CBCT-based Adaptive Intensity Modulated Proton Radiotherapy

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INTRODUCTION

- Intensity-modulated proton radiotherapy (IMPT) is highly sensitive to changes in tumor size, and patient geometry. Therefore, weekly quality-assurance CT scans (QACTs) are commonly used as indicators for adaptive radiation therapy (ART).
- Cone-beam CT (CBCT) is a widely used imaging method that generates 3D information of the patient in treatment position. Inferior image quality and presence of artifacts produce unreliable Hounsfield units which generate erroneous results in proton dose calculation.

AIM

We investigated the feasibility of using:

- deformable registration, and image processing techniques to generate noise-free, and accurate CBCT based virtual planning CTs.
- the reliability of dose calculated on in-situ CBCTs for patients with bulky head-and-neck (HN), abdomen, and pelvis tumors as ART indicator.

METHOD

- Same-day QACT and CBCTs of 10 IMPT patients (pelvis, head & neck, abdomen and lung) were randomly selected and imported into a research version of the clinical treatment-planning system (TPS; RayStation 9B, RaySearch). Each patient had 1-2 QACTs and CBCTs (total: 15). Virtual-CT based plans were created from CBCT scans (Figure 1) and compared to QACT based plans.

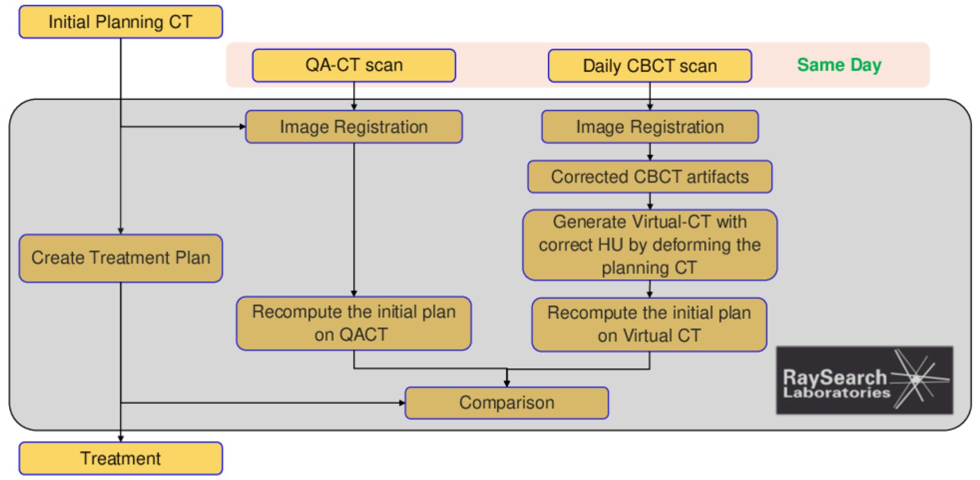

Figure 1. Flowchart of the methodology used to evaluate the virtual CT plans constructed from CBCT scans.

- Differences in clinical target volume (CTV) dose parameters such as D98%, D95%, D2%, mean dose, and V95% were compared between the QACT and virtual CT (CBCT-based) image sets.

RESULTS

- For all 10 patients, the average difference in CTV mean dose, D2%, D95%, D98% and V95% were within 1%.
- Table 1 and Figure 2 present a comparison of dosimetric parameters between QACT and virtual CT (CBCT-based) plans.
- Figure 3 and 4 present case-studies where virtual-CTs accurately indicated need for ART in agreement with QA-CTs.

	Treatment Sites				All (mean ± SD)
	Pelvis (mean ± SD)	Head & Neck (mean ± SD)	Abdomen (mean ± SD)	Lung (mean ± SD)	
D98% difference	0.5% ± 1.0%	-0.2% ± 1.4%	1.8% ± 2.5%	1.8% ± 1.9%	0.8% ± 1.6%
D95% difference	1.2% ± 1.6%	0.2% ± 0.6%	1.2% ± 1.4%	0.7% ± 3.2%	0.8% ± 1.7%
D2% difference	-0.2% ± 0.6%	0.1% ± 0.6%	0.2% ± 1.1%	0.4% ± 1.2%	0.0% ± 0.8%
Mean dose difference	0.5% ± 0.5%	0.2% ± 0.2%	0.7% ± 1.0%	-0.3% ± 0.4%	0.3% ± 0.5%
V95% difference	0.8% ± 0.7%	0.1% ± 0.6%	-0.8% ± 1.8%	0.8% ± 0.3%	0.4% ± 0.9%

Table 1. Comparison of QACT and CBCT based virtual-CT estimated target volume coverage for ten cases (15 scenarios). In all cases, average dosimetric parameters have less than 2% difference between the two image sets.

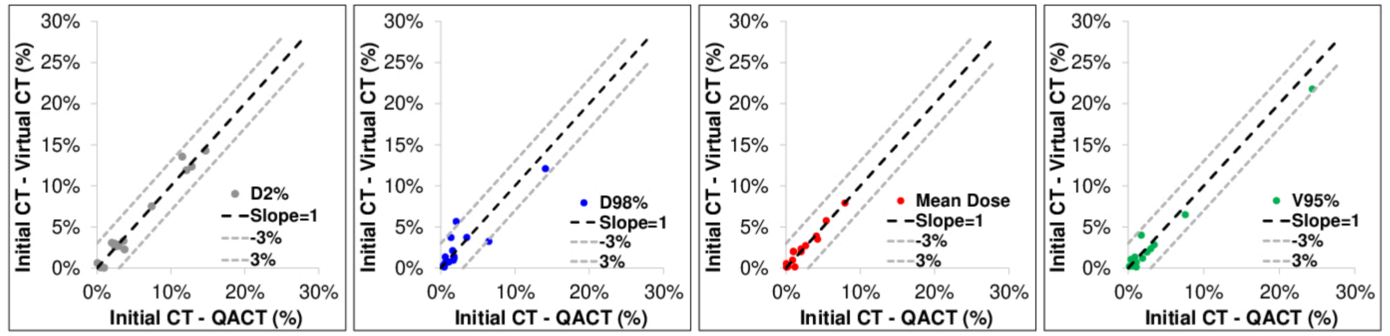

Figure 2. Difference (in %) of the change in target coverage metrics (D2%, D98%, mean dose, and V95%) with respect to the planning CT. For the majority of cases, the difference estimated by QACT and CBCT-based virtual CTs are linear, and lie on the line of unity within a 3% window. The virtual-CT was able to indicate differences with respect to the planning CT.

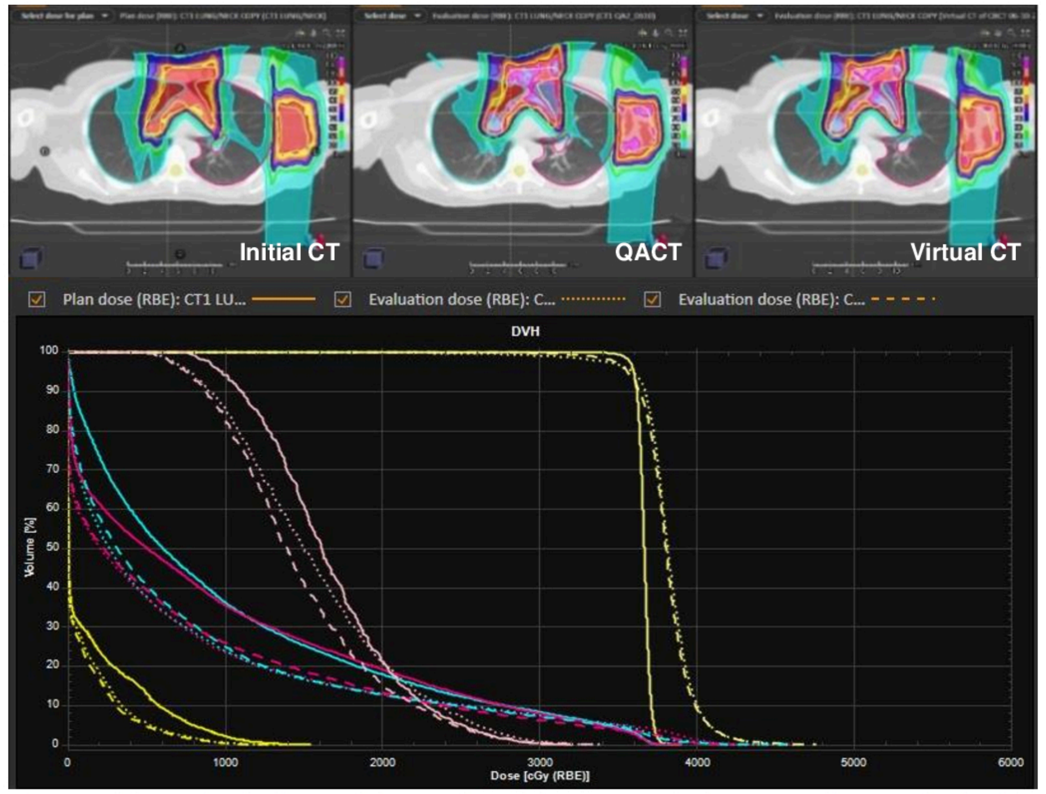

Figure 3. Dose distribution and dose volume histograms of a lung case that required ART. High agreement between the virtual-CT and reference QA-CT were observed. Solid line (planning CT), dotted line (QA-CT), dashed line (CBCT-based Virtual CT).

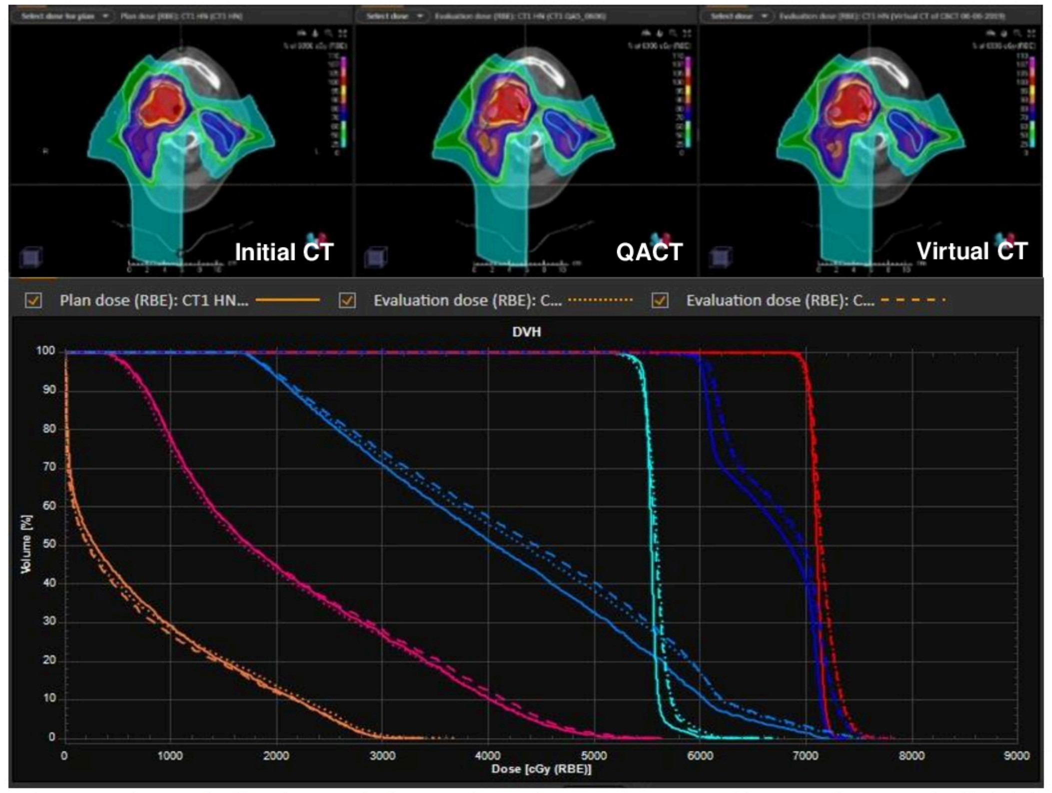

Figure 4. Dose distribution and dose volume histograms of a HN case that required ART. High agreement between the virtual-CT and reference QA-CT were observed. Solid line (planning CT), dotted line (QA-CT), dashed line (CBCT-based Virtual CT).

CONCLUSION

- Our results indicate that the dose calculated on virtual CTs closely matches the current clinical standard-of-care high fidelity quality assurance CT scans.
- CBCT-based dosimetry can be used to evaluate treatment plans, and guide the decision for ART over the treatment course.

CONTACT INFORMATION

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