DETERMINATION OF COMPUTED TOMOGRAPHY QUANTITIES USING A NEW PEDIATRIC PHANTOM

E.W. MARTINS
Nuclear Energy Research Institute
São Paulo/São Paulo, Brazil

J.V. CARDOSO
Lisbon Superior Technical Institute
Bobadela/Lisboa, Portugal

M.P.A. POTIENS
Nuclear Energy Research Institute
São Paulo/São Paulo, Brazil
Email: mppalbu@ipen.br

Abstract

A computed tomography pediatric head phantom that uses special materials to simulate the cortical and the cancellous bone was developed. This paper shows its behavior to determine the specific computed tomography radiation quantities at two calibration laboratory, the LCI-IPEN, Brazil and LMRI-IST, Portugal. The specific quantities measured were: air kerma index(Ca,100), weighted air kerma index (Cw), average volumetric air kerma index (C_{vol}) and the air kerma-lenght product (P_{KL}). The reference radiation qualities used in both laboratories were the radiation qualities recommended by the norm IEC 61267 (RQT8, RQT9 e RQT10) to computed tomography dosimetry measurements. The calculated values of C_W show attenuation of 11%, 13% and 10% for the qualities RQT 8, RQT 9 and RQT 10, respectively, from cortical to cancellous bone.

1. INTRODUCTION

The main specific quantities applied to computed tomography (CT) dosimetry are: air kerma index(Ca,100), weighted air kerma index (Cw), average volumetric air kerma index (C_{vol}) and the air kerma-lenght product (P_{KL})[1]. To determine or evaluate these quantities it is necessary to use physical or computational phantoms. The phantom must be able to reproduce as close as possible the absorption characteristics and scattering of some part of human body in the presence of a field radiation [2][3]. At the Insituto de Pesquisas Energéticas e Nucleares (IPEN), a pediatric phantom was developed for CT dosimetry considering the cranial bone. Several tests were done in specific standardized quality beams for CT in the Instruments Calibration Laboratory (LCI) of IPEN. In order to compare the results obtained from the tests done, the pediatric phantom was subjected to the same tests in standardized beams at the Ionizing Radiation Metrology Laboratory (LMRI) which is part of the Technical Superior Institute (IST), Lisbon, Portugal. The objective of this study is to present the results obtained using the new phantom and checks its behaviour in two different laboratories, but to the same radiation qualities.

2. MATHERIALS AND METHODS

2.1. Pediatric cranial phantom construction

The developed phantom is constituted of four parts, all in cylindrical form: two cylinders built in PMMA (the external with dense material and the intern with space for water addition or other materials), a cylinder built in aluminum (SP_{AL}) and other in PVC (SP_{PVC}), these last two simulate the skullcap and are used one at a time[4]. Fig. 1 shows its project with dimensions and Fig. 2 shows the constructed pediatric phantom, with all pieces separately and coupled. The aluminum cylinder simulates the cortical bone and the PVC cylinder simulates the cancellous bone.

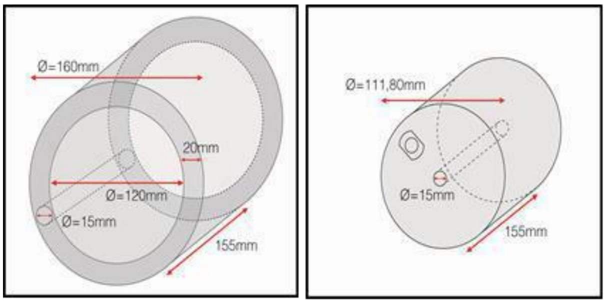

FIG. 1. Pediatric phantom project

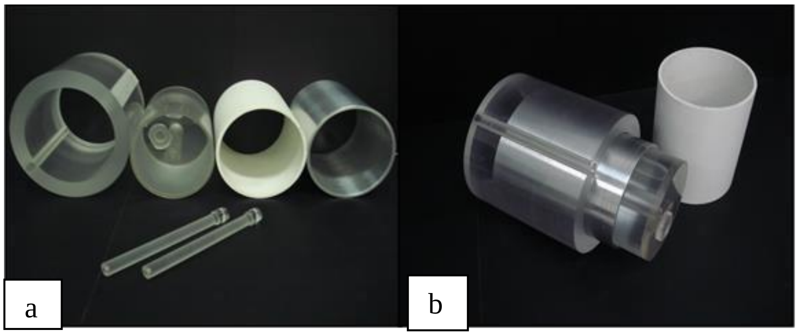

FIG. 2. Pediatric head phantom: a) separated pieces and b) mounted with the aluminum cylinder; the PVC cylinder is outside

2.2. Dosimetric systems

2.2.1. LCI-IPEN, BRAZIL

The IPEN reference dosimetric system is a Radcal Corporation ionization chamber, model 10x5-3CT, with the volume of 3 cm^3, attached to the Radcal electrometer, model 9015. The X radiation system used was a Pantak/Seifert, model Isovolt HS 160, MXR–160/22 tube model; its range of operation is from 5 kV to 160 kV

2.2.2. LMRI-IST, PORTUGAL

The LMRI-IST dosimetric system was a PTW ionization chamber, model 77336, with 73 cm^3 of volume, attached to an electrometer PTW, model UNIDOS E. The X radiation used was a Philips, model MGC 41 and tube model MCN 165. The maximum operation voltage of the X radiation system is 160 kV.

2.3. Radiation qualities

The reference radiation qualities used in both laboratories (IPEN and LMRI-IST) were the Computed Tomography radiation qualities recommended by the norm IEC 61267 (RQT8, RQT9 e RQT10)[5]. Prior to the measurements, the reference dosimetric systems were calibrated in terms of air kerma-lenght product (P_{KL}) for all the qualities. All measurements were corrected to the environmental conditions.

2.4. Specific CT quantities determination

For each radiation quality (RQT8, RQT9 and RQT10) it was calculated the CT free in air kerma ($C_{a,100}$) according to the equation:

$$C_{a,100} = \frac{1}{NT} M N_{P_{KL},Q_0} k_Q k_{TP}$$

where NT is the nominal width of irradiated beam, M is the obtained measurement with the dosimetric system, N_{PKL} is the calibration coefficient in terms of P_{KL}, k_Q and k_{TP} are the corrections factors for energy and environmental conditions, respectively.

After that, the air kerma index using the phantom was measuring inserting the ionization chamber in the peripherical hole ($C_{PMMA,100,p}$) and in the central hole ($C_{PMMA,100,c}$). In all measurements the empty hole was filled with a PMMA rod.

With those values it was possible to determine the weighted CT air kerma index, C_W, that combines the values of $C_{PMMA,100}$ measured at the centre and periphery of a CT dosimetry phantom by (1):

$$C_W = \frac{1}{3}\left(C_{PMMA,100,c} + 2C_{PMMA,100,p}\right)$$

3. RESULTS

The obtained results for CT specific quantities measured in both laboratories (Brazil and Portugal) can be seen in the next tables. Table 1 show the CT free in air kerma index. Those values were used to derivate the other quantities.

TABLE 1. CT free in Air Kerma index (Ca,100) obtained in both laboratories, IPEN (Brazil) and IST (Portugal).

Radiation Quality	$C_{a,100}$ (mGy/min)	
	LCI/IPEN	LMRI/IST
RQT 8	22.72 ± 0.21	23.81 ± 0.32
RQT 9	33.21 ± 0.32	35.11 ± 0.22
RQT 10	55.41 + 0.50	59.12 + 0.31

From those values and using the new pediatric phantom with the pencil ionization chamber were determined the air kerma index quantities. Tables 2 and 3 show the air kerma index obtained inserting the ionization chamber in the central hole ($C_{PMMA,100,c}$), for aluminium and PVC cylinder.

TABLE 2. CT air kerma index in the central hole ($C_{PMMA,100,c}$), using the new pediatric phantom with the aluminium cylinder (cortical bone), SP_{AL}

Radiation Quality	$C_{PMMA,100,c}$ (mGy)	
	LCI/IPEN	LMRI/IST
RQT 8	1.66 ± 0.31	1.06 ± 0.21
RQT 9	2.45 ± 0.21	1.69 ± 0.32
RQT 10	4.27 ± 0.10	2.88 ± 0.31

TABLE 3. CT air kerma index in the central hole ($C_{PMMA,100,c}$), using the new pediatric phantom with the PVC cylinder (cancellous bone), SP_{PVC}

Radiation Quality	$C_{PMMA,100,c}$ (mGy)	
	LCI/IPEN	LMRI/IST
RQT 8	2.02 ± 0.31	1.17 ± 0.21
RQT 9	3.12 ± 0.12	1.78 ± 0.31
RQT 10	4.82 ± 0.41	2.98± 0.22

Tables 4 and 5 show the air kerma index obtained inserting the ionization chamber in the peripherical hole ($C_{PMMA,100,p}$), for aluminium and PVC cylinder.

TABLE 4. CT air kerma index in the peripherical hole ($C_{PMMA,100,p}$), using the new pediatric phantom with the aluminium cylinder (cortical bone), SP_{AL}

Radiation Quality	$C_{PMMA,100,p}$ (mGy)	
	LCI/IPEN	LMRI/IST
RQT 8	2.85 ± 0.23	3.37 ± 0.10
RQT 9	4.48 ± 0.31	4.66 ± 0.20
RQT 10	7.48 ± 0.12	7.25 ± 0.30

TABLE 5. CT air kerma index in the peripherical hole ($C_{PMMA,100,p}$), using the new pediatric phantom with the PVC cylinder (cancellous bone), SP_{PVC}

Radiation Quality	$C_{PMMA,10\,0,p}$ (mGy)	
	LCI/IPEN	LMRI/IST
RQT 8	3.11 ± 0.42	3.44 ± 0.41
RQT 9	4.75 ± 0.31	4.64 ± 0.41
RQT 10	7.80 ± 0.21	7.21 ± 0.31

Using the $C_{PMMA,100,c}$ and $C_{PMMA,100,p}$ obtained values it was possible to calculated the weighted CT air kerma index values, C_W. The calculated values of C_W show attenuation of 11%, 13% and 10% for the qualities RQT 8, RQT 9 and RQT 10, respectively, from cortical to cancellous bone, as can be seen in Tables 6 and 7.

TABLE 6. Weighted CT air kerma index C_W, using the new pediatric phantom with the aluminium cylinder (cortical bone), SP_{AL}

Radiation Quality	C_W (mGy)	
	LCI / IPEN	LMRI / IST
RQT 8	2.46 ± 0.21	2.60 ± 0.31
RQT 9	3.80 ± 0.22	3.67 ± 0.12
RQT 10	6.41 ± 0.42	5.79 ± 0.32

TABLE 7. Weighted CT air kerma index C_W, using the new pediatric phantom with the PVC cylinder (cancellous bone), SP_{PVC}

Radiation Quality	C_W (mGy)	
	LCI / IPEN	LMRI / IST
RQT 8	2.74 ± 0.10	2.68 ± 0.41
RQT 9	4.21 ± 0.41	3.69 ± 0.30
RQT 10	6.82 ± 0.21	5.81 ± 0.31

4. CONCLUSIONS

It was possible to determine, in both laboratories, the specific quantities for CT: $C_{a,100}$, $C_{PMMA,100,c}$, $C_{PMMA,100,p}$ and C_W. Since these measurements were made in pre-established standard beams in each laboratory, it was used the scanning length of each one, causing a meaningful variation in the values of C_W and C_{vol}, which takes into account the helical pitch or axial scan spacing, in this case the helical pitch is 1, so C_W and C_{vol} are equals.

ACKNOWLEDGEMENTS

The authors acknowledge the partial financial support of the CAPES, FAPESP, CNPq and INCT (project: Radiation Metrology in Medicine) for the partial financial support.

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