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Application of a Tandem system for HVL evaluation in Computed Tomography

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ABSTRACT

Computed tomography (CT) is a method of imaging used for the diagnosis and treatment of diseases. Different from the conventional diagnostic radiology equipment, where the test for the determination of the half value layer (HVL) is recommended, in CT equipment due to its geometry, the determination of the HVL is a difficult task and is usually only provided by the manufacturer. The effective energy of a beam is determined by definition, by means of HVL determination. When HVL values are not easily determined, as in the case of CT, it is possible to evaluate the effective energy of the beam through a system consisting of the use of different energy dependent dosimeters, where the ratio between the calibration curve responses in energy can provide the effective energy of the beam (Tandem system). The system used in this work for the evaluation of HVL in computed tomography is composed of groups formed by an ionization chamber of the pencil-type and cylindrical absorber layers of aluminum and Polymethyl methacrylate (PMMA).

1. Introduction

The evolution of diagnostic imaging equipment using X rays brought great benefits to mankind but the concern with the quality control and radiation dose received by the patients increased. Computed tomography is a method of obtaining images used for both diagnosis and medical treatment.

In Brazil, the publication of ordinance 453 (Brasil, 1998) of the Ministry of Health in 1988, approved the technical regulation that establishes the basic guidelines for radiological protection in medical and dental diagnostic radiology and has the use of diagnostic X-rays throughout the national territory, establishing the Implementation of quality assurance programs, as well as their frequency. In 2005, the Sanitary Surveillance Agency (ANVISA) published a guide to contribute to the standardization of quality control tests and medical diagnostic radiology equipment, including Computed Tomography (Brasil, 2005). Unlike the quality control programs of conventional diagnostic radiology equipment, where the test for the determination of the half value layer (HVL) is recommended, in Computed Tomography equipment due to its geometry, the half value layer is only supplied by the manufacturer.

The effective energy of a beam is determined by definition, by means of HVL determination. To determine the effective energy of a beam in a CT equipment, where the geometry of the equipment makes this task difficult, the objective of this work was to apply a methodology based on a system that uses different dosimeters with different energy dependencies, where the ratio between the responses of the calibration curves in the energy can provide the effective energy of the beam, called Tandem system.

The application of this system was proposed by (Kenney and Cameron, 1963) and (Gorbics and Attix, 1968) that used thermoluminescent materials to determine the energy of gamma radiation and X. In 2004, (Maia, 2005) proposed a Tandem system model to be used in the evaluation of HVL values in Computed Tomography. The proposed system consisted of a pencil-type ionization chamber and aluminum, PMMA and copper absorber layers. Although the proposed system was initially composed of thermoluminescent materials with different energetic dependencies, the sets formed by the pencil-type ionization chamber and the cylindrical absorber layers of different materials can also be considered a Tandem system.

Taking as reference the system developed by Maia, a Tandem system was built at the Institute of Nuclear Energy and Research (IPEN), formed by cylindrical absorber layers of aluminum and PMMA. The thickness of the aluminum layers was chosen from the HVL values of the standard radiation quality based on copper added filter (RQT) beams, implemented in 2010 by (Dias, 2010) in the instrument calibration laboratory of IPEN (LCI / IPEN).

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2. Materials and methods

Was used the Pantak/Seifert X-ray system, model Isovolt HS, that works on radiation qualities in clinical diagnostic radiology range (40–160 kV) located at the LCI/IPEN. Was used the radiation quality based on copper added filter (RQT) which are used for the determinations in CT applications. The current was 10 mA, for the RQT radiation qualities implanted, listed in Table 1, where RQT 9 quality is the reference quality.

The tandem curves were constructed according to the HVL, obtained of the ratio between the responses of the sets formed by the Radcal pencil-type ionization chamber, 10 × 5 CT model calibrated and coupled to the aluminum and PMMA cylindrical absorber layers. The thicknesses of the cylindrical absorber layers are listed in Table 2.

The length of the cylindrical absorber layers is 15 cm. Fig. 1 shows the aluminum and PMMA cylindrical absorber layers.

The arrangement assembled to obtain the readings for the construction of the Tandem curves was with the pencil-type ionization chamber in the air and with the cylindrical absorber layers, positioned 1 m from the focal point, with the collimated beam in the center of the ionization chamber. Then, using the same arrangement, readings were taken with the sets formed with the aluminum and PMMA cylindrical absorber layers and the pencil-type ionization chamber. The arrangement used to obtain the readings can be seen in Fig. 2.

The higher the slope of the Tandem curve the better will be the identification of values close to HVL which makes the system useful. The Tandem curve was chosen based on the percentage differences between the ratios obtained by each set, for subsequent HVL.

Table 1
Characterization of radiation quality series RQT established.

Radiation quality	X ray tube voltage (kV)	Added filtration (mmCu)	Nominal first HVL (mm Al)
RQT 8	100	0.20	6.9
RQT 9	120	0.25	8.4
RQT 10	150	0.30	10.1

Table 2
Thickness of cylindrical aluminum and PMMA absorbers made to form the Tandem system.

Layers	Thickness (mm)
1 mm Al	1 ± 0.54
2 mm Al	2 ± 0.33
2 mm Al	2 ± 0.39
2 mm Al	2 ± 0.28
3 mm Al	2 ± 0.09
15 mm PMMA	15 ± 0.17
10 mm PMMA	10 ± 0.10
10 mm PMMA	10 ± 0.48

Fig. 1. Cylindrical absorber layer made of aluminum and PMMA built to form the Tandem system.

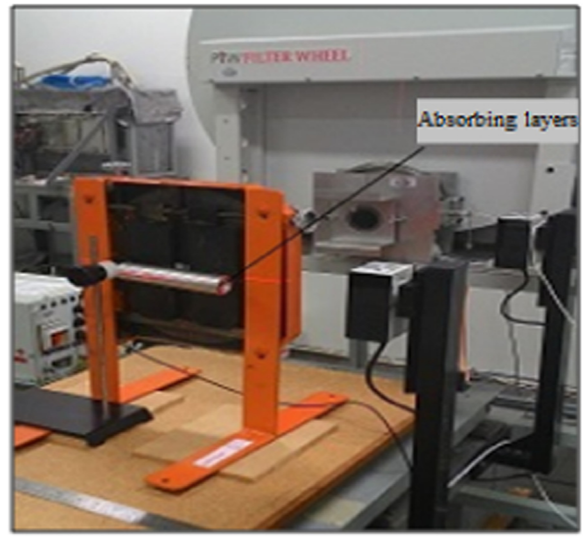

Fig. 2. Arrangement mounted on the LCI/IPEN to obtain the readings with the sets formed by the ionization chamber of the pencil-type and as cylindrical absorber layers for the construction of the Tandem curves.

The curve that presented the best response was obtained by the ratio between the responses of the set formed with the pencil-type ionization chamber coupled to a 10 mm thickness aluminum cylindrical absorber layer and the pencil-type ionization chamber coupled to the layer PMMA cylindrical absorber of 35 mm.

2.1. Application of the Tandem system in Tomography Computed

Clinical tests with the Tandem system were performed on the CT equipment Siemens Somaton Definition AS, using the parameters shown in Table 3. The parameter chosen was the skull that had the voltage of the X-ray tube closest to the RQT 9.

Table 3
Parameters used to perform clinical trials with the Tandem system.

Nominal thickness (mm)	Number of slices	Pit (mA.s)	X ray tube voltage (kV)
2.0	1	170	130

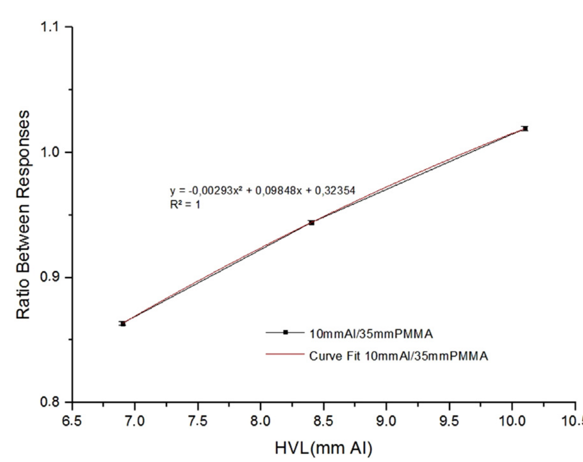

Fig. 3. Tandem curve obtained from the LCI through the ratio of the responses of the sets formed by the pencil-type ionization chamber coupled to a 10 mm thick aluminum cylindrical absorber and the pencil-type ionization chamber coupled to the PMMA cylindrical.

3. Results

The Tandem curve used for evaluation of the half value layer in the CT equipment Siemens Somaton Definition AS can be seen in Fig. 3. The adjustment applied to the curve was a polynomial adjust with $R^2 = 1$.

The ratio of the responses obtained with the Tandem system on the CT equipment Siemens Somaton Definition AS beam to the sets formed by the pencil-type ionization chamber and the 10 mm aluminum cylindrical absorber layers and the pencil-type ionization chamber and the layers 35 mm cylindrical PMMA absorbers was equal to 0.966.

Using the Tandem curve equation (Fig. 3) and comparing the ratio between the responses obtained in the CT scanner beam and the (LCI/IPEN) beam, it was possible to evaluate the approximate HVL value, which was equal to 8.4 mm Al.

4. Conclusion

Although determination of HVL in computed tomography beams is not an easy task, the proposed Tandem system proved to be feasible as a method of evaluation HVL values in CT. It is necessary that the users to construct the calibration curve of their system using a tandem system and the values provided in the calibration certificates of their equipment.

The Tandem system is inexpensive and easy to build and, this allows users to construct curves with the necessary adjustment over the beams of different TC equipment, varying the thicknesses of the materials that make up their own system.

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