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STUDY AND METHODOLOGIES FOR FIXING EPOXY RESIN IN RADIOACTIVE SOURCES USED FOR BRACHYTHERAPY

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ABSTRACT

The World Health Organization (WHO) estimates that the number of new cancer cases worldwide will reach 15 million by 2020. The disease is already the second leading cause of death worldwide, being behind only cardiovascular disease. It is unquestionable that it is a public health problem, especially among developing countries. Prostate cancer is the most common among men, approximately 28.6%. The choice of type of treatment for prostate cancer should consider several factors such as: tumor size and extent, apparent aggressiveness (pathological characteristics), age, health. Among the methods applied, brachytherapy has been used in the initial and intermediate stages of the disease. Brachytherapy is a safe and effective treatment for localized prostate cancer. Brachytherapy is a form of radiotherapy in which radioactive seeds are placed in contact with or within the organ being treated. This technique allows a large dose of radiation to be released only on the target tumor that protects healthy surrounding tissues. Sources may have different shapes and sizes, but the one used for prostate cancer is usually 4.5 mm in length and 0.8 mm in diameter. About 80 to 120 seeds can be used per patient. Iodine-125 is the radioisotope most used in brachytherapy of the prostate, it emits 35,49keV X-rays in 100% of the decays, with average energy of 29 keV. The treatment of prostate cancer with permanent implantation of iodine-125 seeds has grown dramatically in the world in recent years. Most patients can return to normal life within three days with little or no pain.

1. INTRODUCTION

According to global estimates of the Globocan 2012 project of the International Agency for Research on Cancer (IARC) of the World Health Organization (WHO), there were 14.1

million new cases of cancer and a total of 8.2 million deaths by cancer, throughout the world, in 2012 [1,2]. Recent studies show that in 2030, the overall burden will be 21.4 million new cases of cancer and 13.2 million deaths from cancer [2,3].

The estimate for the years 2016 and 2017, indicates the occurrence of about 600 thousand new cases of cancer in Brazil[4].

1.1. Prostate Cancer

A total of 68,800 new cases of prostate cancer were reported for Brazil in 2016. These values correspond to an estimated risk of 61.82 new cases per 100,000 men [4,5,6,7]. The latest global estimate pointed to prostate cancer as the most frequent type in men, about 1.1 million new cases in 2012. Approximately 70% of the diagnosed cases in the world occur in developed countries.

In Brazil, the increase in life expectancy, the improvement and evolution of the diagnostic methods and the quality of the country's information systems, as well as the occurrence of overdiagnosis, due to the dissemination of prostate cancer screening with PSA and touch can explain the increase in incidence rates over the years. The only well established risk factor for the development of prostate cancer is age. Approximately 62% of the diagnosed cases in the world occur in men aged 65 years or older. With the increase in the world life expectancy, it is expected that the number of new cases of prostate cancer increase by about 60% [4,5,8-12].

1.2. Forms of Treatment of Prostate Cancer

The choice of type of treatment for prostate cancer should consider several factors such as tumor size and extent, apparent aggressiveness (pathological characteristics), age, health, and patient preferences [9,13,14]. Treatment may be by surgical intervention, radiotherapy, or even vigilant observation. The first option, radical prostatectomy, is a surgical procedure where the prostate and neighboring tissues are removed. The main side effects are urinary incontinence, which affects 35% of patients, and sexual impotence, which affects 65% to 90% of patients [15].

1.3. Seeds of Iodine-125

The treatment of prostate cancer with the permanent implantation of iodine-125 seeds has grown significantly in the United States in recent years [16,17,18]. In the international market, the minimum seed cost is US $ 45.00 and the quantity of seeds required per implant is 80 to 120 units [9,12,20]. In Brazil, implants are made with imported seeds. IPEN-CNEN / SP established a project for the development and production of iodine-125 seeds (Fig. 1) with the purpose of minimizing costs and allowing distribution to public health entities, since Brazil's demand for this type of therapeutic product is large [9,12,20,21].

Figure 1: Photo of the seeds (IPEN file).

1.4. Epoxy Resin

Epoxy resins also called polyepoxide is a thermosetting plastic that hardens when mixed with a catalyst and hardener. The most frequent epoxy resins are the products of a reaction between epichlorohydrin and bisphenol-A. There are also resins based on bisphenol F and Novolac epoxy resins[25].

These resins have good adhesion to other materials, good chemical and environmental resistance, good mechanical properties, good electrical insulation properties being a rigid resin. Epoxy resins or simply epoxy are polymers characterized by the presence of glycidyl groups in their molecule, as well as other functional grou ps. These epoxy resins deserve high interest to be used in the preparation of a polymer matrix for the immobilization of radioactive material [24,25] because they present:

- Low viscosity;
- Good penetration capacity;
- High adhesion strength;
- Easy application;
- Fast hardening / reduced waiting times;
- Diversified application;

Commercial epoxy resins, for the most part, do not contain significant amounts of radioactive impurities, leading to a very low background, total activity and sealed source calibration procedures [25]. It is one of the oldest resins of the epoxy class offering low costs, ease of acquisition and availability in the market. They are of low toxicity and, consequently, low possibility of chemical contamination during their manipulation (characteristic of epoxy resins). The process can simply be starte by the addition of a nucleophilic catalyst such as an alkoxide or amine. After the curing process, they have obtained polymer material of high compressive strength and adhesion strength [13] and with high resistance to radiation [15], as well as high resistance to thermal decomposition, which make them a material with high chemical stability. Also, after curing, practically insoluble polymers in water occur, either in acidic or alkaline media, which hinder the casting or diffusion of the radioactive component even when immersed in same media (water) [13].

2. METHODOLOGY

Iodine-125 is produced in a nuclear reactor from xenon-124. It decays by electronic capture and internal conversion to tellurium-125 (Fig. 2) [22]. In the process, it emits photons of 27keV, 31keV and 35keV, with average energy of 29 keV. Due to the low average emission energy, its photons have low penetration power. The isotope has a half-life of 59.89 days [11,21-23].

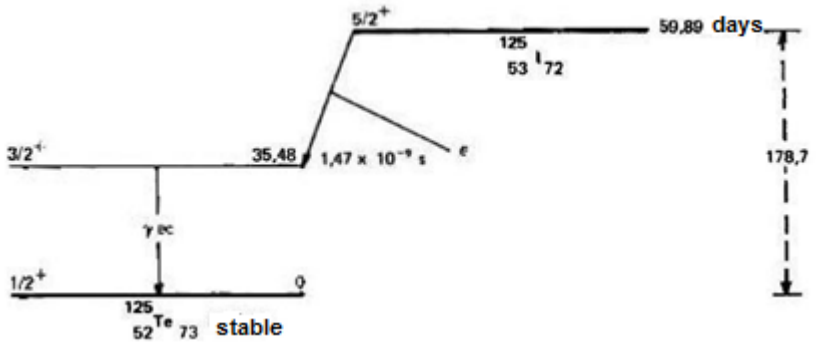

Figure 2: Schematic diagram of the decay of iodine-125.

The epoxy resin was mixed with the radioactive solution and placed in a silicone mold. In this assay, 10 mL (11.2 g) resin (Epichlorohydrin reaction with Bisphenol A) was mixed with 20% hardener (modified polyethylene diethylenetriamine-DETA, used in all experiments) 2.04 mL (2.24 g), totaling a mass of 13.4 g of solution. The template contains four spaces in which the solution was placed. These spaces have the dimensions of the seeds. After the resin curing process the four pellets were removed (Fig.3) and taken to a Capintec CRC-15W ionization chamber (Fig. 4), to measure the activities one by one. Each core was measured three times and averaged as shown in Table 1.

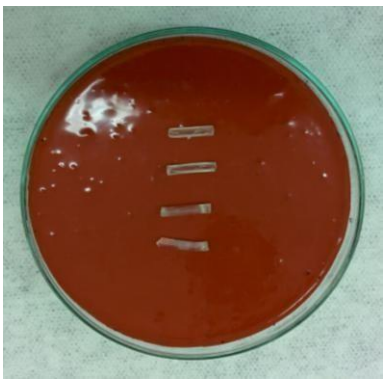

Figure 3: *Pellets* removed after the resin curing process.

Figure 4: Capintec15W. Emphasis on sample holder for the measures.

Table 1: Average pellets activities

Core Number	Average of activities (μCi)
1	49.5
2	40.4
3	39.7
4	33.9
Average	40.9

The evaluation of the yield of the fixation reaction was calculated as follows (equation 1):

$$E_{\%} = \frac{\sum A_n}{A_T} . 100 \quad (1)$$

$E_{\%}$= efficiency of the process in percentage;
$\sum A_n$=sum of core activities;
A_T= total activity of the corrected solution for radioactive decay.

This efficiency was obtained through numerous measures of activities of the formed nuclei. And all the results obtained presented a high percentage of acceptance, above 80% and a minimum and acceptable standard deviation.

3. CONCLUSIONS

With the proposed work and the results obtained, it was possible to develop a new methodology for obtaining iodine-125 seed for brachytherapy, which makes the treatment more feasible in financial matters. The epoxy resin was efficient in adsorbing the iodine-125 solution. The decrease in activity day after day was given solely and exclusively by the natural decay of the radioisotope.

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