ICMP 2011
April 17-20 · Porto Alegre - RS - Brazil

Optimization of the Evaluation of Important Parameters from the Standpoint of Radiological Protection, for Radiotherapy, through TLD Use

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Abstract— **The proposed methodology aims to optimize the evaluation of important parameters from the standpoint of Radiological Protection, the ensure that factors calculated only during commissioning are assessed more frequently, even with the exhausting of physicists in hospitals. Through this methodology, it was shown that irradiations with only few are able to evaluate several parameters in different positions and depths, making evaluation more practical and fast. The results showed that the thermoluminescent dosimeters used had a slightly higher deviation, however, can still be used for a initial assessment and if something is found wrong in this, another dosimeter more precise, but with more complex methodologies and time-consuming, would be employed Such as ionization chambers, for example.**

Keywords— **dosimetry, radiation protection, thermoluminescent dosimeters.**

I. INTRODUCTION

The use of ionizing radiation in medicine began with the discovery of X-rays in 1895 by Roentgen, and extends to the present day, passing by several advances that allow you to optimize its clinical use both for therapeutic and diagnostic. However, by the use of radiation, there was a concern in monitoring the harmful effects of that due to its absorption and distribution among various organs and tissues of the human body. For any observation of these effects is made, there is a need for knowledge of the dose at which the individual was exposed, as well as the distribution of this [1] [2].

The radiation dosimetry (or just dosimetry) is the measurement of absorbed dose or dose rate resulting from the interaction of ionizing radiation with matter. A more comprehensive way, refers to the determination of quantities that have some relevance radiological, such as exposure, kerma, fluence, equivalent dose, deposited energy, among others, through both experimental measurements and by calculations [3].

More specifically in cases of clinical dosimetry for therapeutic purposes, such as radiotherapy, the two main parameters to be evaluated consist of how much individuals occupationally exposed (workers) and individuals from the public (patients) were exposed and in control of quality of radiation beam employed in treatment, it is extremely important to meet the basic principles of radiological protection [2][4][5].

In order to attend the basic requirements of radiation protection and follow the protocols for clinical dosimetry of beams, various types of radiation detectors and meters have been developed and the most widely used in the medicine are the ionization chamber, chemicals dosimeters, photographic dosimeters and thermoluminescent dosimeters (TLDs).

This paper proposes a methodology that aims to optimize the evaluation of physical parameters of the beam of extreme importance for clinical treatments that use large fields of irradiation. Through this methodology are obtained, so convenient and fast, the percentage depth dose (PDP), the radial distribution exercise (flatness of the beam), and from this, the values of off-axis, which usually, due to routine comprehensive hospitals, are obtained only in the commissioning of the equipment. Thus, from the proposed methodology, the values obtained in the commissioning can be reviewed and confirmed with greater frequency, making it even safer the evaluation of the treatment's dosimetry.

II. METHODOLOGY

The method consists in mounting a radiation scheme composed of solid water slabs and thermoluminescent dosimeters of lithium fluoride (LiF-100).

A. Manufacture of plates: of solid water, for irradiation, and of metal, for heat treatment

The first step of the methodology consists in building a plate of solid water, which is especially adapted to the use of TLDs. This plate was machined in the workshop of the Institutes of Energy and Nuclear Research and has the following dimensions: 30 cm x 30 cm x 1 cm. Then 676 holes were made, arranged in a network of 26 holes x 26 holes, spaced 0.5 cm from each other and with a margin of 2 cm on the sides. Each hole has 0.5 cm of diameter and 0.12 cm of depth. The illustration of the scheme sent to the workshop is shown in Fig. 1 and the plate in Fig. 2.

At the same time, a metal plate was made for use in thermal treatment of TLDs (Fig. 3 and 4), with the following dimensions: 17 cm x 12 cm x 0.3 cm. In this, there have been 140 holes arranged in a grid of 14 holes x 10 holes with 0.5 cm of diameter and 0.2 cm of depth, spaced by 0.3 cm. The margins kept on board were: 2.1 cm, 2 cm, 2.1 cm and 4 cm. The largest margin was maintained to facilitate the handling of this plate with the use of pliers, because in this way, there is no risk of burns to place it in the oven for heat treatment of TLDs.

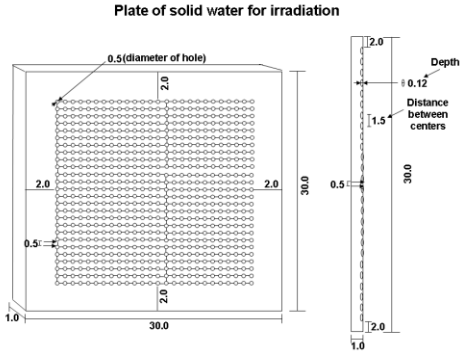

Fig. 1 Scheme sent to workshop to build the plate of solid water.

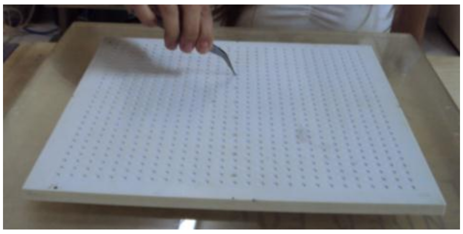

Fig. 2 Plate of solid water used in irradiation.

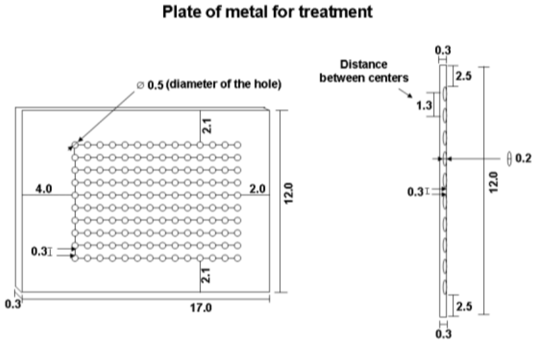

Fig. 3 Scheme sent to workshop to build the plate of metal.

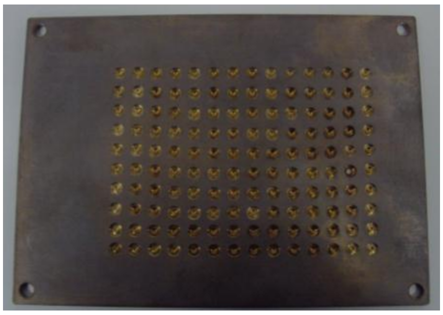

Fig. 4 Plate of metal used in heat treatment.

B. TLDs´ preparation

Before the irradiation, the TLDs need to pass through a thermal treatment, called pre-irradiation heat treatment that ensures that there remains no noise related to previous irradiation.

For each kind of TLD there is a more appropriate heat treatment, so that for the group used, it has 115 TLDs, type LiF-100, the procedures adopted were the following:

- Heating for one hour at 400ºC: it´s performed to “clear” the dosimeters, that’s, to reset the readings of these.
- Cooling: to remove from oven, the slab with the dosimeters are placed on other plaque of cold metal, which is in the fridge to cool the dosimeters faster and to keep their properties;
- Heating for two hours at 100ºC: it´s performed to fix the impurities in the crystal´s structure and make it more sensitive to the measures;
- Cooling: the same process have already described first is repeated.

The ovens used in this treatment are located in IPEN/MB-01´s building reactor at Institute of Nuclear and Energy Research (IPEN/USP).

After the treatment is done, the dosimeters are removed of de slab used and stored every ten, in plastic pots with lids and, later, these pots are reserved in a single container, that is a plastic box, closed too, for ensure more safety in the dosimeters´ transport.

C. Irradiation procedure optimization of the evaluation of the field and beam irradiation.

The proposal for optimization is to evaluate, with few irradiations, the uniformity of the beam along the axes *x*, *y* and the *xy* plane (Fig. 5), besides the radial distribution at different depths and thus to obtain the PDP and the factors off-axis.

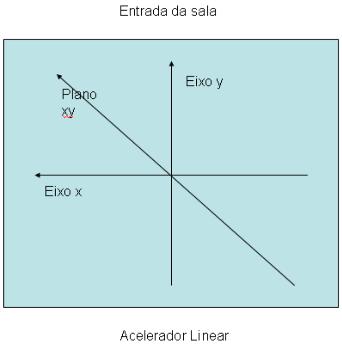

Fig. 5 Axis direction evaluated.

Fig. 6 Irradiation scheme adopted.

The irradiations to validate the methodology were made in the Hospital of the Faculty of Medicine, UNESP, Botucatu, in the Section of Radiotherapy, using the linear accelerator Varian, Clinac 2100C. The energy of the photon beam used were 10MV, 100 monitor units (MU) were applied, corresponding to a dose of 1Gy for a irradiation field of 36cm x 36cm, and the depth evaluated were:

- 0cm: three TLDs were positioned at this depth, at 0 cm, -1 cm and +1 cm (relative to central axis) in the x-axis, just to get the area of build-up in curve of PDP;
- 2,4cm: TLDs were placed every 1 cm from the position -15 cm to +15 cm in the x-axis;
- 4cm: the same number of dosimeters was used, with the same layout as the previous item, but in the y-axis;
- 12cm: in this depth, the TLDs were positioned in the xy plane, in diagonal, from -18,4 cm to 18,4 cm, every 1 cm;
- 6cm: in this position were used less TLDs, those were placed from -12 cm to 12 cm, every 3 cm, in x-axis;
- 2,4cm: this depth was repeated, with reminiscent dosimeters, with the same position as the previous item, due to be a depth where occurs the maximum dose. This was done to improve the statistical error.

The TLDs were numbered, so that when this procedure is repeated, the same dosimeters occupy the same positions in order to minimize variations in measured values. The scheme of irradiation can be seen in Fig. 6. After each irradiation, the TLDs should be read in a special reader and again subjected to heat treatment before being reused. In this work, the TLDs were read individually in a reader HarshallQS , model 3500, there were three irradiations, in order to assess the value of statistical measurement performed with TLD and compare it to that with an ionization chamber.

III. RESULTS E DISCUSSION

With this sequence of only six irradiations can get 5 points on the curve of the PDP, allow for the analysis of this and thus the behavior of these points are very different than expected, to investigate possible causes. Otherwise, there is no need for a more complex and lengthy process, avoiding the need to use other procedures with dosimeters that spend more time working, often the routines of hospitals do not have.

The uniformity of irradiation field can be also verified for the five depths evaluated and by comparing with the behavior obtained in the commissioning of the equipment, validate the values obtained initially, or to investigate possible changes in the most current value. Furthermore, it is possible to obtain values for the factors of off-axis to the points that were measured, using equation 1.

$$FatorOff-Axis=\frac{medidanoponto(x,y)}{medidanopontoCentral(0,0)} \qquad (1)$$

Thus, the values of some factors of off-axis may be recalculated, validating the originally measured during the commissioning and investigating whether they still apply to equipment and irradiation conditions in question. This check is very important for treatments that employ large fields, since these factors should be considered in the calculations of treatment planning, especially in cases of body regions that require protection over this, so that the limits proposed by the Radiological Protection are not exceeded, preserving the principles of Radioprotection (Justification, Optimization and Limitation of Dose).

This procedure was performed for a given field size and for a certain amount of energy, but the same can be applied for investigation of these factors for any field size and energy, simply position the dosimeters in the most appropriate locations and depths for each case.

As an example of the result obtained with the optimization process, are presented in Fig. 7 and 8, the PDD obtained from this procedure compared with that achieved in the commissioning, with the ionization chamber and the comparison between the radial distributions at a depth of 4cm, obtained with this methodology and commissioning, also with an ionization chamber, respectively.

It can be verified from the graphs presented in Fig. 7 and 8, which TLDs have a high value of deviation in regard to the measures made with ionization chamber, however, for the evaluation methodology proposed by this paper, these deviations are acceptable well as the values obtained with the TLDs. These values would be investigated if, considering the inherent deviation of the dosimeter, measurements of these were not close to from those obtained with the chamber during commissioning.

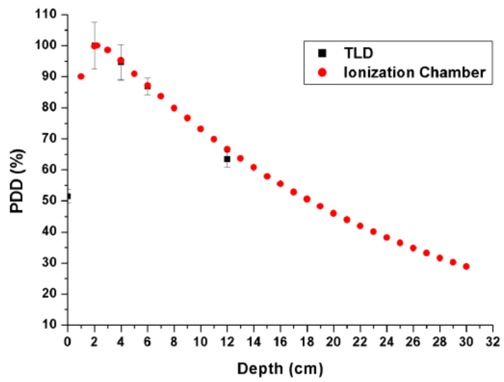

Fig. 7 Comparation between PDD obtained using TLD and using ionization chamber during the commissioning.

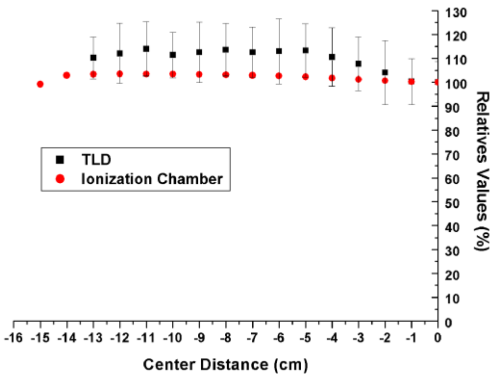

Fig. 8 Comparation between radial distributions, to 4 cm depth, obtained using TLD and using ionization chamber during the commissioning.

Given these results, it can be stated that the proposed methodology can be used for rapid and initial assessment of a beam and a given radiation field so that if there is any doubt about the behavior expected and obtained, they should then be analyzed through measured with ionization chamber.

IV. CONCLUSIONS

The results showed that the thermoluminescent dosimeters used had a slightly higher deviation, however, can still be used for a initial assessment and if something is found wrong in this, another dosimeter more precise, but with more complex methodologies and time-consuming, would be employed such as ionization chambers, for example.

Therefore, the TLDs and the proposed methodology can be used for avoid more complex and time-consuming methods. Thus these would be used only in cases that really are necessary and the dosimetric assessments can be made more simple and regular, further increasing the safety of radiotherapy procedures.

ACKNOWLEDGMENT

The authors acknowledge the financial support of CNPq, process 145293/2009-2, the Department of Radiotherapy, Faculty of Medicine of Botucatu (FMB / UNESP) and the Department of Radiotherapy of the Hospital Israelita Albert Einstein (HIAE).

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