Direct dose calculation on CBCTs for various treatment sites in adaptive radiotherapy

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Introduction

Online adaptive Radiotherapy (ART) is implemented to enhance the clinical outcome and to improve the quality of life of the patient. The wider use of CBCTs has made online ART available on commonly commercialized treatment machines. In the past the usage of CBCT based dose calculation came along with a considerable effort, like site specific calibrations, averaging over several machines, density overrides etc[1]. Current technologies often rely on synthetic CTs created by AI, density overrides, or by deforming the planning CT to the CBCT of the day. Although highly sophisticated, these techniques introduce their intrinsic uncertainties to the final dose distribution. This study tests whether introducing iterative CBCTs (iCBCT) has decreased the complexity of calibration enough to allow for a direct CBCT dose calculation in daily clinical routine eliminating the uncertainties of artificial CTs.

Materials & Methods

Three different anthropomorphic phantoms were used to gain a comprehensive overview and to discover site specific drawbacks: CIRS (Asbury, USA) Model 801-P for prostate, Kyoto Kagaku's (Kyoto, Japan) CT Torso Phantom CTU-42 for larynx and brain metastases, and the female Alderson radiation therapy phantom by RSD (Long Beach, USA) for breast and lung. iCBCTs were acquired on a Halcyon™ 3.0 (Varian (Palo Alto, USA)) with the default pelvis protocol at 125kVp. Planning CTs (simCT) were acquired on a Siemens (Erlangen, Germany) Somatom® Edge Plus with the PelvisRT protocol of 120kVp.

Calibration curves in the treatment planning system, Varian's Eclipse™ v16.0, were defined based on the CIRS 062MA electron density phantom.

For all sites, IMRT and VMAT plans were tested setting standard clinical constraints. For dose comparison, PTW's (Freiburg, Germany) Verisoft® was used to calculate a 3D local gamma of 2%/2mm with a 20% low dose cutoff between the plan calculated on the simCT, which was then copied over to the iCBCT image volume and just recalculated (no re-optimization). The acceptance threshold was set to 95% passing rate (PR).

In addition to the commercially available reconstruction algorithm, an in-house prototype algorithm was used, which includes AcurosCTS scatter correction and an improved HU assignment in the reconstruction.

Figure 1: The three different anthropomorphic phantoms for different treatment sites, from left to right: CIRS Model 801-P, Kyoto Kagaku Phantom CTU-42, and the female Alderson radiation therapy phantom by RSD.

Results

Table 1 shows the passing rates for the different clinical sites for the IMRT and VMAT plans. The AcurosCTS scatter correction and improved HU assignment increased the PR in prostate due to better HU accuracy.

The low PR in lung using the CTU-42 were caused by the unrealistic phantom characteristics in the lung with almost 25% of the voxels being at -1000HU. However, the Alderson phantom better resembles the HU distribution of real patients in simCTs (mean value around -800HU), thus it was chosen as the golden standard for lung plan creation/ comparison.

Table 1: Passing rates in % for the different treatment sites in the various anthropomorphic phantoms for clinical standard plans with IMRT and VMAT for a local 3D gamma criterion of 2%/2mm and 20% low dose cutoff.

Treatment site		Commercial Halcyon 3.0	AcurosCTS + improved HU assignment
Prostate	IMRT	98.7	99.2
	VMAT	99.5	99.3
Head and Neck	IMRT	96.5	96.7
	VMAT	99.1	99.3
Brain	IMRT	98.1	98.0
	VMAT	100.0	100.0
Breast	IMRT	95.0	97.4
	VMAT	95.1	97.4
Lung on CTU-42	IMRT	86.6	65.3
	VMAT	87.0	62.5
Lung on Alderson	IMRT	97.6	99.6
	VMAT	99.6	99.9

Conclusion

The study revealed that iCBCT has the potential to be used for direct dose calculation in ART. At least with the phantom centered on the table, the commercial iCBCT algorithm created already acceptable passing rates excluding the CTU-42 phantom results. Also, all phantoms were rather skinny. Thus, future experiments will focus on the change introduced by enlarging the phantoms with slabs, positioning them off-center, and changing the scan length of the CBCT, as it was shown (see related poster: PO-GeP-I-176) that this affects the HU accuracy and thus will affect the dose accuracy.

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