Original Article

Depth Dose Calculation of Holmium-166 for Different Shape Source by VARSKIN3 Code

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ABSTRACT

Introduction: Using beta emitter radionuclide is a useful therapeutic modality in the treatment of skin cancers in areas which are difficult to cure by other methods. The aim of this research is to evaluate the tissue response to beta rays of ^{166}Ho and determine the feasibility of beta emitting radionuclide for treatment of skin cancers.

Methods: In this work, we have calculated depth dose distribution of ^{166}Ho using Varskin3 code. The code has been run for various input parameters to calculate absorbed depth dose for different shape of source.

Results: Absorbed depth dose variation has been calculated for ^{166}Ho beta emitter, in different shape of sources such as slab, spherical, cylindrical and 2-D disk shapes. Comparison of the result for different shape sources has been presented.

Conclusion: The result shows that 2-D disk source induces damage to skin cells more than other shape of sources. These computational and Lee et al. experimental results are shown that ^{166}Ho radionuclide treatment is very useful for skin cancer therapy. One of advantages of using ^{166}Ho radionuclide is that no adverse effect on underlying bone and soft tissue due to the physical characteristics of beta rays, high linear energy transfer or rapid depth dose fall off is observed.

Keywords: Holmium-166, Varskin3 code, Skin cancer, Source shape

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INTRODUCTION

Skin cancer is the most common malignancy in human, and more than 95% of basal cell carcinomas, the most common form of skin cancer, occur in patients more than 40 years of age (1). Due to the increasing life span in many countries, the incidence of skin cancer has been increased continuously. In spite of the malignant nature of this cancer, the death rate is not high, because basal cell carcinomas are slowly progressive (2).

Radiation therapy of skin cancer using an electron beam (3) X-rays (4) or a neutron beam (5) has been reported. Treating skin cancer with topical application of a radioisotope has also been reported, such as using ^{125}I-seeds on a gold plaque (6), also a very effective and convenient brachytherapy for this application using a ^{166}Ho-patch has been reported by Chung el al. (7).

However; several factors such as total dose, fractionation regimens, and field size and beam quality affect the treatment outcome. In general, a total dose ranging 35-70Gy with daily fractionation lying in the 2.0-3.5Gy is accounted for the optimal therapeutic regimen (8-9). The aim of this research is to evaluate the tissue response to beta rays of ^{166}Ho and determine the effective shape of source for treatment of skin cancers. In this work, we have run the code to calculate skin absorbed depth dose variation from the skin surface. This code also contained a volume averaged dose model and an offset particle model. The volume averaged dose model that we have used allowed us to calculate the dose averaged over a volume of tissue defined by a cylinder with diameter equal to that of the dose averaging area and bounded at the top and bottom by two selected skin depths. This model can be used to calculate the dose averaged between two depths in tissue, which is useful when characterizing the dose measured by a finite volume dosimeter such as a thermo luminescent dosimeter (10, 11).

METHODS

Varskin3 computer code calculates skin dose due to radioactive skin contamination provided by RSICC in USA. To run the code in windows XP after installation, user can contact the basic information section of the code to select radionuclide. When the desired geometrical parameters and options are selected, the calculation is initiated. The calculation time is greatly affected by the number of radionuclide used in the calculation and the various options that are selected. This code calculates doses using a compiled FORTRAN program while the main program that collects the input data is written in visual basic (10, 11). With running Varskin3 code for calculating dose, the required input parameters contain: activity of source, cover thickness, cover density, air gap thickness, radiation time and different source geometry. We have selected the default value of 10 cm^2 for skin average area and 60 minutes for exposure time.

^{166}Ho is a beta emitter radioisotope with E_{max}=1.84 MeV and half life 26.9 hr. It also emits the following photons: 0.081MeV with 5.4% and 1.38 MeV with 0.9% intensity per decay.

RESULTS AND DISCUSSION

By running Varskin3 code, we have calculated the absorbed depth dose variation for ^{166}Ho in different form of sources shape as shown in Figure 1. The disk source geometry model is simple and need to enter its diameter and Varskin3 code calculates the area of the disk, vice versa when we enter the area of the source; it calculates the diameter. Source with spherical geometry is the simplest three-dimensional geometry; because it requires just the source diameter. For cylinder model source, requires knowledge is the cylinder diameter and the cylinder thickness. This geometry require the same amount of time to execute as the spherical model but generally offers a more accurate dose calculation. Computational result shows the calculated dose is more sensitive to the cylinder. The slab source geometry requires knowledge of three physical dimensions: the x-side length, the y-side length, and the thickness. The slab source geometry requires two to five times more execution time than the cylinder and sphere geometries, and the accuracy of the calculation is significantly lower. The geometry characteristics of different sources with 60 minutes irradiation time, and any cover or air gap have been presented in Table 1.

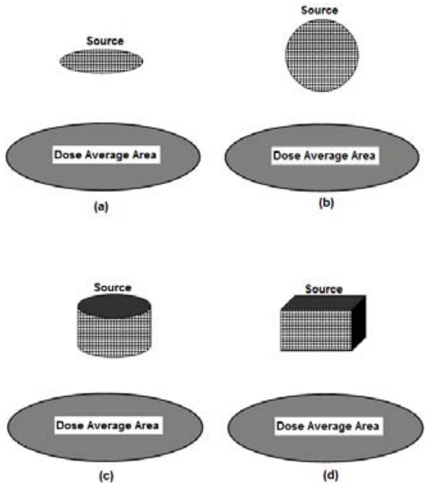

Figure 1. Schematic representations of the 4 type source geometry: (a) Disk, (b) Sphere, (c) Cylinder, and (d) Slab.

Table 1. The geometry characteristics of different sources with any cover or air gap and 60 min irradiation time.

Source shape	**Diameter**	**Thickness**	**Other lengths**
Cylindrical	1000 µm	1000 µm	---
Spherical	1000 µm	---	---
2-D Disk	1000 µm	---	---
Slab	---	1000 µm	X =Y=44 µm

The result of the absorbed depth dose variation for three different shapes of ^{166}Ho are shown in Figure 2, which the default unit of measure for activity is 1µCi for all sources.

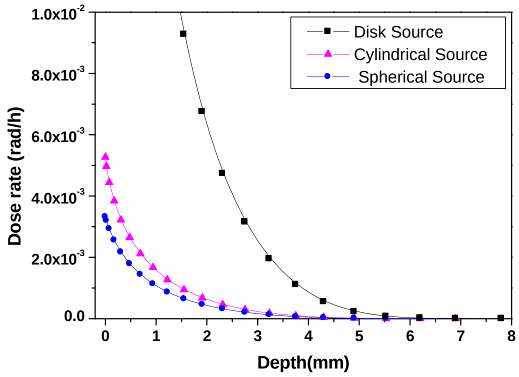

Figure 2. Absorbed depth dose variation for different shapes of ^{166}Ho with activity 1µCi.

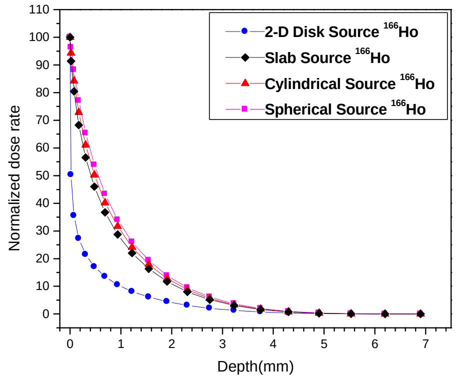

Figure 3. The normalized dose rate variation for all of the sources.

As it can be seen, absorbed depth dose variation is like an exponential function because of the short range of beta ray. The results show dose gradient is high near the source but with different behavior for different sources shape.

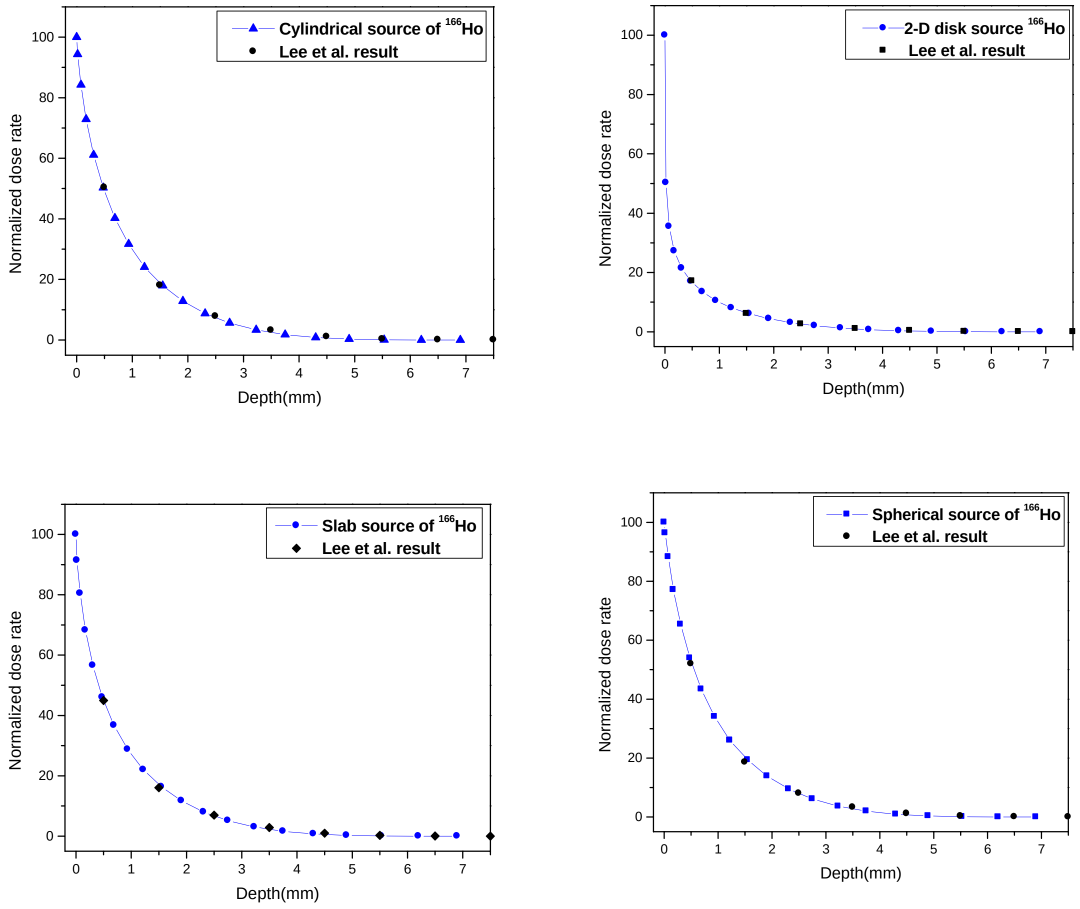

Figure 4. Comparison of the normalized absorbed rate variation against to the depth for 1µCi of ^{166}Ho d with the result of Lee et al.

Regarding to computational results for the same activity, disk source induces more dose than others to the skin surface and minimum dose is due to the slab source. We have presented the normalized dose rate for all of the sources in Figure 3. We must mention that the absorbed dose rate has been normalized to the dose rate in 0 mm depth for each source in order to show the effect of source geometry on dose rate variation.

Lee et al. (12) used ^{166}Ho source for curing five patients including 4 women and 1 man in age range 41-95 yr, as well as several animal models with superficial squamous cell, basal cell carcinoma and Bowen's disease in their experimental research. We have compared our results with Lee et al. experimental data as shown in Figure 4 with a very good agreement.

CONCLUSION

The result shows that 2-D disk source induces damage to skin cells more than other shape of sources. Our results are in good agreement with the experimental data of Lee et al. Our computational study and Lee et al. experimental results revealed that ^{166}Ho radionuclide can be used effectively for skin cancer therapy. The advantage of ^{166}Ho radionuclide is that no adverse effect on underlying bone and soft tissue due to the physical characteristics of beta rays, high linear energy transfer or rapid depth dose fall off is seen. Varskin3 code is a very useful tool for skin dosimetry, as well as it is fast, accurate and user friendly. It can be used for dose optimization calculation especially in beta source over the human skin.

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