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Topic category: RTT meeting : treatment planning and dose calculation

Presentation preference: oral

Keywords: kV-CBCT calibration, ART, in room imaging, interfraction changes

Title: Calibration and validation of kv-CBCT in room imaging for dose calculation and adaptive radiotherapy.

Purpose: To investigate the accuracy of dose calculation on cone beam CT (CBCT) data sets after HU-RED calibration and validation in phantom studies and clinical patients.

Material and methods: Calibration of HU-RED curves for kV-CBCT were generated for three clinical protocols (H&N, thorax and pelvis) by using a Gammex RMI phantom with human tissue equivalent inserts and additional perspex blocks to account for patient scatter. Two calibration curves per clinical protocol were defined, one for the Varian Truebeam 2.0 and another for the OBI systems (Varian, Palo Ato). Differences in HU values with respect to the CT-calibration curve were evaluated for all the inserts.

Four radiotherapy plans (breast, prostate, H&N and lung) were produced on an anthropomorphic phantom (Alderson) to evaluate dose differences on the kV-CBCT with the new calibration curves with respect to the CT based dose calculation. Dose differences were evaluated according to the D2%, D98% and Dmean metrics extracted from the DVHs of the plans and γ- evaluation (2%, 1mm) on the three planes at the isocenter for all plans. Clinical evaluation was performed on 5 patients and dose differences were evaluated as in the phantom study.

Results: HU values on the kV-CBCT calibration curves exhibited deviations with respect to the CT-calibration curve on the low- (lung) and high-density (bone) inserts. Differences between the Truebeam 2.0 and OBI-system for HU-RED curve were ca.14 %. These deviations were found to be ca. 250 HU depending on the protocol. Radiotherapy plans calculated on the anthropomorphic phantom showed very good agreement with the CT-based calculated plans (Table 1, Figure 1). Only few structures for some specific metrics, such as Dmean rectum and D98% parotid glands exhibited deviations larger than 3%. γ-analysis (2%, 1mm) on the three planes at isocenter showed a pass-rate higher than 98% for all cases. Clinical evaluation in 5 patients showed very good agreement with the dose calculation on the CT as expressed by the D2%, D98% and Dmean of the delineated structures. Several drawbacks were also found: the limited FOV of the kV-CBCT, which impairs the dose evaluation of those structures in its vicinity and the difference in beam profile of the kV-CBCT with respect to the CT, reducing the accuracy of the dose estimation at nearby the surface of the patient.

Conclusion: The generation of three kV-CBCT specific HU-RED curves for the pelvis, thorax and H&N cases resulted in accurate dose calculation on kV-CBCT images. A very good agreement was found with the CT based dose calculated plans according to DVH dose parameters and γ-evaluation. Limitations in the kV-CBCT warrant some caution when evaluating dose differences for adaptive radiotherapy.

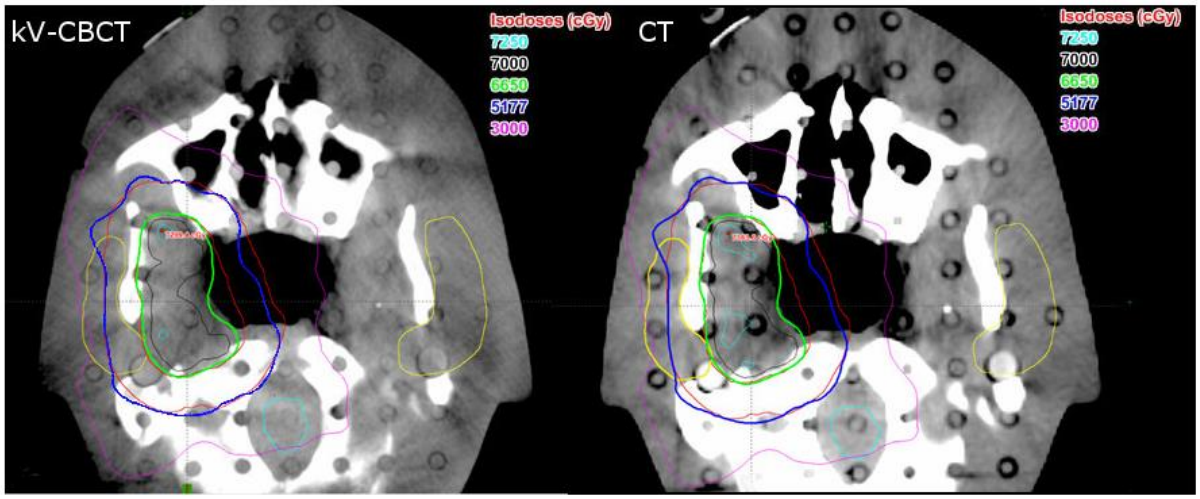

Figure 1. Head & Neck plan comparision in antropomorphic phantom. Dose calculation on kV-CBCT (left) is shown next to that on CT (right). PTVboost and PTVelective are shown in red. Isodoses 95% for both PTVs are shown in green and blue.

Prostate				Lung				Head & Neck			
	$D_{2\%}$	D_{mean}	$D_{98\%}$		$D_{2\%}$	D_{mean}	$D_{98\%}$		$D_{2\%}$	D_{mean}	$D_{98\%}$
PTV	-0.4	-0.2	0.6	PTV	1.2	2.2	4.0	PTVboost	-0.6	0.0	1.9
Rectum	-0.6	0.4	-0.9	GTV	1.3	1.5	0.9	PTVelec.	-0.6	-0.1	0.7
Bladder	-0.6	-0.6	-1.0	IL Lung	0.0	1.1	0.0	Brainstem	-2.1		
Hip Left	0.8	0.1	0.0	CL Lung	0.0	-1.2	0.0	Parotid L.	-0.7	0.3	8.3
Hip Right	0.4	0.1	0.7	Myelum	0.3			Parotid R.	-0.8	0.1	1.1

Table 1. Estimated dose differences (%) for dose calculations on kV-CBCT (Truebeam) from dose calculation on CT for a prostate, lung and head & neck plan on an antropomorphic phantom.