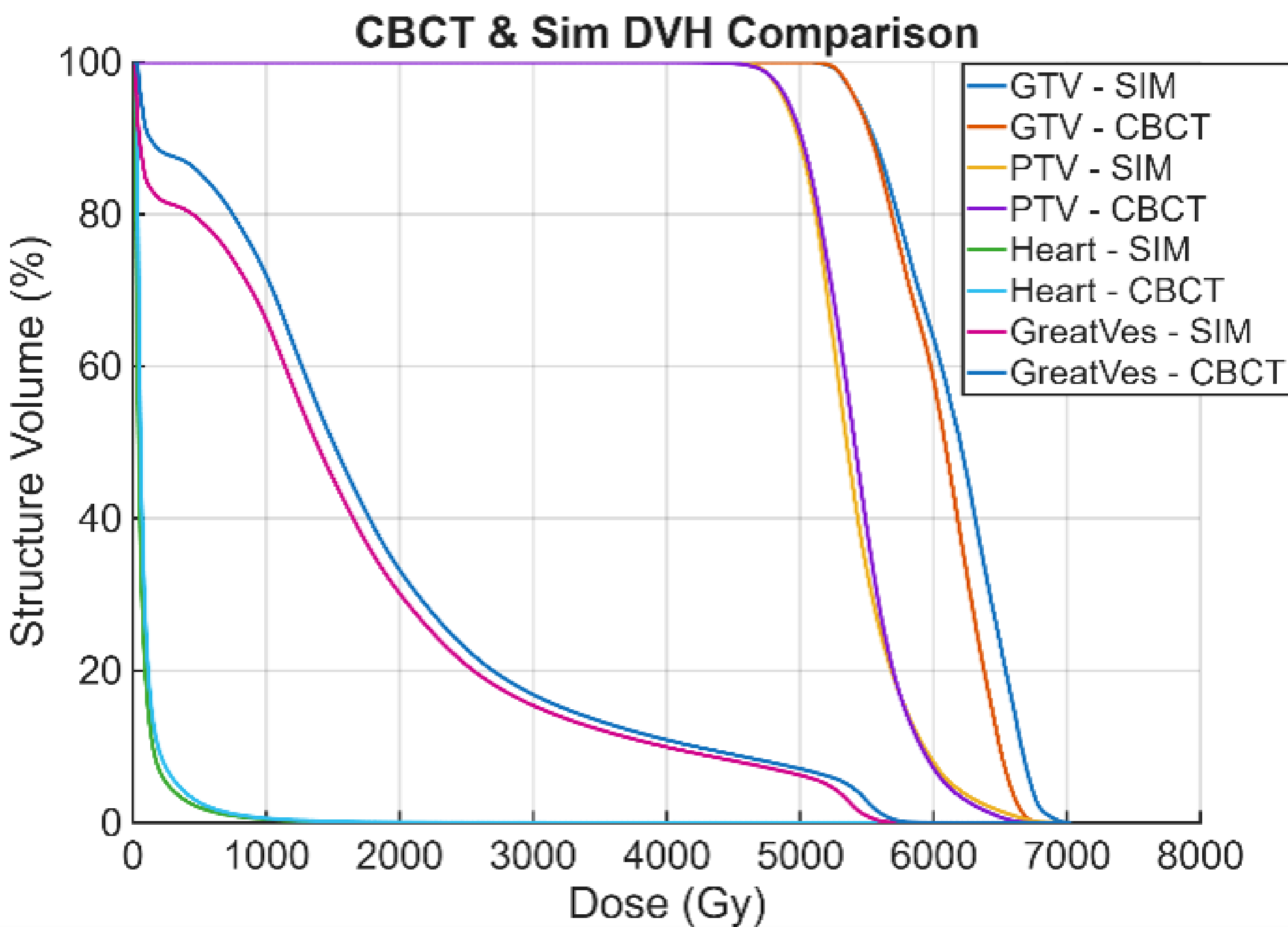


Fig 6: Dose Volume Histogram for GTV, PTV, Heart, and Great Vessels in sample patient. Contours were copied from Sim to the deformed CBCT volume, so volume is equivalent but anatomy contained depends on registration accuracy.

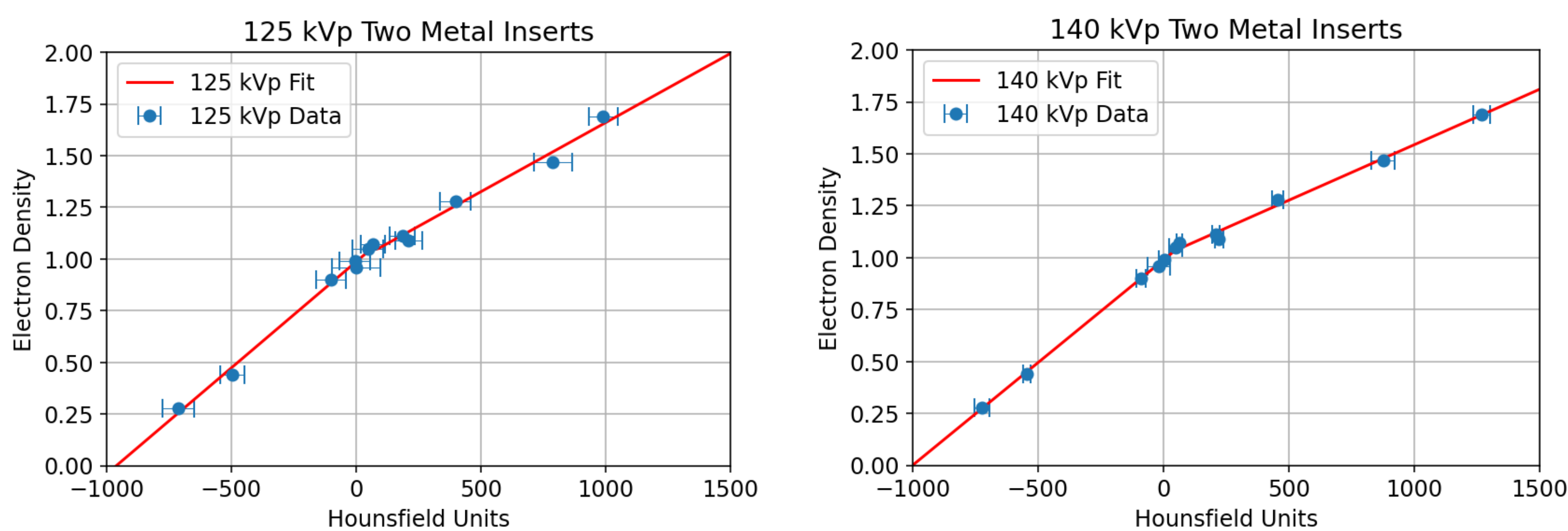


Fig 2: Bi-linear HU-ED calibration curves for HyperSight imager at 125 and 140 kVp. Calibration used for dosimetric calculations done in Eclipse treatment planning software.

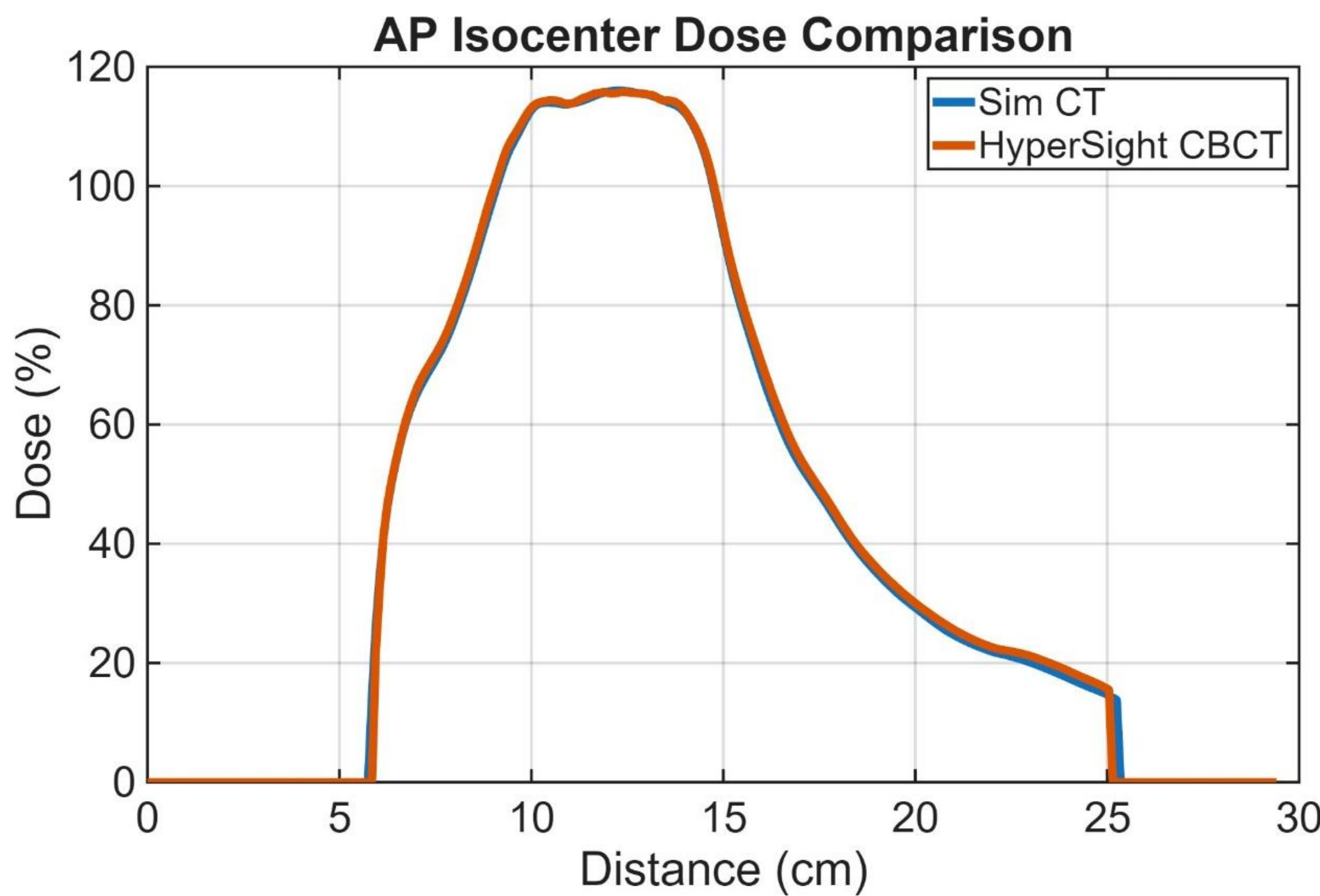
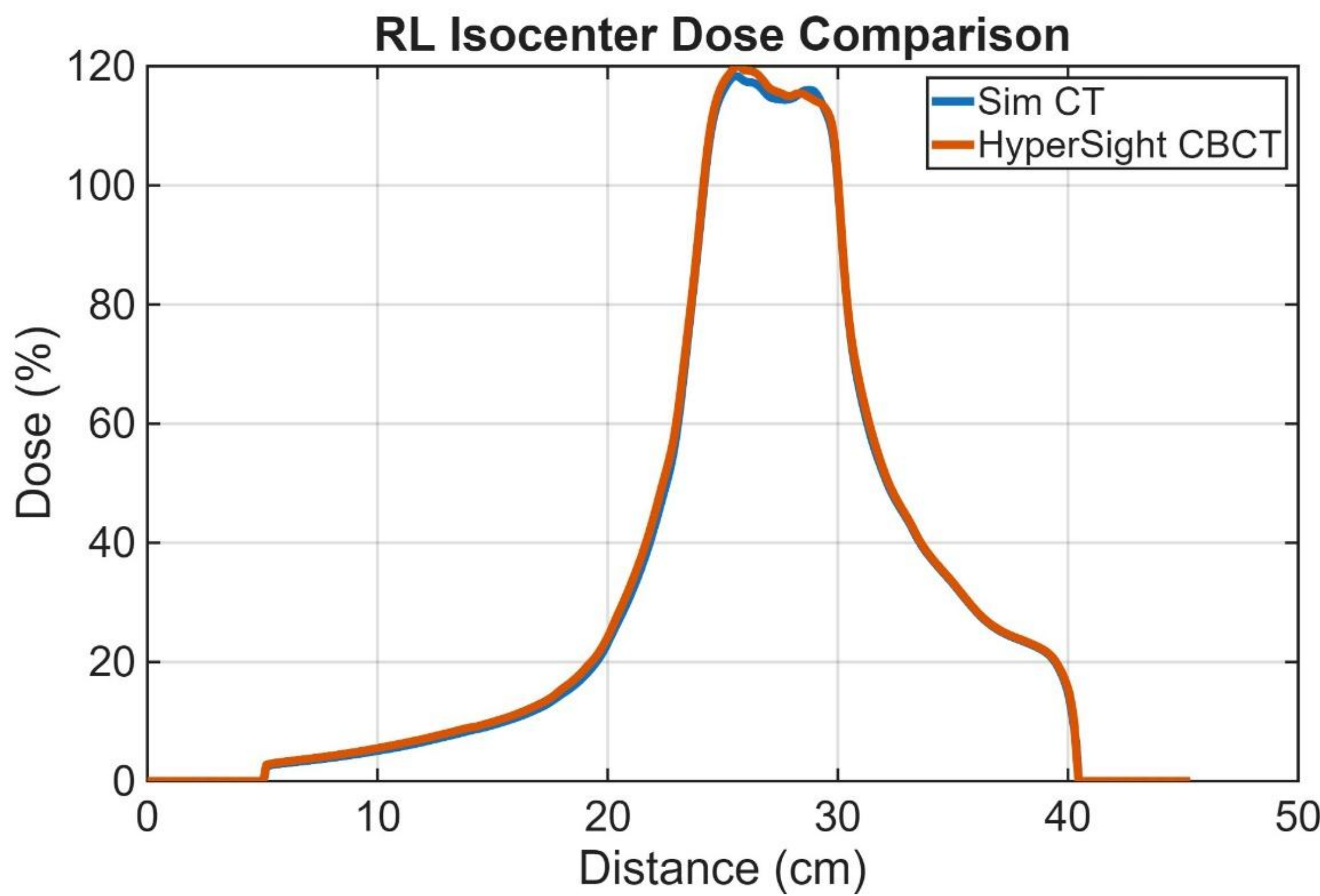


Fig 5: Dose profiles through isocenter (Fig 3 red line). Root mean square difference between HyperSight and Simulation profiles were 0.79% & 1.46% for RL (top) and AP (bottom) respectively.

Table 1: Gamma results for patient average and phantom measurements. Both data sets passed a 1%/1mm 95% pass rate with 10% global dose threshold. Currently 10 patients have been evaluated. Measurements with a stricter 80% global dose threshold (TH) were also evaluated, yielding a drop from ~99% to ~87% with 1%/1mm criteria. High dose thresholds focus on high dose target regions only, and neglect data in surrounding affected tissue.

10% Global Threshold		Gamma Pass Rate				
Subject	Energy	3%/2mm	2%/2mm	2%/1mm	1%/2mm	1%/1mm
Patient Average	125 kVp	99.95%	99.91%	99.61%	99.74%	98.94%
Patient Average (80% TH)	125 kVp	98.92%	97.90%	94.10%	95.12%	86.67%
Phantom	140 kVp	100.00%	100.00%	100.00%	100.00%	99.97%
Phantom	125 kVp	100.00%	100.00%	100.00%	99.99%	99.95%