Validation of a Commercial Continuous Hounsfield Unit (HU) Pelvis Synthetic CT Platform for MR-only Prostate Radiotherapy Treatment Planning

Memorial Sloan Kettering Cancer Center

Victoria Yu, Margie Hunt, Laura Cervino, Antonio Damato, and Neelam Tyagi

Department of Medical Physics, Memorial Sloan Kettering Cancer Center, New York, New York, USA

Purpose

MRCAT (MR for Calculating ATtenuation) Prostate, a commercial synthetic CT solution with bulk density assignment, is routinely utilized in our clinical workflow for MR-only prostate radiotherapy. In this study, we evaluate the Hounsfield Unit (HU) assignment and dosimetric accuracy of MRCAT-General Pelvis, an extended version with continuous-HU assignment, for clinical use.

Methods

MRCAT Prostate and MRCAT General Pelvis images were acquired on a Philips 3T Ingenia MR-RT simulator for 8 patients receiving MR-only prostate radiotherapy to compare dosimetric differences between the two versions. Acquisition parameters are shown in Table 1. To evaluate HU differences between the two methods and CT as the ground truth, for the two patients that also had full CT acquired, voxel-by-voxel correspondence was established between all three scans through deformable image registration performed in MIM Vista and Mean absolute error (MAE) for soft tissue region, bone, and total body contours were calculated. Similarity between CT-derived and SynCT-derived DRRs was evaluated by computing the Pearson correlation coefficients between the DRRs. Dosimetric comparison was performed by recalculating clinical VMAT plans on the MRCAT-General Pelvis synthetic-CT and associated CT after rigid registration. Plans varied between hypofractionated and standard fractionation for prostate or prostate with lymph nodes. Dose metrics for the target volumes and surrounding organs-at-risk (OAR) were compared. Digitally reconstructed radiographs (DRR) were generated and qualitatively compared among the CT and the two synthetic-CT methods. The Pearson correlation coefficient between the DRRs generated from the CT and continuous HU MRCAT General Pelvis synthetic CT were calculated to examine DRR similarity.

Synthetic CT generation MR sequences		
	MRCAT Prostate	MRCAT General Pelvis
	Bulk density	Continuous HU
Sequence type	3D dual echo mDixon fast field echo (FFE)	
FOV (AP,LR,HF)	(36.8, 55.2, 30) cm^3	(36.8, 55.2, 36) cm^3
Bandwidth	1072 Hz	866.3 Hz
TR/TE1/TE2	3.8/1.21/2.4 ms	4.7/1.4/2.8 ms
Acq voxel size	(1.7, 1.7, 2.5) mm^3	(1.4, 1.4, 1.4) mm^3
Recon voxel size	(1, 1, 2.5) mm^3	(1.14, 1.14, 1.14) mm^3
# Stacks	1	2

Table 1: MR sequence parameters for synthetic CT generation

Tissue	HU values
Air	-968
Fat	-95
Soft Tissue	34
Spongy Bone	152
Compact Bone	803

Table 2: MRCAT Prostate HU assignments

Acknowledgment

This study was performed in collaboration with Philips Healthcare under a masters research agreement

Results

Improved HU agreement to CT was shown for MRCAT General Pelvis, as demonstrated by the visual synthetic CT and DRR comparison to CT (Figure 1), and example profile comparison (Figure 2). Significant improvements are also shown in MAE of Bone, soft tissue, and body (Table 3). No significant dosimetric differences were observed between the two synthetic CT generation methods. (Figure 3, Table 5)

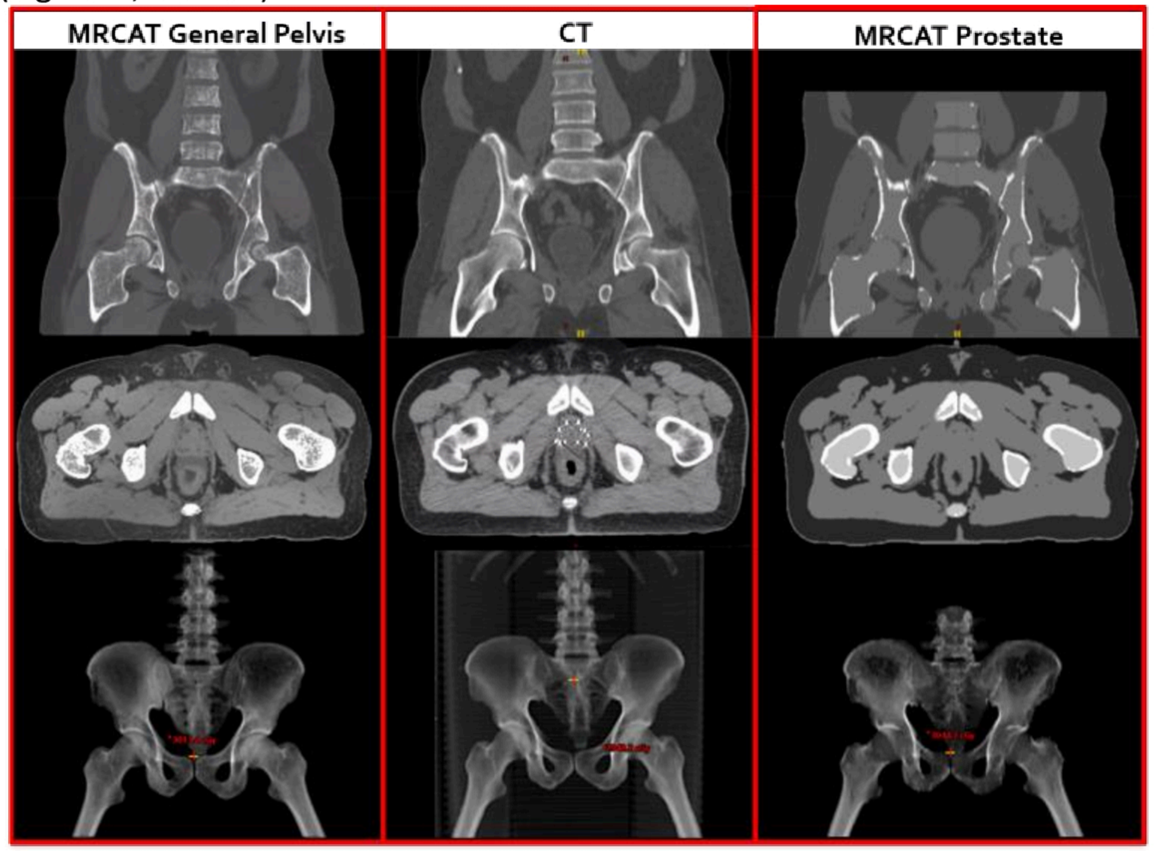

Figure 1: Comparison between CT and MRCAT General Pelvis and MRCAT Prostate synthetic CTs, and all associated DRRs

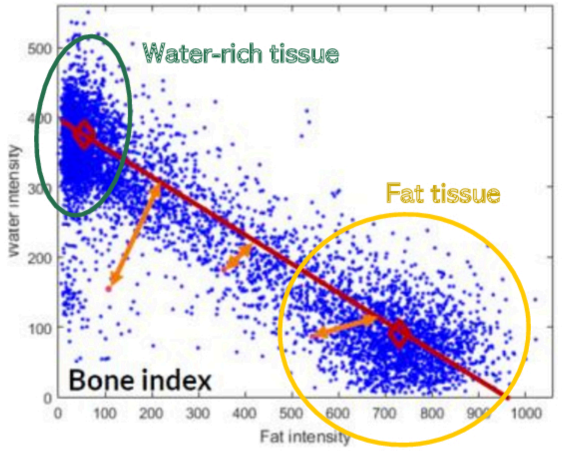

Figure 4: intensity based HU classification using voxel intensities in the fat and water mDixon MR source images. Soft tissue voxels are mapped continuously between the water and fat clusters (cluster centers indicated by red diamond). Voxels within the bone mask classified based on the distance of the voxels from the water-fat classification line (Red). Example bone voxel classifications (orange). Courtesy of Philips Healthcare

Mean Absolute Error (MAE) with respect to CT (HU)				
		Bone	Soft Tissue	Body
Patient 1	General Pelvis	125.42	32.51	38.05
	Prostate	137.07	39.64	45.95
Patient 2	General Pelvis	108.11	32.18	37.03
	Prostate	148.42	37.67	44.83

Table 3: MR sequence parameters for synthetic CT generation.

Pearson Correlation Coefficent		
	AP DRR	RLAT DRR
Patient 1	0.949	0.968
Patient 2	0.977	0.985

Table 4: Pearson correlation coefficient between CT and MRCAT General Pelvis DRRs

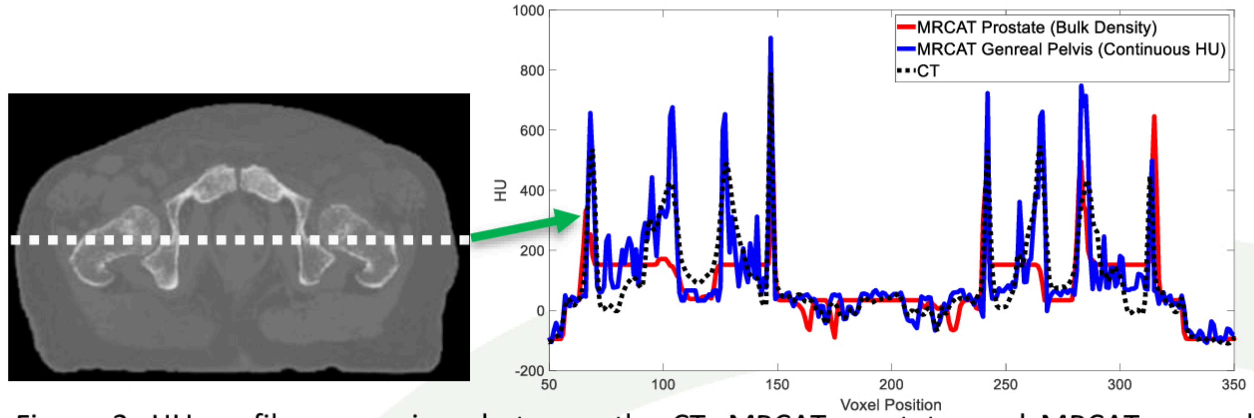

Figure 2: HU profile comparison between the CT, MRCAT prostate, and MRCAT general pelvis scans from an example patient. MRCAT Prostate bulk density method in red, MRCAT general pelvis continuous HU in blue, CT profile shown as black dashed line. Continuous HU method more closely mimics the fluctuations shown from the gold standard CT scan.

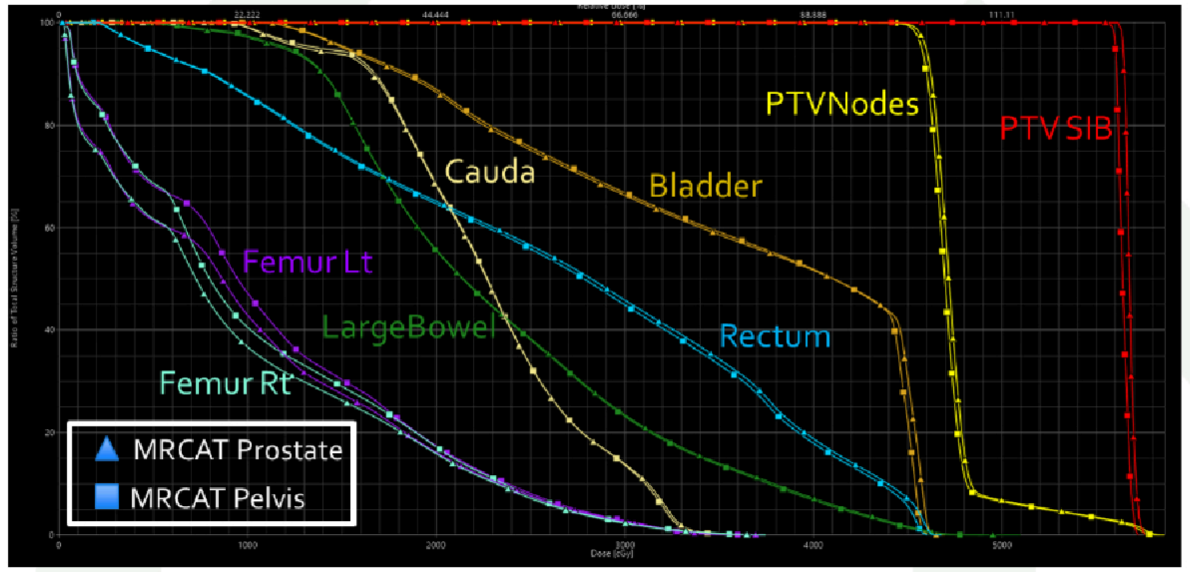

Figure 3: Example DVH comparing MRCAT Prostate and MRCAT Pelvis

OAR and Target volume average % dose difference: MRCAT Pelvis - MRCAT Prostate (%)								
Rectum	Dmax	-0.22	Urethra	Dmax	-1.02		PTV	CTV
	Dmean	-0.32		Dmean	-0.42	D95	-0.77	-0.90
Femur Lt	Dmax	-0.28	Large Bowel	Dmax	0.86	Dmax	-0.30	-0.45
Femur Rt	Dmax	-0.80	Body	Dmax	-0.31	Dmean	-0.65	-0.70
Bladder	Dmax	-0.32	Cauda	Dmax	-1.27			
	Dmean	-0.73						

Table 5: Dose differences on key OAR and target dose metrics between MRCAT General Pelvis and MRCAT Prostate

Conclusion

The continuous HU MRCAT General Pelvis provides more accurate synthetic CTs and DRRs, and is dosimetrically comparable to the currently utilized MRCAT Prostate with bulk density assignments. The generalizability of the method to other pelvic disease sites and increased superior-inferior coverage allows for further expansion of MR-only treatment planning and delivery.