Dosimetry Measurements in Computerized Tomography Standard Beams using a Pediatric Phantom

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Abstract. The dose in computed tomography (CT) is a matter of concern since in some centers the same protocol is used for adults in pediatrics. In this work it was performed measurements in CT standard radiation beams using a pediatric phantom. The goal was to evaluate values for the parameters: air kerma (K_{ar}), K_{ar} length product (P_{KL}) and phantom's surface measurements to obtain kerma input values (K). The measurements were performed for 100, 120 and 150 kV.

1 Introduction

Computed tomography is a technique in the field of radiology with remarkable technological advances in the last ten years. Although its effectiveness in diagnosing pathologies accurately, there is a concern regarding radiological protection. In 2011 the International Atomic Energy Agency published the Implementation of the International Code of Practice for Dosimetry in Diagnostic Radiology (TRS457) having as main objective the safety of the application of nuclear techniques in medical diagnostics and prevention of diseases for humanity[1].

The dose limitation is calculated using CT phantoms trunk and head based in dosimetric quantities: C_w (weighted index of dose), C_{vol} index (volumetric air kerma) and P_{KL} (air kerma-length product).

In Brazil reference levels for a typical adult patient radiodiagnosis CT are determined on the rotation axis of a water phantom 15 cm long and 16 cm of diameter to the head and 30 cm to the abdomen[2].

According to the reference levels, the average dose for multiple slices does not apply to pediatric patients but only in adults, making it a topic of discussion.

The equipments used in CT have had major technological breakthrough because of the increased number of channels associated with increased potency of the X-ray tube resulting in increased speed of the slices thereby reducing the exposure time of the patient. It means excellent tomography for cardiac diagnoses and examinations in children. Although the big efforts for CT result in good quality image with shorter exposure, CT remains the method in diagnostic radiology that the patient receives the highest dose of ionizing radiation.

The largest increases in the use of CT are in the category of pediatric diagnosis. This increasing use of CT in children has been mainly because of the reduction in the time required for the exam - now less than 1 second - eliminating in most cases, the use of anesthesia to prevent the child movement during the image acquisition [3,4].

The main goals of the patient dosimetry related to the X-rays used in medical imaging is to determine the dosimetric quantities for the creation and use of diagnostic reference levels for benchmarking and risk of stochastic effect [5]. For this purpose this work was developed.

2 Materials and Methods

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

The reference pencil ionization chamber is from Radcal, RC3CT model, with 3 cm^3, is shown in Fig 2. The ionization chamber is a kind of dosimeter used in radiology area to determine the absorbed dose in an environment exposed to ionizing radiation and to measure air kerma quantity. Its basic principle is to use a gas in its interior for performing measurements [6-9]. This chamber was calibrated at the Physikalisch-Technische Bundesanstalt (PTB), Germany.

The pediatric phantom developed by IPEN has the dimension of 10.0 cm X 15.4 cm (Fig. 3). It has 9 holes with 1.3 cm of diameter.

To perform the measurements, the pediatric phantom was positioned one meter away from the X-ray focus. The pencil ionization chamber for Ke measurements was positioned in the air closed to the phantom and to calculate the Cw the camera was positioned in the central cavity of the phantom. All measurements were corrected to reference ambient conditions (T_{ref} = 20ºC, P_{ref} = 101.32 kPa).

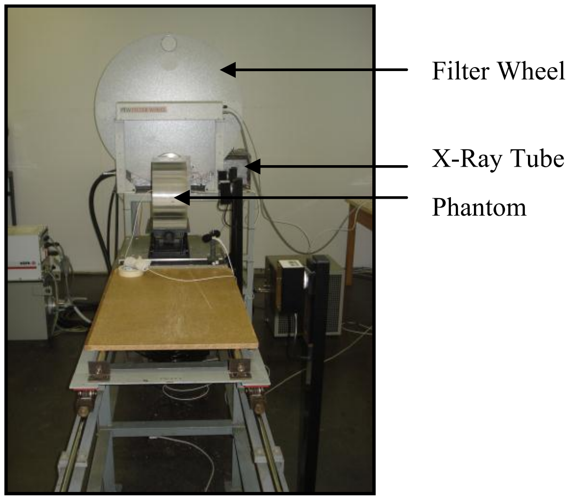

Fig. 1: ISOVOLT X radiation system (160 kV)

Fig. 2: Calibrated pencil ionization chamber

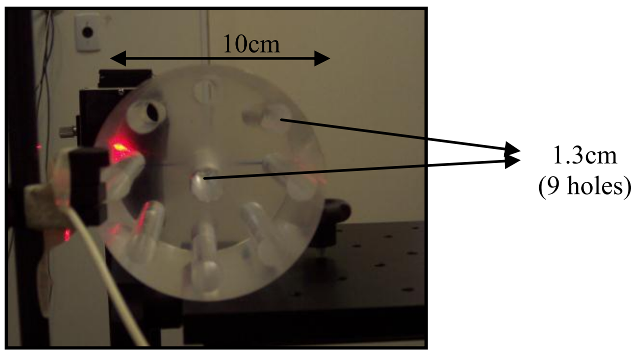

Fig. 3: Pediatric phantom developed by IPEN

3 Results

The obtained results for air kerma rates (K_{air}) and the air kerma length product (P_{KL}) are presented in Table 1. 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 TSR457 [1], are in Table 2.

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

Radiation qualities	Tube Voltage (kV)	Filter	HVL (mmAl)	K_{air} Gy/min	K_e Gy/min	P_{KL} Gy.cm
RQT 8	100	3.2mm Al + 0.3 mm 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 Ck, CPMMA, CW (free in air and in pediatric phantom) and Cvol (derived from CW).

Radiation qualities	C_k	C_{PMMA}	$C_{PMMA,P}$	C_w	C_{vol}
RQT 8	0.018	0.023	0.032	0.029	0.2
RQT 9	0.027	0.035	0.048	0.044	0.4
RQT 10	0.045	0.058	0.079	0.072	0.7

4 Discussion and 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 of the use of a calibration standard beam for CT measurements in order to establish methods to analyze CT parameters. In addition, measurements at the pediatric phantom surface developed at IPEN were done to obtain the entrance surface air kerma (K_e).

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References

1. International Atomic Energy Agency. Implementation of the international code of practice on dosimetry in diagnostic radiology (TRS 457): Review of Tests Results. (IAEA Human Health Reports nº 4). Vienna, 2011.
2. Ministério da Saúde. Diretrizes de proteção radiológica em radioadignóstico médico e odontológico. Brasília: 1998. (Portaria 453).
3. White, K. S. Helical/Spiral CT scanning: a pediatric radiology Perspective. Pediatr Radiol. 26:5-14, 1996.
4. Linton, O. W.; Mettler, F. A. Jr. National conference on dose reduction in CT, with an emphasis on pediatric patients. AJR Am J Roentgenol. V.9, p. 181:321, 2003.
5. ZOETELIEF, J., PERNICKA, F., CARLSSON, G. A., DANCE, D.R., DeWERD, L.A., DREXLER, G., JÄRVINEN, H., KRAMER, H.-M., NG, K.-H. Dosimetry in diagnostic and interventional radiology: International Commission on Radiation Units and Measurements an IAEA Activities. Standards and Code of Practice in Medical Radiation Dosimetry. Proceedings of an International Symposium, Vienna, 25-28 November, 2002.
6. Knoll, G. F. Radiation detection and measurement 2nd ed. New York, NY: John Wiley & Sons, 1989.
7. Boag, J. W. Ionization chambers. In: Kase, K. R.; Bjarngard, B.E.; Attix, F.H.; editors. The dosimetry of ionizing radiation. Orlando, FL: Academic Press Inc., 1987, v. 2, pp. 169–243.
8. Rajan, K. N. G. Advanced medical radiation dosimetry. New Delhi: Prentice-Hall of India, 1992.
9. Attix, F. H. Introduction on radiological physics and radiation dosimetry. 2nd ed. New York, NY: John Wiley & Sons, 1986.