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H. Chesneau, Delphine Lazaro-Ponthus, Johann Plagnard, Caroline Lafond, O. Henry, et al.. Comprehensive validation of a Monte Carlo kV-CBCT model using OSL and spectral measurements. ESTRO 35, Apr 2016, Torino, Italy. Radiotherapy and Oncology, 119 (Supplement 1), pp.S751, 2016, ESTRO 35, 29 April - 3 May 2016, Turin, Italy. 10.1016/S0167-8140(16)32865-1. hal-02268749

HAL Id: hal-02268749 https://hal.science/hal-02268749

Submitted on 14 Oct 2019

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Comprehensive validation of a Monte Carlo kV-CBCT model using OSL and spectral measurements

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I. Purpose and Objective

The use of Cone-Beam computed Tomography (CBCT) is progressively increasing in radiotherapy treatments and there is a need from the medical physics community to develop tools to estimate, report and drive strategies to reduce CBCT doses. Hence, we developed a Monte Carlo (MC) model for the XVI kV-CBCT system, and the aim of this work is to validate our simulator in pre-clinical conditions against :

- Experimental spectra measured with a CdTe semi-conductor.
- Organ dose measurements with OSL nanoDot (Landauer) in CIRS ATOM anthropomorphic phantoms.

II. Material and Methods

1. Spectral measurements

Measurements were performed in air with the CdTe detector, on the central beam axis, and were corrected for detection artifacts [1].

2. Dosimetric protocol for OSL measurements

a. <u>In air calibration</u>

Cross calibrations in air with a FARMER type ionization chamber were performed for 6 beam qualities: 120, 100 and 80 kVp, filtered with F1 bowtie and unfiltered. Thus, we obtained calibration factors $N_{K_{air},Q_{ref}}$ linking air Kerma values to OSL signals S_{OSL} :

$$K_{air,Q_{ref}} = N_{K_{air},Q_{ref}} \cdot S_{OSL}$$

b. Irradiation in CIRS phantoms

measurement, and of the important energy dependence of OSL, an energy correction had to be applied. To this end, the evolution of calibration factors $N_{K_{air},Q_{ref}}$ with spectrum mean energy \overline{E} was fitted with a linear function (Fig. 1). This curve allows the determination of the $N_{K_{air},Q}$ for the beam quality Q at the location of the OSL in the phantom:

$$K_{air,Q} = (a\overline{E} + b).S_{OSL}$$

Variations of beam qualities in CIRS phantom were estimated by MC simulation with spectra validated by CdTe measurements.

(mGy/coups)

2.2

2.1

1.9

d. <u>Medium correction</u>

The correction was made under the hypothesis of electronic equilibrium to convert air

OSL were inserted in heterogeneities of the CIRS phantoms, and irradiated with usual CBCT acquisition protocols. They were read three times and corrected for the background.

c. <u>Energy correction</u>

Because of spectral variations between calibration and

II. Results

1. Spectral measurements

Comparisons of experimental and MC spectra for various CBCT beam qualities showed very good agreement (Fig 2 and Tab 1).

(1)	_	Spectre photons CBCT XVI 115kVp filtré	Tab. 1: Spectra mean energies			
oabilité (sans unité	7 6	Simulation Monte Carlo Mesure CdTe	Beam qualities	$\overline{E}_{meas.}$	 <i>EMC</i>	
	2		120 kV F0	59.7 keV	60.0 keV	
	4 2		120 kV F1	61.7 keV	63.1 keV	

2. Comparisons of OSL measurements and MC dose values

A total of 84 OSL were irradiated in CIRS phantoms and a mean difference between measured and MC dose values of 8,6% was obtained. Tables 2 and 3 present examples of comparisons.

Tab. 2: 5 y	ears old - Lung	g 80 kV F0	Tab. 3: Female adult - H&N 100kV F0		
Location	D _{meas.} (mGy)	D_{MC} (mGy)	Location	<i>D_{meas.}</i> (mGy)	D_{MC} (mGy)
Lung Left	3.07 ± 0.05	3.08 ± 0.14	Lung	0.72 ± 0.03	0.67 ± 0.08





II. Conclusion and Perspectives

The MC simulator of the XVI CBCT was validated against an extensive set of experimental measurements, and enables the organ dose calculation with accuracy. It can now be used to compute and report doses to organs for clinical cases.

[1]] Plagnard, J. (2014). Comparison of measured and calculated spectra emitted by the X-ray tube used at the Gustave Roussy radiobiological service. (W. O. Library, Éd.) *X-Ray Spectrometry, 43*(5), pp. 298-304.





