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DETERMINATION AND COMPARISON OF COMPUTED TOMOGRAPHY QUANTITIES IN STANDARD BEAMS USING STANDARD ADULT AND PEDIATRIC PHANTOMS

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ABSTRACT

The computed tomography (CT) is a segment of diagnostic radiology that uses higher radiation dose comparing to others fields of conventional radiology. In 2011, for decreasing the uncertainty in the diagnostic radiology beams dosimetry, the International Atomic Energy Agency (IAEA) published an implementation on the Technical Reports Series no. 457 from 2007, which is a code of practice recommending procedures for calibration and dosimetry in diagnostic radiology field. The objective of this study was to compare CT measurements on standards beams using adult and pediatric phantoms. The same procedure was used for two types of phantoms. Measurements were performed on the surface of the phantoms obtaining values of entrance surface air kerma (K_e). Measurements were taken from 100 to 150 kV (RQT 8, 9 and RQT 10), with the center of the simulators positioned at a distance of 100 cm from the focal spot. The values for the CT quantities air kerma index (in free air, C_K, and in phantom, $C_{PMMA,C}$ / $C_{PMMA,P}$) and air kerma lenght product (P_{KA}) were found. The results were significant and the largest difference between the two phantoms was found for the radiation quality RQT 10.

1. INTRODUCTION

The objective of computed tomography (CT) is providing to radiologists, technologists and technicians - the inside view of the human body through images derived from X-ray. The bases of their physical principles to generate the images are the same as those used in conventional radiology [1]. The generated images allow monitoring the development of diseases and their early removal as well [2].

Since its discovery in the 1970, the CT use has increased rapidly and in the same direction the technological innovations which results in faster equipment (scanners) and tomographic images with best settings providing more accurate diagnoses. Currently, in the USA is estimated that more than 62 million of CT scans are performed per year, being 4 million in children procedures [3]. In Brazil there was a significant increase in the acquisition of CT equipment. In 1999, it was 0.9 CT scanners for 100.000 inhabitants and in 2009 this number was 1.6 according to data provided by the Health Ministry [4].

The use of CT can be classified considering the age group (adult or pediatric) and the purpose of the image (diagnosis in symptomatic patients or screening of asymptomatic patients) [5].

The largest increases in the use of CT are in the pediatric diagnosis scan category, and it can be expected that this trend will continue in the next years [6,7,8,9,10,11,12]. The increasing use of CT in children has been mainly by reducing the required time for the exam - now less than 1 second – which mostly eliminates the use of sedation to prevent the child from moving during image acquisition [5].

Although this technique provides benefits, increasing its use in the pediatric become a concern about dosimetry. The radiation dose used for good quality imaging is high, being more harmful in pediatric patients since they are under development and have smaller body structures than adult patients.

Another issue is about the use of a specific pediatric protocol. Frequently is applied the same protocol for pediatric and adult diagnostic CT scanners, resulting in unnecessary doses for children. Therefore, there is a need to determine the adequate radiation dose for the definition of appropriate pediatric diagnostic reference levels in order to avoid risks of stochastic effects [2].

The CT dose index can be obtained by different methods depending on the kind of phantom used, acrylic or acrylic water-filled [4]. The use of a calibrated radiation measuring instrument in radiation standard beams by metrology laboratories should take into account the energy dependence of the instrument for clinical beams using the adequate quality factor for the clinical energy range.

The use of a pencil ionization chamber together with an appropriate phantom is one of the most accurate methods for the determination of specific CT dosimetric quantities (Incident air Kerma, Entrance surface air Kerma, Air kerma–length product and CT air kerma indices, absorbed dose, kerma rates, CT index). Its cylindrical geometry allows measurements in devices that emit radiation while spinning, resulting in non-uniform field which is the case of scanners [13,14].

The objective of this work is to determine the adequate CT dosimetric radiation quantities (CT air kerma indices) comparing the behavior of a reference pencil ionization chamber in adults and pediatric phantoms (using identical procedures).

2. MATERIALS AND METHODS

The CT standard dosimetric radiation qualities were established at Pantak/Seifert, Isovolt HS 160 X radiation system with a voltage variation from 100 kV to 150kV, Fig. 1.

The reference pencil ionization chamber Radcal, RC3CT model, with a volume of 3 cm³, is shown in Fig 2. It is a vented ionization chamber, which means that it has air in its interior for performing measurements [15,16]. This chamber was calibrated at the Primary Standard Dosimetry Laboratory Physikalisch-Technische Bundesanstalt (PTB), Germany.

The measurements were performed using two bodies PMMA phantoms representing adult and pediatric, as Fig. 3. To obtain the values of entrance surface air kerma (K_e), the ionization chamber was placed on the surface of the phantoms. The measurements were taken from 100 to 150 kV (RQT 8, 9 and RQT 10), with the center of the simulators positioned at a distance of 100 cm from the focal spot.

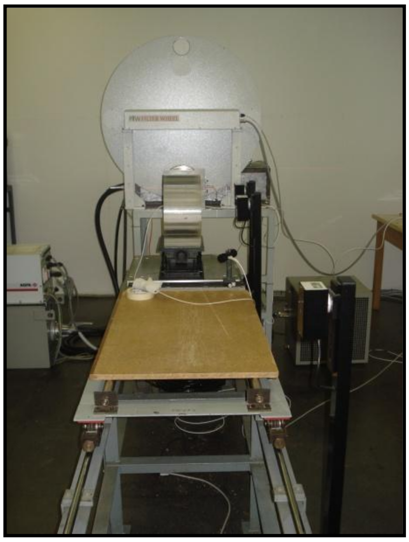

Figure 1: Set up of the X radiation system, Pantak Isovolt HS 160 l

Figure 2:Pencil ionization chamber, Radcal

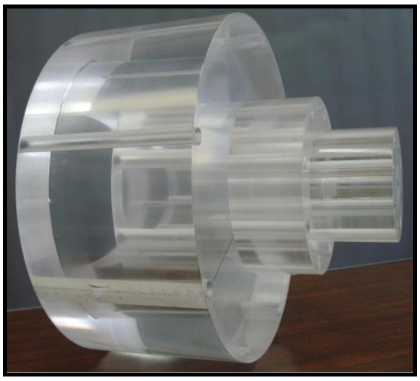

Figure 3: Adult and pediatric phantom developed by IPEN

3. RESULTS

The air kerma rates (K_{air}) and air kerma length product (P_{KL}) obtained are presented in the Tables 1, 2 and 3. Additionally the entrance surface air kerma (K_e) were determined using the pediatric phantom. The ionization chamber was positioned outside the phantom. The CT air kerma indices $C_{a,100}$, C_W (free in air and in phantom) and C_{vol} (derived from C_W), were calculated according to IAEA, TSR457 [17].

Table 1. Dosimetric radiation qualities air kerma rates (K_{air}), air kerma length product (P_{KL}) and the entrance surface air kerma rates (K_e) characteristics

Radiation qualities	Tube Voltage (kV)	Filter	HVL (mmAl)	K_{air} Gy/min	K_e Gy/min	P_{kl}
RQT 8	100	3.2mm Al + 0.3mm Cu	6.90	0.018	0.008	0.18
RQT 9	120	3.5mm Al + 0.35mm Cu	8.40	0.027	0.010	0.27
RQT 10	150	4.2mm Al + 0.35mm Cu	10.1	0.045	0.017	0.45

Table 2. CT air kerma indices C_k, $C_{PMMA,C}$, $C_{PMMA,P}$, C_W (free in air and in pediatric phantom) and C_{vol} (derived from C_W).

Radiation qualities	C_k	$C_{PMMA,C}$	$C_{PMMA,P}$	C_W	C_{vol}
RQT 8	0.018	0.010	0.043	0.032	0.3
RQT 9	0.027	0.017	0.064	0.048	0.4
RQT 10	0.045	0.029	0.106	0.080	0.8

Table 3. CT air kerma indices C_k, C_{PMMA}, C_W (free in air and in adult phantom) and C_{vol} (derived from C_W).

Radiation qualities	C_k	$C_{PMMA,C}$	$C_{PMMA,P}$	C_W	C_{vol}
RQT 8	0.018	0.005	0.043	0.030	0.3
RQT 9	0.027	0.009	0.064	0.046	0.4
RQT 10	0.045	0.016	0.106	0.076	0.7

4. CONCLUSIONS

The CT air kerma indices C_k, C_{PMMA}, and C_W (free in air and in the pediatric phantom) and the air kerma-length product (P_{KL}) were determined in this study allowing the possibility to evaluate the CT parameters (in clinical procedures) using the indices provided by a

Metrology Laboratory reducing uncertainties. In addition, measurements at the pediatric phantom surface developed at IPEN were done to obtain the entrance surface air kerma (K_e).

The C_w values obtained showed variation over 4% when the same techniques is used to adults and children procedures. The values obtained for the radiation dosimetric quality RQT 8 shown the largest difference between the two phantoms, about 6.7%. This behavior indicates that specific techniques are necessary for pediatric patients in order to reduce the absorbed dose. Moreover a good quality control program must be as close as possible to the used in medical clinics and hospitals considering the difference between adult and pediatric protocols.

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