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Development of a new design ^{125}I-brachytherapy seed for its application in the treatment of eye and prostate cancer

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ABSTRACT

Palladium coated silver beads of 0.5 mm (∅) were used to adsorb ^{125}I and encapsulated inside a titanium capsule by Nd:YAG laser, for use as a brachytherapy source. Experimental conditions were optimized for maximum adsorption of ^{125}I and uniformity of radioactivity was ascertained. Leachability of ^{125}I was found to be $<0.01\%$. The dose rate constant of the new source was estimated to be 1.045 cGy h^{-1} U^{-1}. This newly developed source could be an alternative to other ^{125}I sources.

1. Introduction

Radiation sources are often used in the brachytherapy treatment of cancers to deliver the radiation dose to the affected lesion. Teletherapy using ^{60}Co is most widely used in the treatment of cancers, by keeping the source away from the body. Where as in brachytherapy, the radiation sources prepared from radioisotopes such as ^{137}Cs, ^{192}Ir, ^{125}I, ^{103}Pd etc., are kept in close proximity of the lesion. In most brachytherapy treatments, sealed radioactive sources are used as temporary implants and are removed after delivering the desired radiation dose to the affected site. However, in few situations such as prostate cancer, the sources are permanently implanted in the organ. Cancers of the eye such as retinoblastoma and ocular melanoma can be treated by brachytherapy using low energy X or gamma ray sources and this technique has shown promising results as a vital vision saving technique. Radioactive seeds incorporating low energy photon emitting radionuclides such as ^{125}I, ^{103}Pd etc., are in demand for the treatment of eye, prostate and brain cancers (Perez et al., 1997; Finger, 1997). In view of its suitable radiation characteristics such as ~27.4–35 keV X and gamma radiations and reasonably long half-life of ~60 days and ease of production in medium flux nuclear reactors, ^{125}I is considered to be one of the best isotopes among the available options for use in both eye and prostate brachytherapy. ^{125}I seed sources are also being tried for the treatment of various tumor sites, because their low energy photon emissions produce a rapid decrease in dose with increasing distance and thereby minimize the dose to adjacent vital organs (Johnson et al., 2007; Monge et al., 1999). Source preparation methods such as electrodeposition, impregnation of radioactivity into ceramics, ion implantation etc., are adapted by different manufacturers (Bret et al., 2001) for preparation of the sources. Owing to the IPR concerns and the commercial interests, the technical details on the preparation of such sources, their encapsulation in body compatible materials etc., are not revealed by the international suppliers. However, the dosimetric aspects of various types of seeds are reviewed occasionally and have been reported in the literature. (Karaikos et al, 2001; Anagnostopoulos et al.; 2002, Li. et al., 2000). The development of a source suitable for such application not only needs a reproducible production procedure but also requires careful quality evaluation prior to the clinical application. Palladium coated silver rods of size 0.5 mm (∅) × 3 mm (*l*), containing ~74–111 MBq (2.0–3.0 mCi) of ^{125}I have already been developed by our group and are being used in India as brachytherapy sources for ocular brachytherapy (Saxena et al., 2006). There is currently great interest in the brachytherapy treatment of prostate cancer due to its increasing profile in the older male population. Low dose rate implants using permanently implanted radioactive seeds and high dose rate treatments using afterloading machines are two methods that are used for the treatment of this disease. Both techniques require close integration between imaging and the placement of the radioactive sources (Bownes and Flynn, 2004). ^{125}I seeds in the low activity range of ~18.5–37 MBq (0.5–1.0 mCi) are effectively used as permanent implants for the treatment of localized prostate cancer. The physical characteristics of the photons emitted by a low-energy brachytherapy source are strongly dependent on the construction of source. Beside from absorption and scattering caused by the internal structures and the source encapsulation, the photoelectric interactions occurring with source-construction materials can generate additional characteristic X-rays with energies different from those emitted by the radionuclide. As a

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result, the same radionuclide encapsulated in different source models can result in dose rate constants (DRC) and other dosimetric parameters that are strikingly different from each other (Nath and Chen, 2007). It is because of this, that there is a continuous interest in developing sources of different geometries. In the present communication, we describe the studies carried out at our end to develop a new design of ^{125}I source, consisting of six ^{125}I-adsorbed palladium coated silver spheres of ~0.5 mm (∅) arranged collinearly within a titanium capsule. In the present communication, the details about optimization of conditions for preparing stable source cores, their quality evaluation, laser encapsulation in tiny titanium capsules of size 0.8 mm (OD) × 4.75 mm (*l*) and determination of DRC are described.

2. Materials and methods

^{125}I as sodium iodide in dilute NaOH solution procured from M/s Institute of Isotopes Co. Ltd., Hungary as well as produced in our Division was used in our work. High purity silver beads of ~0.5 mm (∅) were procured from M/s Silver Plaza, Mumbai. Titanium capsules of 0.8 mm (OD) × 4.75 mm (*l*) were fabricated at the Center for Design & Manufacture (CDM) of our Institute. A 50 W Nd:YAG laser welding system M/s Quanta Systems, Italy was used for welding the sources. Model-1008 well type re-entrant ion chamber from M/s Sun Nuclear Corporation, USA was used for source activity measurement. Optical density measurements of exposed X-ray films were made using OPTEL-B&W transmission densitometer. TLD-100 cylindrical rods of 1 mm (∅) × 6 mm (*l*) were used for recording the dose rates. GAF-Chromic films and Model-37-443 radiochromic densitometer, both procured from M/s Nuclear Associates (A Division of M/s Victoreen Inc., USA) were used for the measurement of optical density in autoradiography experiments. All other chemicals used in our work were of GR/AR grade procured from well-established manufacturers.

3. Experimental

The experimental conditions for adsorption of ^{125}I on palladium coated silver beads of ~0.5 mm (∅) size were optimized and sources were characterized as follows.

3.1. Studies on the percentage adsorption of ^{125}I

The process to prepare the ^{125}I microspheres was optimized by initially coating the 0.5 mm (∅) silver beads with palladium followed by adsorption of ^{125}I. Cleaned silver beads were treated with 0.05% $PdCl_2$ solution at ~100 °C for 15–20 minutes (Saxena et al., 2006). In tracer level adsorption experiments, palladium coated silver beads were individually taken in separate small glass reaction tubes and treated with ~5 μL of ^{125}I solution containing ~0.5 μCi (18.5 KBq) of ^{125}I. Different amount of carrier iodide ranging from 0.2 to 1.2 μg was added separately to the individual reaction tubes and total reaction volume in each experiment was maintained as 15 μL. Reaction temperature and adsorption time were optimized for quantitative adsorption. ^{125}I-adsorbed beads were washed with warm (~50 °C) distilled water and percentage adsorption of ^{125}I was estimated by measuring the radioactivity of beads, using a well type NaI (Tl) scintillation counter. Subsequently, beads containing up to ~27.7 MBq (0.75 mCi) each of ^{125}I were made under optimized conditions. The radioactivity of such beads was estimated with the help of re-entrant ion chamber. The source activity in final encapsulated form was also estimated in the same way at the maximum response position of ionization chamber.

3.2. Polymer coating on radioactive beads

In order to provide a physical barrier between the source and the titanium capsule, radioactive beads were coated with polystyrene solution by immersing them in polystyrene solution. Polystyrene beads of ~6 mm (∅) were dissolved in benzene at different concentrations and beads were immersed in the solution for 10 seconds. Coated beads were dried in air and were subsequently washed with luke warm water at ~35 °C.

3.3. Laser encapsulation

Inactive dummy sources were encapsulated in 50 μm thick titanium capsules of 0.8 mm (OD) × 4.75 mm (*l*), using a laser beam from 50 W Nd:YAG laser welding unit. Laser beam was focused to the weld joint horizontally and parameters such as capacitor bank discharge voltage, pulse width, frequency, rotational speed etc., were optimized to obtain quality welds. In the final assembly of radioactive source, six palladium coated silver beads, each containing ~27.7 MBq (0.75 mCi) of ^{125}I were arranged as shown in Fig. 1 and encapsulation was carried out using previously optimized parameters.

3.4. Quality assurance

3.4.1. Leachability

The leachability of unencapsulated ^{125}I-adsorbed beads was determined under static conditions as per the Atomic Energy Regulatory Board (AERB) stipulated procedure (AERB SS-3 Rev-1, 2001). Individual radioactive beads containing ~27.7 MBq (0.75 mCi) of ^{125}I were kept in 100 mL of distilled water for 48 hours, after which an aliquot of the water was assayed using well type NaI (Tl) scintillation counter set for ^{125}I energy. Based on this value, total radioactivity released in 100 mL of water was estimated.

3.4.2. Uniformity of activity

The uniformity of the activity in ^{125}I-adsorbed beads was assessed by autoradiography. A special copper gadget of 44 mm (∅) × 14 mm (*l*) was used to hold a 2 mm (∅) glass tube containing radioactive bead in the center of the gadget (Mathew et al., 2002). Individual radioactive beads having radioactive strength of ~27.7 MBq (0.75 mCi) were kept in a glass tube that was subsequently mounted on the gadget. An industrial radiographic X-ray film was wrapped along the circumference of the brass disk. The optical density of the X-ray films after exposure to the radioactive beads for an optimized duration of ~30 minutes was measured at the eight different points of film with the help of B&W transmission optical densitometer.

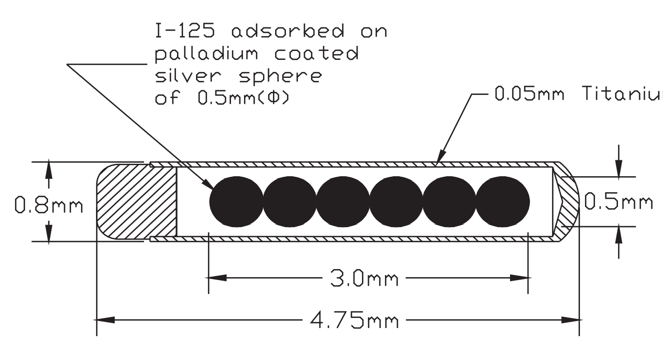

Fig. 1. Sketch of ^{125}I brachytherapy source.