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STATISTICAL DIFFERENCES AND SYSTEMATIC EFFECT ON MEASUREMENT PROCEDURE IN THERMOLUMINESCENT DOSIMETRY OF THE IODINE-125 BRACHYTHERAPY SEED

Carlos A. Zeituni[1,2,*], Eduardo S. Moura[1], Maria Elisa C. M. Rostelato[1], José E. Manzoli[1], João Augusto Moura[1], Anselmo Feher[1] and Dib Karam[3]

[1] Instituto de Pesquisas Energéticas e Nucleares (IPEN/CNEN-SP);
Avenida Prof. Lineu Prestes 2242
CEP 05508-000 São Paulo, SP
*czeituni@ipen.br

[2] Universidade Presbiteriana Mackenzie
Rua Consolação 930
CEP 01302-907 São Paulo, SP

[3]Universidade de São Paulo – Escola de Artes, Ciências e Humanidades- EACH (USP Leste)
Rua Arlindo Béttio, 1000 - Ermelino Matarazzo
CEP: 03828-000 São Paulo, SP

ABSTRACT

In order to provide the dosimetry for Iodine-125 seed production in Brazil, Harshaw thermoluminescent dosimeters (TLD-100) will be used. Even if measurements with TLD-100 of the same batch of fabrication are performed, the response will not be the same. As a consequence, they must be measured one by one. These dosimeters are LiF type with a micro-cube (1mm x 1mm x 1mm) shape. Irradiations were performed using Iodine-125 seeds to guarantee the same absorbed dose of 5 Gy in each dosimeter. It has been used a Solid Water Phantom with three concentrically circle with 20mm, 50mm and 70mm diameters. The angle of positions used was 0º, 30º, 60º and 90º. Of course there are 2 positions in 0º and 90º and 4 positions in 30º and 60º. These complete procedures were carried out five times in order to compare the data and minimize the systematic error. The iodine-125 seed used in the experiment was take off in each measure and put again turning his position 180º to guarantee the systematic error was minimized. This paper presents also a little discussion about the statistical difference in the measurement and the calculation procedure to determine the systematic error in these measurements.

1. INTRODUCTION

In the world, the number of new cases diagnosed was 15.3% of all types of cancer in development countries and only 4.3% in sub-developed countries. The main reason can be the previous diagnosis that has been done in the richest countries. However Brazil is not a developed country, the National Institute of Cancer (INCA) has reached a good index to the richest states (in South Region, the tax is 6.8% and in Southeast region is 6.3%), but worse index in the poorest regions, such North region with 2.2% and Northeast region with 3.4%. The diagnosis rate increases in regions that the Prostate Specific Antigen test was conducted. The mortality caused by prostate cancer has low rate explained mainly by previous diagnosis. The prostate cancer was considered a third age illness, because 75% of cases occur in 65 years old men [1, 2].

One of the treatments used was interstitial brachytherapy with Iodine-125 seed, because the procedure has low impact, allowing most patients to return to their normal activities between one or three days after the intervention, with a small or no pain. The other important benefits for the patients are the low impotence rates and few incidents of urinary incontinence. But to diminish the effects of radiation in the tissues is very important that dose prescription is as low as it can be. For this reason an accuracy dosimetry is expected to use iodine-125 seeds. This dosimetry is realized using detectors to measure the dose directly or indirectly. In brachytherapy, the thermoluminescence dosimetry (TLD) using LiF crystals are an experimental method that has been extensively applied with relative success for dose measurements [3].
This work study the difference of measurements in TLD-100 micro-cube LiF crystals with Iodine-125 seeds applied for brachytherapy using different angles of measurement in a slab phantom of Solid Water RW1.

2. MATERIALS AND METHODS

2.1. Iodine-125 Sources

For this work an Iodine-125 sealed source or more often term Iodine-125 seeds (due to small sizes), model IMC6711 manufactured by Oncura GE Healthcare Ltd, was used. This model is a cylindrical welded titanium capsule with 4.5 mm in length and 0.8 mm in external diameter, inside of this capsule has a silver rod with 3.0 mm in length and 0.5 mm in external diameter which contains Iodine-125 adsorbed on the silver rod's surface.
Iodine-125 seeds has a half-life of 59.43 days and emits photons of 27.4 to 35.5 keV, and these seeds are available with air kerma strength values between 0.243 and 7.92 $\mu Gym^2/h$ ($\pm 7\%$ with 2σ) and apparent activity values between 0.191 and 6.24 mCi ($\pm 7\%$ with 2σ) [4].

2.2. TLD-100 Irradiation

A batch of TLD-100 micro-cube (1 mm^3) manufactured by Thermo Scientific Corporation was utilized. For this work, 28 pre-selected dosimeters were chosen to perform the relative measurements, these dosimeters were selected because they shown more reproducibility compared with the whole batch, more details escapes from the scope of this work but they are find in the reference 5 [5].
Annealing procedures adopted for the dosimeters was 400 ^0C for 1 hour and 100 ^0C for 2 hours with a homogeneous temperature to pre-irradiation annealing. Due to relative low time of exposure used in the measurements, none post-irradiation annealing was realized, to avoid any influence in the measurements [5, 6].

2.3. Solid Water RW1 Phantom

The dosimeters were irradiated in a solid phantom water equivalence called Solid Water^{Tm} model RW1, manufactured by PTW-Freiburg. This Solid Water RW1 has a density of 0.970 g/cm^3 and your atomic effective number is very low ($Z_{eff} = 5.53$). [5, 7]
This solid phantom has three circular discs (each disc with 36 spaces) with 2, 5 and 7 cm. the iodine-125 seed was positioned in the geometric center of the discs. And in this work we used the first disc (2 cm) and the positions 0º, 30º, 60º and 90º.

You can see the phantom schema in Figure 1.

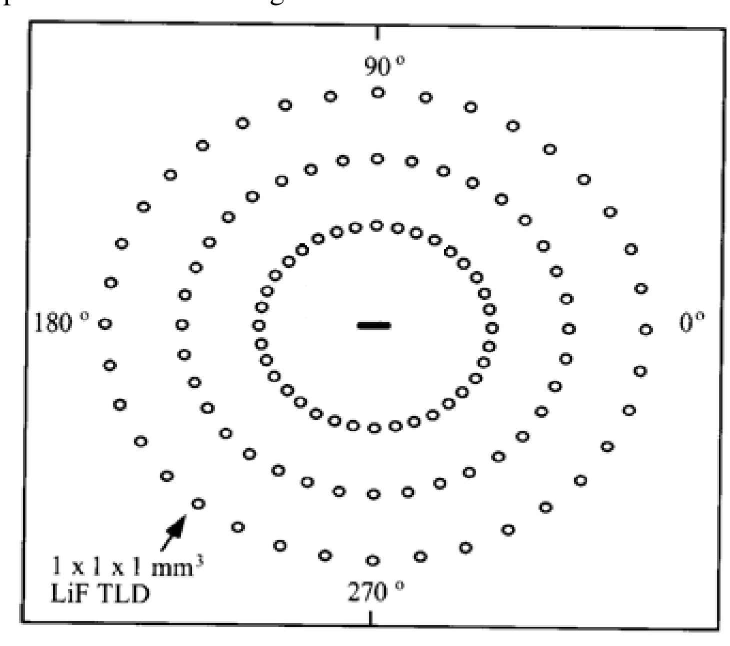

Figure 1. Phantom schema showing the idine-125 seed position and the three concentrical disks with 2, 5 and 7 cm.

2.4. Uncertainties Analysis

Every experimental system can only be considered valid if an uncertainties analysis shows a good acceptance with the experimental method sed. Of course, not all experimental uncertainties can be known, but at least these uncertainties need to be estimated to guarantee that the results are trustfully or not.

The thermoluminescent experiments are a destructive assay, by this mean, once you read a crystal, this reader cannot be repeated. Then, measurement process repeatability cannot be calculated. Then, it is important to diminish the uncertainties parameters to evaluate the process repeatability.

There are two types of uncertainties: type A and type B. The type A uncertainty source is related only with statistical factors, thus, to evaluate this type of uncertainty a series of repetitions in equal conditions must be executed. The type B uncertainty source is based on non-statistical factors such as calibration certifications, instrument standards, manufacturer technique data and estimation effects based on previous experiment, in case that they exist.

For this work, some parameters can be considered stable in the sequence of measurements, and like they are stable, they won't be evaluated alone, and they are:

a) Temperature, pressure and humidity of the room in the moment of the measurement;
b) stabilized electric net;
c) gaseous flux that enter in the TLD reader on the reader moment;
d) TLD reader stress
e) Variation of the heating of the oven in the pre-treatment
f) Limit of detection of the reader

And the parameters listed above and your maximum uncertainty considered for combined uncertainty effect was:

a) Reproducibility of the measures in the TLDs – Type A – 4.0% [8];
b) Calibration of iodine-125 seed used – Type B – 5.0%, manufactory data;
c) LiF energetic dependency correction – Type B – 5.0%, manufactory data;
d) Crystal measurement position error to the center of the seed – Type B – 0.1%, maximum error of the CNC equipment used for phantom manufacture;
e) Crystal measurement position error to the seed position – Type B – 2.17%, maximum error of positioning the crystal in the end of the seed.

Some of these uncertainties are not independent, but for safety analysis, it can be calculated that the maximum expect combined uncertainty can be 8.41%.

Uncertainties analyses in the TLD-100 measurements are fundamental to trace the possible uncertainties sources around the experiments as trying to diminish them. Uncertainty methods in literature are insufficient to establish a fixed manner to estimate these influence on the TLD's values.

3. RESULTS

The measures were repeated 3 times with 12 TLD-100 crystals. Each measurement was done putting the crystals in the positions 0º, 30º, 60º, 90º, 120º, 150º, 180º, 210º, 240º, 270º, 300º and 330º. And if you thing in a trigonometric circle, we can write in four quadrants, named Q1, Q2, Q3 and Q4. The measure values are shown in table 1.

For hypothesis of this work, the iodine-125 seed are homogeneous, then the Q1 – 30º measurement (30º) is equivalent of Q2 – 30º measurement (150º), Q3 – 30º measurement (210º) and Q4 – 30º measurement (330º).

Table 1. Three series measure values split in angles relatively of the center of the iodine-125 seed.

Angles	Meas. 1 (nC)	Meas. 2 (nC)	Meas. 3 (nC)
0º - Q1 = 0º	4.36	3.73	3.30
0º - Q3 = 180º	4.53	3.75	3.45
30º - Q1 = 30º	4.30	3.58	3.20
30º - Q2 = 150º	4.29	3.43	3.02
30º - Q3 = 210º	3.90	3.46	3.19
30º - Q4 = 330º	4.15	3.72	3.12
60º - Q1 = 60º	3.37	3.00	2.51
60º - Q2 = 120º	3.14	3.18	2.95
60º - Q3 = 240º	3.70	2.88	2.50
60º - Q4 = 300º	3.45	3.18	2.73
90º - Q1 = 90º	1.83	1.84	1.63
90º - Q3 = 270º	1.83	1.75	1.43

These measurements need to be normalized for each measurement series because each measurement have its own dose and its own fading time. To normalized it will continue using the hypothesis of same angle same measurement. Then, we split the table in angles and we calculate the average of each angle in measurement and the average of averages. These results are shown in Table 2.

Table 2. Three series measure values split in angles relatively of the center of the iodine-125 seed showing the average of each measurement calculated per angle and the average of averages per angle.

Angles	Meas. 1 (nC)	Meas. 2 (nC)	Meas. 3 (nC)	Average (nC)
0º - Q1 = 0º	4.36	3.73	3.30	
0º - Q3 = 180º	4.53	3.75	3.45	
Average	**4.45**	**3.74**	**3.38**	**3.86**
30º - Q1 = 30º	4.30	3.58	3.20	
30º - Q2 = 150º	4.29	3.43	3.02	
30º - Q3 = 210º	3.90	3.46	3.19	
30º - Q4 = 330º	4.15	3.72	3.12	
Average	**4.16**	**3.55**	**3.13**	**3.61**
60º - Q1 = 60º	3.37	3.00	2.51	
60º - Q2 = 120º	3.14	3.18	2.95	
60º - Q3 = 240º	3.70	2.88	2.50	
60º - Q4 = 300º	3.45	3.18	2.73	
Average	**3.41**	**3.06**	**2.67**	**3.05**
90º - Q1 = 90º	1.83	1.84	1.63	
90º - Q3 = 270º	1.83	1.75	1.43	
Average	**1.83**	**1.80**	**1.53**	**1.72**

With this individual average calculated, it can be normalize the entire table 1 in the table 3 showed.

Table 3. Three series measure values split in angles relatively of the center of the iodine-125 seed normalized per average of averages.

Angles	Meas. 1 (nC)	Meas. 2 (nC)	Meas. 3 (nC)
0º - Q1 = 0º	3.80	3.85	3.77
0º - Q3 = 180º	3.93	3.86	3.94
30º - Q1 = 30º	3.73	3.64	3.70
30º - Q2 = 150º	3.72	3.49	3.48
30º - Q3 = 210º	3.39	3.53	3.67
30º - Q4 = 330º	3.61	3.79	3.60
60º - Q1 = 60º	3.01	2.99	2.86
60º - Q2 = 120º	2.80	3.16	3.36
60º - Q3 = 240º	3.30	2.87	2.86
60º - Q4 = 300º	3.08	3.17	3.11
90º - Q1 = 90º	1.72	1.76	1.83
90º - Q3 = 270º	1.72	1.68	1.61

For the hypothesis, these values must be the same for each angle. Of course, like this is an experimental measurement, there are some variations relatively of the method used. Then, we can calculated the standard deviation of the measurements. That can be shown in table 4.

Table 4. Standard deviation of normalized values of table 3 per angle of measurement.

Angles	SD
0º	0.07 (nC)
30º	0.12 (nC)
60º	0.18 (nC)
90º	0.07 (nC)

4. CONCLUSIONS

For the low standard deviation calculated in this work we can concluded that all quadrants shown the equivalence measure per angle. Then any experimental measurement with iodine-125 seed can be made using one quadrant and the other three can be used as a reproducibility measurement of the first one. It is very important for TLD experiments, because like known per TLD users, these measures cannot be repeatable.

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REFERENCES

1. *Estimativa 2006: Incidência de câncer no Brasil*. Instituto Nacional de Câncer. Rio de Janeiro, Brazil (2005).
2. M. E. C. M. Rostelato, Paulo R. Rela, C. A. Zeituni, A. Feher, J. E. Manzoli, J. A. Moura, E. S. Moura and C. P. G. Silva, "Development and production of radioactive sources used for cancer treatment in Brazil", Nukleonika, V. 53, pp. S99-S103 (2008)
3. A. S. Meigooni, V. Mishra, H. Panth and J. Williamson, "Instrumentation and dosimeter-size artifacts in quantitative thermoluminescence dosimetry of low-dose fields", *Medical Physics*, V. 22, pp. 555-560 (1995).
4. OncoSeed™, Instructions for the use of Iodine-125 seeds for medical brachytherapy treatments – user's guide, Oncura Inc. 2005.
5. C. A. Zeituni. *Dosimetria de fontes de Iodo-125 aplicadas em braquiterapia*. Ph.D. thesis, São Paulo, 2008.
6. M. Ghiassi-Nejad, M. Jafarizadeh, M. R. Ahmadian-Pour and A. R. Ghahramani, "Dosimetric characteristics of 192-Ir sources used in interstitial brachytherapy" *Applied Radiation and Isotope*, V. 55, pp. 189-195 (2001).
7. J. A. Meli, A. S. Meigooni, "On the choice of phantom material for the dosimetry of ^{192}Ir sources" *International Journal Radition Oncology Biology Physics*, V.14, pp. 587-594 (1988).
8. C. C. Popescu, J. W. Wise, K. Sowards, A. S. Meigooni, G. S. Ibbott, "Dosimetric characteristics of the Pharma Seed model BT-125-I source", *Medical Physics*, V. 27, pp. 2174-2181 (2000).