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Comparison of two CBCT correction methods for daily adaptive therapy dose tracking

Pittock D, B.S.[1], Lamba N, B.S.[1], Ginsburg S, Ph.D.[1], Dragojevic I, Ph.D.[2], Kruzer A, B.S.[1], Nelson AS, M.D.[1]

1 MIM Software Inc., Cleveland, OH, United States
2 UC San Diego, Chula Vista, CA, United States

MIM SOFTWARE.

INTRODUCTION

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) and may also contain shading artifacts, which negatively affect 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.

AIM

This study evaluates two methods for correcting CBCT HU intensities in order to calculate dose directly on daily CBCT images. A third approach using a deformed planning CT as a surrogate for the CBCT is also reviewed. These approaches are intended to improve the accuracy of daily dose tracking.

METHODS

A planning CT (pCT), a replan CT (rCT), and a CBCT acquired close in time to the rCT (mean 3 days; range 0 to 10) were selected from 25 patients across multiple centers and treatment areas. This cohort consists of 9 head and neck, 7 pelvis, 6 thorax, and 3 abdomen subjects. To create a reference dose, the original plan was transferred to the rCT (used as a reference series) and the dose was calculated on the rCT using a commercially available Monte Carlo-based algorithm.[2] For the two CBCT correction methods, the shading artifacts were estimated and suppressed. Then, the CBCT intensity values were adjusted by either modifying the rescale slope and intercept for all voxels in the body (**C1 method**), or the pCT was deformed to the CBCT and HU values were bulk-assigned into air, soft tissue, and bone classes based on the deformed pCT's HU values (**C3 method**). For both methods, the corrected CBCTs were then deformably stitched with the pCTs by deforming the anatomy on the pCT to the anatomy on the CBCT in the proximity of the CBCT FOV. The third method (**DpCT**) deformed the pCT to the CBCT in the FOV of the CBCT and replaced the same FOV in the original pCT with the deformed pCT. All deformable registrations were performed using a commercially available multi-modality deformation algorithm.[3]

The original plan was transferred to the C1, C3, and DpCT series. Doses were calculated on all test series using the same Monte Carlo-based algorithm.

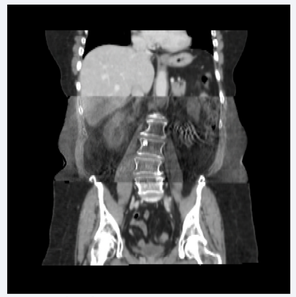
DVH statistics were calculated on target and avoidance structures for the reference series and each test series. The regional dose mean and max absolute differences were calculated and then averaged for prostate and head and neck patients. Gamma was evaluated with both 2%/2mm and 3%/3mm criteria for all patients. The volume was divided into high and low dose regions using a threshold of 15% of the max dose.[4] Local gamma analysis was performed in the high dose region and global gamma analysis in the low dose region.

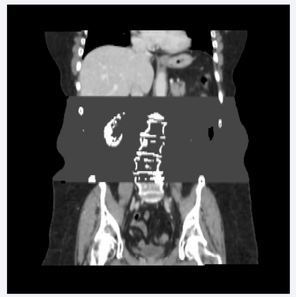
RESULTS

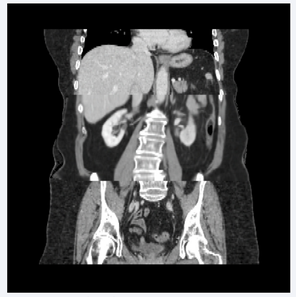
The DVH statistics for prostate and head and neck targets and avoidance regions are shown in Table 1. The prostate avoidance region group refers to the bladder and rectum, and the head and neck avoidance region group was comprised of the brainstem, spinal cord, mandible, and left and right parotids.

The Gamma pass rates are shown in Table 2. The three methods demonstrated similar results to the reference dose.

Figure 1


C1 Method


C3 Method


DpCT Method

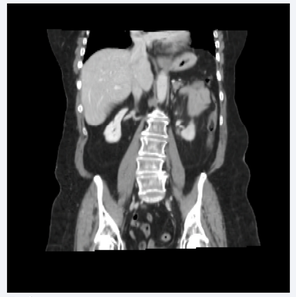

Reference

Table 1

Common Contours	C1 Mean	C3 Mean	DpCT Mean	C1 Max	C3 Max	DpCT Max
Prostate	1.09 +/- 1.30	1.11 +/- 1.49	0.55 +/- 0.65	1.13 +/- 1.17	1.09 +/- 1.33	0.55 +/- 0.62
Prostate Avoidance	3.80 +/- 2.88	3.84 +/- 2.90	3.78 +/- 3.01	0.85 +/- 1.51	1.00 +/- 1.46	0.93 +/- 0.94
H&N GTV	0.84 +/- 0.93	1.03 +/- 0.97	1.34 +/- 1.09	0.82 +/- 0.77	1.62 +/- 1.78	1.42 +/- 1.06
H&N Avoidance	2.08 +/- 2.08	2.07 +/- 2.01	2.04 +/- 2.03	1.52 +/- 1.79	1.62 +/- 1.78	1.70 +/- 1.75

DVH Statistics - Absolute Difference from Reference (Gy)

Table 2

Method	2%/2mm High Dose Region	2%/2mm Low Dose Region	3%/3mm High Dose Region	3%/3mm Low Dose Region
C1	89.3 +/- 7.7	99.3 +/- 1.1	95.2 +/- 5.4	99.5 +/- 0.9
C3	88.5 +/- 8.5	98.7 +/- 1.5	94.3 +/- 5.6	99.3 +/- 0.9
DpCT	89.4 +/- 9.0	99.2 +/- 1.2	94.6 +/- 6.5	99.4 +/- 0.9

Gamma Analysis Results (%)

CONCLUSION

All three methods 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, the C1 method also has the advantage of retaining the original CBCT anatomy on the image on which dose calculation is performed. The C3 method loses this information through the bulk assignment of HU values. Although the DpCT method accounts for anatomic information, it relies on the accuracy of the deformation performed from the pCT to the CBCT and also contains discontinuities at the boundaries of the CBCT FOV.

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CONTACT INFORMATION

Dane Pittock
Clinical Engineer
dpittock@mimsoftware.com
216-455-6110