Toward daily dose tracking for adaptive therapy: feasibility of using Monte Carlo dose calculation on corrected CBCT images

Lamba N, B.S.[1], Pittock D, B.S.[1], Ginsburg S, Ph.D.[1], Darkow D, B.S.[1], Bonsall H, M.S.[2], Fung WWK, M.Phil.[3], Man HMC, B.S.[3], Kruzer A, B.S.[1], Nelson AS, M.D.[1]

1 MIM Software Inc., Cleveland, OH, United States

2 RBS Evolution, Pleasant View, TN, United States

3 Hong Kong Sanitorium & Hospital, Happy Valley, Hong Kong

Purpose/Objectives

Accurate dose computation on daily CBCT is needed for adequate dose tracking of target volumes and organs at risk in the context of adaptive radiation therapy.[1] However, CBCT intensity values do not properly match standard Hounsfield Units (HU). This negatively affects the accuracy of dose calculations performed on them. Additionally, daily CBCT images have small fields of view (FOV), which may obscure anatomy that needs to be tracked during daily adaptive therapy.

This study evaluates a slope-intercept model for correcting CBCT HU intensities in order to calculate dose directly on daily CBCT images. This approach is intended to improve the accuracy of daily dose tracking as either a standalone correction method or a part of a larger correction process.[2]

Materials/Methods

A planning CT (pCT) and a CBCT acquired close in time to the pCT (mean 6 days; range 2 to 12) were selected from 20 patients across multiple centers and treatment areas. This cohort consists of 4 head and neck, 6 pelvis, 5 thorax, and 5 abdomen subjects. To create a reference dose, the dose was calculated on the pCT using a commercially available Monte Carlo-based algorithm.[3] For the CBCT correction method, the CBCT intensity values were adjusted by modifying the rescale slope and intercept for all voxels in the body. The corrected CBCT was then deformably stitched with the pCT by deforming the anatomy on the pCT to the anatomy on the CBCT in the proximity of the CBCT FOV. All deformable registrations were performed using a commercially available multi-modality deformation algorithm.[4]

The original plan was transferred from the pCT to the deformed merged pCT/corrected CBCT. Doses were calculated on all test series using the same Monte Carlo-based algorithm.

DVH statistics were calculated on target and avoidance structures for the reference series and the test series. The regional dose mean and max absolute differences were calculated and then averaged for each treatment area. Gamma was evaluated with both 2%/2mm and 3%/3mm criteria for all patients. The volume was divided into high and low dose regions using a threshold of 15% of the max dose.Local gamma analysis was performed in the high dose region and global gamma analysis in the low dose region.[5] A line profile was generated on the pCT, the CBCT, and the corrected CBCT in the same region to show the change in HU values using the correction method.

Table 1

	Absolute Difference in Mean Dose (Gy)	Absolute Difference in Max Dose (Gy)
Abdomen GTV/PTV	0.08 +/- 0.35	0.89 +/- 0.43
Abdomen Avoidance	0.13 +/- 0.17	0.51 +/- 0.46
Thorax GTV/PTV	1.68 +/- 1.22	2.46 +/- 2.67
Thorax Avoidance	0.15 +/- 0.23	0.54 +/- 0.69
Pelvis GTV/PTV	1.02 +/- 1.01	1.39 +/- 1.33
Pelvis Avoidance	0.40 +/- 0.58	0.89 +/- 0.98
H&N GTV/PTV	0.11 +/- 0.08	0.12 +/- 0.10
H&N Avoidance	0.04 +/- 0.06	0.09 +/- 0.13

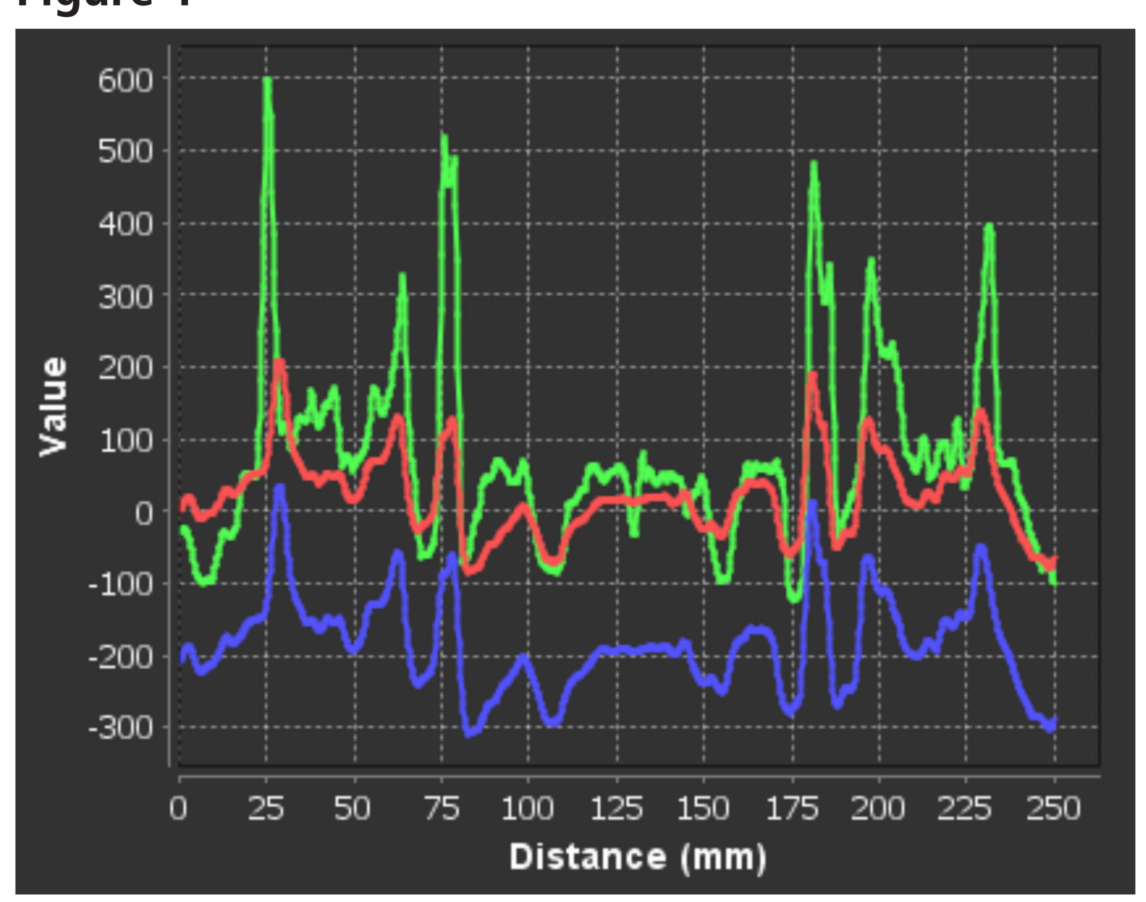
DVH Statistics - Absolute Difference from Reference

Table 2

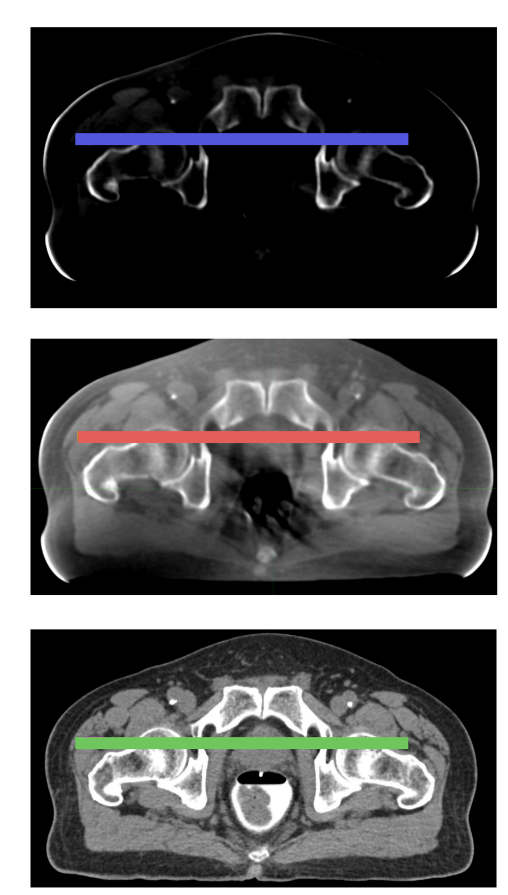
2%/2mm High Dose Region	2%/2mm Low Dose Region	3%/3mm High Dose Region	3%/3mm Lose Dose Region
94.5 +/- 5.1	99.8 +/- 0.6	98.3 +/- 2.6	99.9 +/- 0.5

Gamma Analysis Results

Figure 1



Line Profile Comparison



Line Profile on Original CBCT

Line Profile on HU-Corrected CBCT

Line Profile on Reference pCT

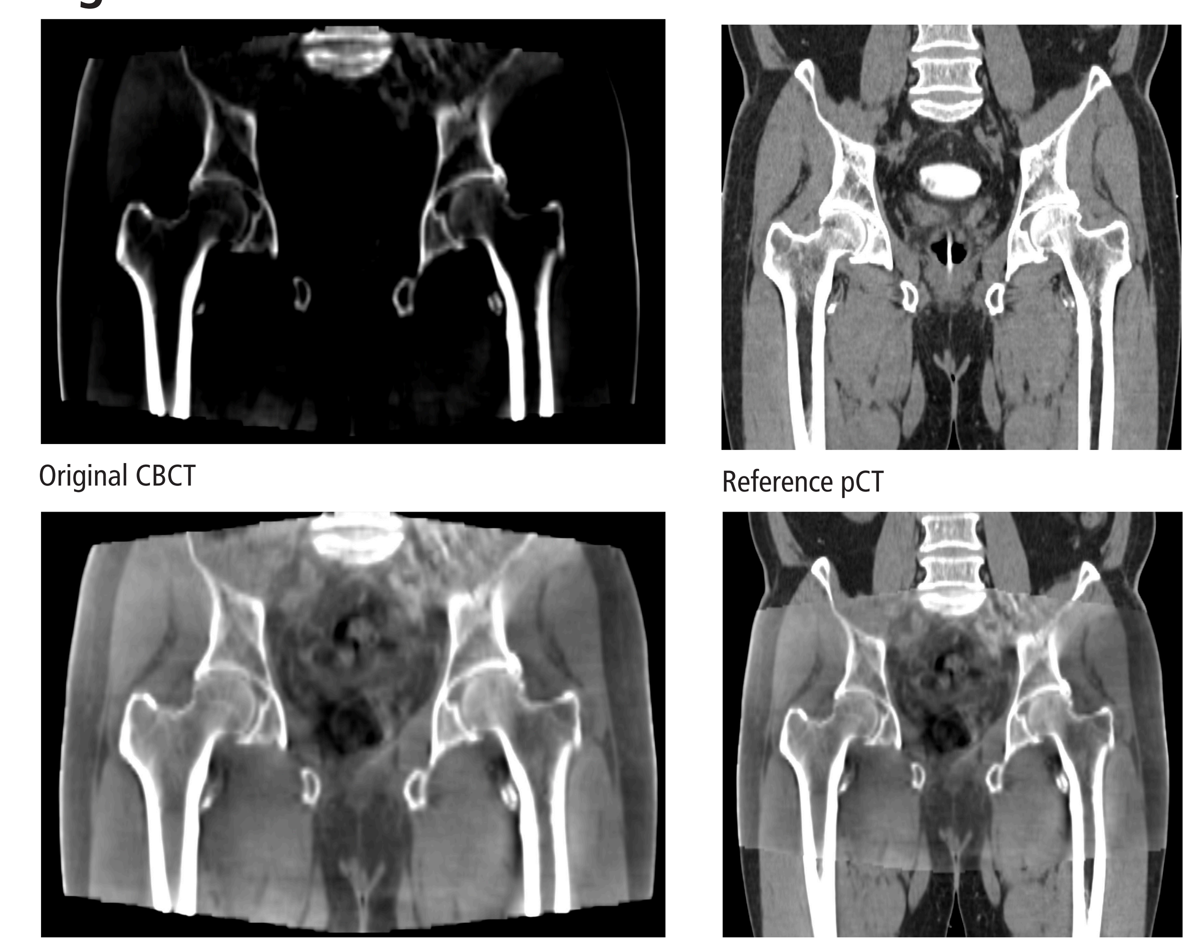
Results

The DVH statistics for the target and avoidance regions in each treatment are are shown in Table 1. The abdominal avoidance region group refers to the kidneys, the liver, the bowels, the spinal cord, and the stomach. The thorax avoidance region group refers to the heart, the lungs, the esophagus, the spinal cord, and the trachea. The pelvis avoidance region group refers to the bladder, the bowels, the rectum, and the femoral heads. The head and neck avoidance region group refer to the brain, the eyes, the spinal cord, the mandible, and the parotids. The specific diseased region was not considered in the calculation of the statistics for each avoidance region group.

The Gamma pass rates are shown in Table 2. The deformed merged pCT/corrected CBCT demonstrated similar results to the reference dose.

The line profiles are shown in Figure 1. The line profiles show that the slope-intercept model is correcting the HU values of the CBCT to the same range as the pCT.

Figure 2



Original CBCT

Reference pCT

HU-Corrected CBCT

Deformed Merged pCT/Corrected CBCT

Summary/Conclusion

The slope-intercept model for HU correction performed well in this experiment and would be viable for daily dose tracking during radiation therapy. In addition to the ability to perform accurate dose calculation, this method also has the advantage of retaining the original CBCT anatomy on the image on which dose calculation is performed.

References

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Contact Information

Nathan Lamba, Clinical Engineer

Phone: 216-455-6088

Email: nlamba@mimsoftware.com