Commentary ISSN 2835-3587

Radiology & Imaging Journal

Role of the Use of Conformal Beta Applicators in the Radiation Treatment of Small Skin Lesions

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Received: 07 May 2023; **Accepted:** 09 Jun 2023; **Published:** 14 Jun 2023

Citation: Eduardo De Paiva. Role of the Use of Conformal Beta Applicators in the Radiation Treatment of Small Skin Lesions. Radiol Imaging J. 2023; 2(1): 1-3.

ABSTRACT

Radiation from beta particles plays an in important role in brachytherapy treatments of various diseases. The use of conformal applicators helps to improve the efficacy of treatment since radiation doses can be delivered focalized sparing the healthy tissues. In this paper the importance of beta applicators is shortly discussed.

Keywords

Beta radiation, Conformal applicators, Brachytherapy.

Introduction

High-speed negative or positive beta particles are spontaneously emitted in the decay of certain unstable nuclei. In the first case a given nucleus has a deficiency of protons and stability is reached (or increased) by the transformation of a neutron into a proton via the beta minus decay; in the second case a nucleus with an excess of protons increases its stability by the conversion of a proton into a neutron via the beta plus (positron) emission. The energy and momentum conservation laws would not be valid if beta emission were not also accompanied by the emission of a second type of particle, which is the antineutrino for beta minus decay and the neutrino for beta plus decay. These neutrinos have no charge and a negligible mass, and do not contribute to the radiation doses given to the medium since they virtually do not interact with the common matter. Beta decay can be summarized by the following equations.

$${}^{A}_{Z}X \rightarrow {}_{Z+1}^{\ A}Y + {}_{-1}^{\ 0}\beta + \bar{\nu}, \quad \text{for beta minus emission,}$$

$${}^{A}_{Z}X \rightarrow {}_{Z-1}^{\ A}Y + {}_{+1}^{\ 0}\beta + \nu, \quad \text{for positron emission.}$$

Several radionuclides decay by emission of beta particles and having a wide range of half-lives, as for example Phosphorus-32 ($T_{1/2}$ = 14.3 days), Vanadium-48 ($T_{1/2}$ = 16 days), Strontium-90 ($T_{1/2}$ = 28.9 years), Yttrium-90 ($T_{1/2}$ = 64.6 hours), Ruthenium-106 ($T_{1/2}$ = 373.6 days), Samarium-153 ($T_{1/2}$ = 46.3 hours), and Holmium-166 ($T_{1/2}$ = 26.8 hours), and the practical uses of their beta radiation include scientific, industrial, and medical applications. The maximum energies of the beta particles can reach values of the order of a few millions of electron-volts, have a short range (less than 10 mm in tissue) and a high radiation dose gradient. These features make them suitable to be used or have the potential to be used in medicine to treat mainly small and/or superficial tumors. Thus, radiation doses from beta particles play an important role in the brachytherapy treatment of various types of diseases. Among them, it can be cited that the energy of beta particles may be used in cardiology to prevent restenosis after angioplasty procedures [1]; several ocular diseases can be treat with beta radiation [2-4]; may be used in the treatment of certain kind of brain tumors [5,6]; in the treatment of hepatocellular carcinomas [7], and may also be used to treat superficial skin lesions [8-13], which is a widespread kind of cancer. It should be mentioned that only in the United States it is estimated more than 4 million cases of nonmelanoma skin cancer are diagnosed per year [14].

One advantage of the use of radiation doses from beta particles in brachytherapy treatments is the relatively simple radiation protection guidelines concerning these particles, since beta particles can be easily shielded by a thin metallic sheet, a piece of wood or some kind of polymer. However, a special attention should be given to the choice of metallic material to shield the beta particles provided that the collision of the beta particles with high atomic number materials may be a source of concern due to the production of unwanted x-rays by the bremsstrahlung process. The possible hazard of handling beta emitters can be conveniently overcome by using applicators (or plaques).

From the patient undertaken radionuclide therapy point of view the beta applicators have two basic functions. First, to allow the radioisotope to give the beta radiation doses to the lesion; second, whenever the target of irradiation is near a healthy structure it can be in a certain extent conveniently protected using applicators. As an example, the curved and asymmetric 106-Ru/106-Rh COB model plaque (manufactured by Eckert & Ziegler BEBIG, GmbH, Berlin, Germany) has a cut-out section intended to treat ocular tumors without affecting the optical nerve [3].

In this sense, there are various available types of applicators, made of different materials and with different shapes (square, circular, concave and symmetric, concave and asymmetric, and so on) intented to be used in the treatment of various diseases.

In recent years conformal applicators, which consider the shape of tumors, have been developed [9,12,13]. They are of special interest to be used in the treatment of small and superficial skin lesions since they can be constructed to match the tumor shape. A qualitative example of such an applicator is depicted in Figure 1.

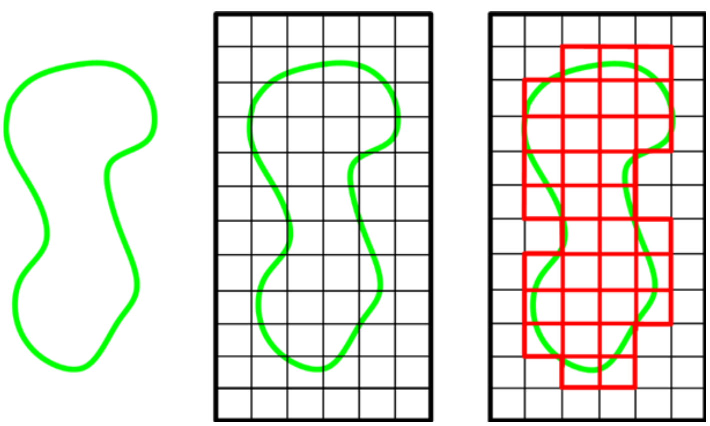

Figure 1: A qualitative example of the use of a conformal beta applicator. Left, a tumor of irregular shape; center, the applicator superimposed over the tumor area; right, the applicator with its square wells filled with a beta emitting isotope according to the tumor shape.

Despite the use of applicators in brachytherapy imposes an important challenger that is the experimental and/or theoretical estimation of beta radiation doses around them, conformal applicators represent an important trend in the current and future use of radiation from beta particles to treat small and superficial skin lesions. Furthermore, new technologies and advances in this field are expected to aid migrate to an individual and personalized concept of beta applicator. Some possible improvements include the use of specific softwares associated to 3D printing of the beta applicators focused on a each particular patient; the study and use of new soft materials to construct the plaques, considering the prevention of unwanted production of x-rays by bremsstrahlung; the study of new possible geometries of the applicators (such as pentagonal or hexagonal, unique or in a multiwell shape) to match as accurately as possible the tumor shape, and a better experimental and theoretical understanding and evaluation of radiation doses distribution around the beta applicators of various different geometric shapes.

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