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COMPARISON AMONG DIFFERENT CT IONIZATION CHAMBERS

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ABSTRACT

The dosimetry in computed tomography (CT) is carried out by the use of a pencil type ionization-chamber, because it has a uniform response at all angles relative to the incident beam of radiation, which is essential for CT equipment since the X-ray tube executes a circular movement around the table during irradiation. The commercial ionization chamber used to perform quality control procedures of this kind of equipment has a length of the sensitive volume of 10 cm. In the Calibration Laboratory of Instruments (LCI) of the IPEN there were already developed some prototypes with small differences in construction, when compared to commercially available ionization chambers. They have been used in previous studies and showed results within internationally acceptable limits. The ionization chambers tested in this study present the sensitive volume lengths of 1 cm, 3 cm and 10 cm. The objective of this study was to present results on the stability test of the three homemade ionization chambers and a commercial chamber, as well to obtain the calibration coefficients for each of them in CT standard X radiation beams. The obtained results for both characterization tests are within the recommended limits, except for the homemade ionization chambers with sensitive volume lengths of 3 cm and 1 cm in the case of the stability test.

1. INTRODUCTION

Computed Tomography (CT) has been showing a growing use when it concerns the implementation of diagnostic tests; this is due to technological advances of this equipment as the process of obtaining images became faster [1]. Therefore, there is an increased concern regarding the dose received by the patients to undergo this kind of imaging procedure.

For the dosimetry of CT beams, the radiation detector is usually a pencil-type ionization chamber. This type of dosimeter presents a uniform response to the incident radiation beam from all angles, which makes it suitable for such equipment since the X-ray tube executes a circular movement around the table during irradiation [2]. The commercial chamber used to perform the quality control testing of the equipment has usually a length of the sensitive volume of 10 cm.

The Calibration Laboratory of Instruments (LCI) of the IPEN has developed over the years some prototypes of ionization chambers, including a pencil type [3,4]. However, these homemade chambers present some small differences in relation to the commercial models. The main differences are in relation to the material used in manufacturing the chamber body (polyvinyl chloride, PVC) and in the positioning of the BNC connector. This new configuration provided a low cost in its construction, and the ionization chamber response to the tests met the internationally accepted standards, as noted in previous studies [3,4].

This work had the objective to study the response stability of ionization chambers, as well as to obtain the calibration coefficients for each of them in CT standard X radiation beams established at the LCI.

2. MATERIALS AND METHODS

Four pencil type ionization chambers were tested in this work; one of them was a commercial chamber (Victoreen 660-6) and the other three chambers were prototypes developed at the LCI, with respectively sensitive volume lengths of 10 cm, 10 cm, 1 cm and 3 cm.

Short- and medium-term stability tests were initially undertaken in this work. Afterwards, the calibration coefficients were obtained for each of them too. Table 1 shows the CT radiation qualities that were established at the LCI.

Table 1: Characteristics of the CT standard X radiation qualities at the LCI [5].

Radiation Quality	Tube Voltage (kV)	Tube Current (mA)	HVL (mmAl)	Additional Filtration (mm)	Air Kerma Rate (mGy/min)
RQT 8	100	10	6.9	3.2 Al + 0.30 Cu	22.0
RQT 9†	120	10	8.4	3.5 Al + 0.35 Cu	34.0
RQT 10	150	10	10.1	4.2 Al + 0.35 Cu	57.0

† LCI Reference CT radiation quality

For the short- and medium-term stability study of the ionization chambers, a ^{90}Sr + ^{90}Y control source (0.3 mCi) was utilized. Eleven consecutive measurements were taken each time. All of the mean values were corrected for the standard environmental conditions.

For the short-term stability test (diagnostic radiology qualities) of the ionization chambers, the standard deviation must not exceed 1%. For the medium-term stability test, the recommended limit is 2 % [5].

In order to obtain the calibration coefficients of the ionization chambers, the X-ray system Pantak/Seifert (ISOVOLT model 160HS) was utilized; it operates up to 160 kV. The standard measurement system used was a pencil ionization chamber, Radcal model RC3CT. Ten consecutive measurements were taken, and all of the mean values were corrected for the standard environmental conditions too.

The uncertainties of type A and type B were determined, with the combined uncertainty of a factor k = 2 when necessary.

3. RESULTS AND DISCUSSION

Initially are presented the results obtained for the short- and medium-term stability tests for the ionization chambers. Figure 1 shows the response normalized to the mean value of the first ten measurements of the ionization chambers.

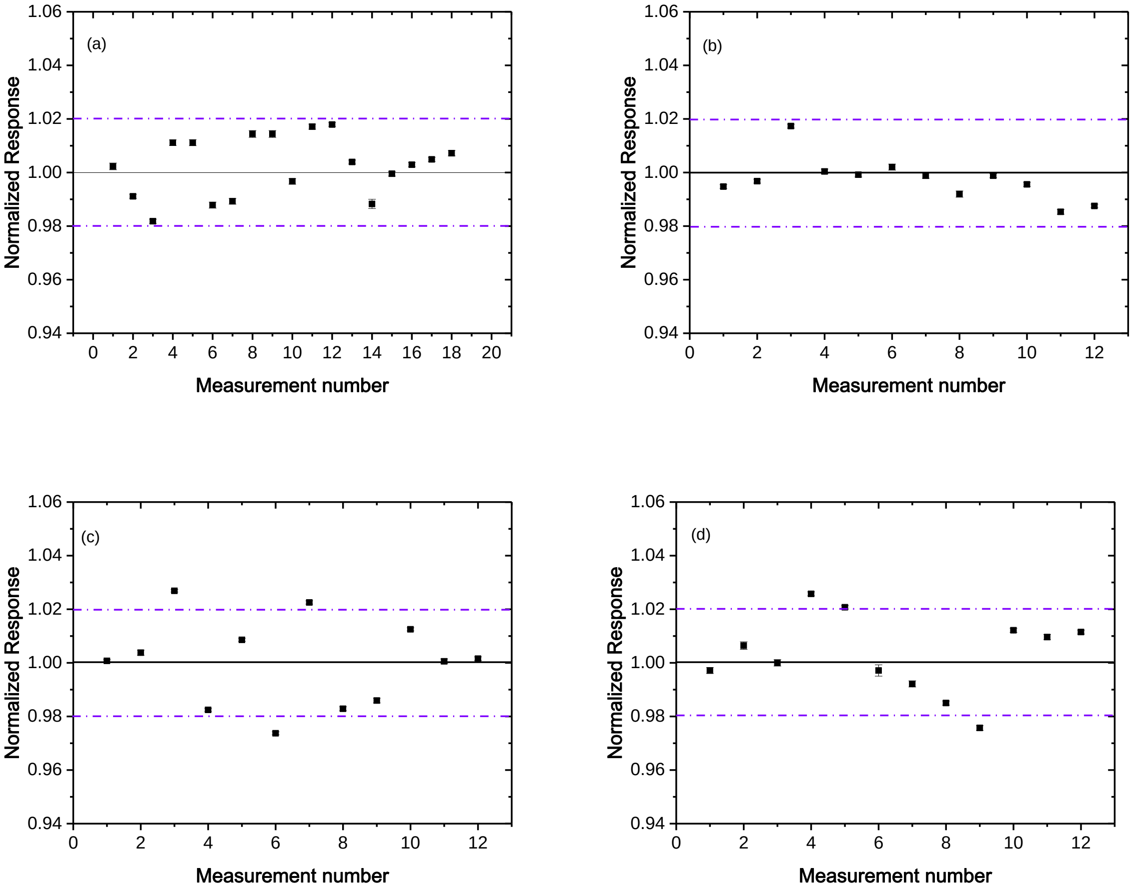

Figure 1: Stability test for the ionization chambers with their sensitive volume lengths of: (a) (Commercial ionization chamber Victoreen) 10 cm; and homemade ionization chambers (b) 10 cm; (c) 3 cm and (d) 1 cm. The maximum uncertainty of the measurements in Figures a, b, c and d was 0.17 %, not visible on the graphs.

As can be observed, both ionization chambers with a sensitive volume length of 10 cm presented results within the internationally acceptable limits. The chambers with 3 cm and 1 cm in the sensitive volume length showed some points outside the recommended limits.

The calibration coefficients and correction factors obtained for each ionization chamber in the CT standard radiation qualities of LCI are presented in Tables 2-5, for respectively the commercial Victoreen ionization chamber, and the homemade ionization chambers with sensitive volume lengths of 10 cm, 3 cm and 1 cm.

The correction factor represents the calibration coefficient normalized to the reference radiation quality (RQT 9).

Table 2: Calibration coefficients and correction factors of the Victoreen ionization chamber for CT radiation qualities.

Quality Radiation	Calibration Coefficient (mGy/pC)	Correction Factor
RQT 8	0.0177 ± 0.0002	1.006 ± 0.013
RQT 9	0.0176 ± 0.0002	1.000 ± 0.017
RQT 10	0.0175 ± 0.0002	0.994 ± 0.013

Table 3: Calibration coefficients and correction factors of the homemade ionization chamber with sensitive volume length of 10 cm for CT radiation qualities.

Radiation Quality	Calibration Coefficient (mGy/pC)	Correction Factor
RQT 8	0.0134 ± 0.0001	0.971 ± 0.013
RQT 9	0.0138 ± 0.0001	1.000 ± 0.017
RQT 10	0.0132 ± 0.0001	1.013 ± 0.027

Table 4: Calibration coefficients and correction factors of the homemade ionization chamber with sensitive volume length of 3 cm for CT radiation qualities.

Radiation Quality	Calibration Coefficient (mGy/pC)	Correction Factor
RQT 8	0.0454 ± 0.0004	0.981 ± 0.013
RQT 9	0.0463 ± 0.0004	1.000 ± 0.017
RQT 10	0.0469 ± 0.0004	1.013 ± 0.014

Table 5: Calibration coefficients and correction factors of the homemade ionization chamber with sensitive volume length of 1 cm for CT radiation qualities.

Radiation Quality	Calibration Coefficient (mGy/pC)	Correction Factor
RQT 8	0.170 ± 0.0016	0.985 ± 0.013
RQT 9	0.174 ± 0.0016	1.000 ± 0.017
RQT 10	0.177 ± 0.0017	1.022 ± 0.014

The highest energy dependence obtained for the four ionization chambers tested in this study was 2.9%. The standard states the recommended limit for energy dependency as a maximum of 5%. As can be observed, the value obtained is in accordance with IEC 61674 [5].

4. CONCLUSIONS

The stability test results of the ionization chambers with 10 cm of sensitive volume length were within the internationally acceptable limits; the homemade ionization chambers with 3 cm and 1 cm need still some improvement, because they presented some points outside the limits. The calibration coefficients and correction factors were obtained for all CT standard beams and were within the internationally acceptable limits.

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