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Adding ^{166}Ho data to VARSKIN2 code and dose calculation to human skin

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Background: Skin cancer can be treated by various methods. Electron radiotherapy has been a useful therapeutic modality in the treatment of skin cancers in areas which are difficult to cure by other methods. Depth dose distribution of ^{166}Ho using VARSKIN2 code is presented in this work. ***Material and Method:*** Depth dose distribution of ^{166}Ho was calculated, using VARSKIN2 code by adding of ^{166}Ho data to the library of VARSKIN2 code. After adding ^{166}Ho radionuclide data to the library of the code, it was run for various input parameters including: density, air gap thickness, radiation time and different source geometry. Different forms of sources which have been used in this research are 2-D disk, cylindrical and spherical shapes. ***Results:*** The result showed that the skin absorbed depth dose variation was an exponential function because of short range of beta ray. Dose gradient was very high near the sources. For the same activity, disk source induced a dose more than spherical and cylindrical source to skin surface. ***Conclusion:*** Superficial skin tumors could be successfully treated by topical application of beta-emitting ^{166}Ho source. VARSKIN2 is a fast, accurate and user friendly code for beta dosimetry and can be used for dose optimization calculation, especially in beta source over the human skin. **Iran. J. Radiat. Res., 2010; 8 (1): 45-49**

Keywords: *Skin cancer, radiotherapy, holmium-166, dosimetry*

INTRODUCTION

Skin cancer is a common malignancy in human. Some of therapeutic modalities for skin cancers are including local destruction, cryosurgery, laser ablation, curettage and ionizing radiation. Beta emitter radionuclide skin path is a useful therapeutic modality in the treatment of skin cancers in areas which are difficult to cure by other methods, especially the central areas of the face, including eyelids, nose and lips. Treatment of Bowen's disease with radioactive skin patch has been reported in many publications [1-9]. A useful review of the conventional radiotherapy skin patches equipped with the ^{166}Ho beta emitter was designed for the treatment of Bowen's disease and other skin cancers has been reported by Neubert and Lehmann in 2008 [1]. Recent publication by Huh *et al.* presented a new application of ^{166}Ho therapy [2]. They examined the therapeutic effectiveness of ^{166}Ho chitosan complex in rat brain tumor model. They found that ^{166}Ho chitosan complex nuclear medicine proved to be effective in destroying the malignant glioma [2]. Generally, 5-6 week of treatment is needed to deliver optimal radiation dose to tumors [3-6]. Several factors such as total dose, fractionation regimens, and field size and beam quality affect the treatment outcomes. In general, a total dose ranging 35-70 Gy with daily fractionation lying in the 2.0-3.5 Gy is accounted for the optimal therapeutic regimen [2, 5-7].

The aim of this research was to evaluate the tissue response to beta rays of ^{166}Ho and to determine the feasibility of beta emitting radionuclide for treatment of skin cancers. ^{166}Ho radionuclide data was first added to the library of the VARSKIN2 code, then it was run to calculate skin absorbed depth dose variation from the skin surface. The code contained a volume average dose model with an offset particle model. The volume average dose model, used in this research, allowed the calculation of the average dose over a volume of tissue defined by a cylinder with diameter

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equal to the dose averaging area and bounded at the top and bottom by two selected skin depths as shown in figure 1. This model can be used to calculate the average dose between two depths in tissue, which could be useful when characterizing the dose measured by a finite–volume dosimeter such as a thermoluminescent dosimeter [10, 11].

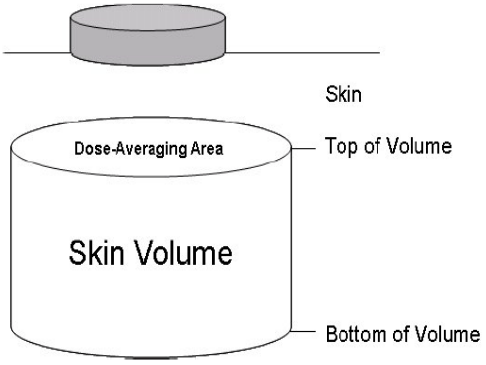

Figure 1. Schematic of the volume average dose model.

MATERIALS AND METHODS

VARSKIN2 Computer Code

VARSKIN2 is a computer code to calculate skin dose due to radioactive skin contamination provided by RSICC (Radiation Safety Information and Computational Center) in USA [10]. To run the code in Windows XP after installation, user contact with the basic code information library to select radionuclide for dose calculation which the default unit of source activity is μCi.

When the desired geometrical parameters and other options are selected by user, the calculation is initiated. The calculation time is greatly affected by the number of radionuclides used in the calculation and the various options that are selected. The code calculates doses using a compiled FORTRAN program. Also, the second section of code that collects the input data is written in VISUAL BASIC [10, 11]. The required input parameters to run VARSKIN2 code contain: source activity, cover thickness, cover density, air gap thickness, radiation time, and source geometry.

In general, VARSKIN2 code performs a five–dimensional integration of the source volume and the target area. The integration is simplified significantly because the dose is symmetric for a circular target area centered under the source. This code calculates the beta dose rate by performing a numerical integration of the Berger point kernel. The kernel is mathematically written as a following equation:

$$B(r) = \frac{kE_{\beta}YF_{\beta}(r_1 / x_{99})}{(\pi\rho r^2 x_{99})} \qquad (1)$$

Where; B(r) is the dose at the dose point from a source at a source point, r is the distance between a source point and the dose point, k is a unit conversion constant, E_{β} is the average beta energy for the radionuclide, Y is the beta yield per disintegration, $F_{\beta}(r_1/x_{99})$ is the scaled absorbed dose distribution, r_1 is the modified path length between a source point and the dose point and ρ is the density of the irradiated medium which assumed to be unity for skin tissue. As well as, x_{99} is defined as the radius of a water sphere surrounding a point source of beta radiation in which 99 percent of the beta energy is deposited inside of the sphere and the range of the beta particle is chosen as the x_{99} distance in VARSKIN code. The code divides the sources into very small sub-volumes called source points which the number of them ranges from 512 to over 10^{18} depending some of factors. The contribution from each source point to the dose point is evaluated using equation 1 and the contributions are summed. The total contribution (dose/Bq) is multiplied by the source strength (Bq) to get the dose to the dose point. This procedure is repeated for each of 60 dose points beginning at the center of the irradiation area and extending to its edge [10, 11].

Adding the data of ^{166}Ho radionuclide to the library of VARSKIN2

^{166}Ho is a beta emitter with 1.84 MeV maximum energy and a half life of 26.9 hr.

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^{166}Ho also emits gamma photons 5.4% of 0.081 MeV and 0.9% of 1.38 MeV. Since ^{166}Ho was not in the library of the code, therefore we have added its data to the library of VARSKIN2 code. Adding the radionuclide is possible by SADE-MODE2.EXE program. The following information is needed to add a radionuclide:

- Name of the radionuclide or mixture; it must be no longer than six characters and must be different with any previous radionuclide name;
- Number of decay modes for the parent radionuclide;
- The atomic number of the daughter nucleus;
- The atomic mass of the parent radionuclide,;
- Endpoint or maximum energy of the particular decay path;
- Probability of the particular decay path;
- Degree of the forbiddances for the particular decay.

The final routine FIT uses linear interpolation to extract the 30 specific values of $F_B(\rho)$ needed by VARSKIN and writes these values to the output file. We have added these values to the BETADATA file and then ^{166}Ho was available in the library [10, 11].

RESULTS AND DISCUSSION

We run VARSKIN2 code to calculate the absorbed depth dose variation for ^{166}Ho in different form of source geometry including disk, spherical and cylindrical shapes. The disk source geometry model was very simple and needed to enter its diameter. Further, the spherical source geometry was the simplest three-dimensional geometry; because it requires just the source diameter. The required knowledge for the cylindrical source model was the thickness and diameter of the cylinder. Figure 2 shows absorbed depth dose variation for these tree different source shapes of ^{166}Ho source with 1μCi activity.

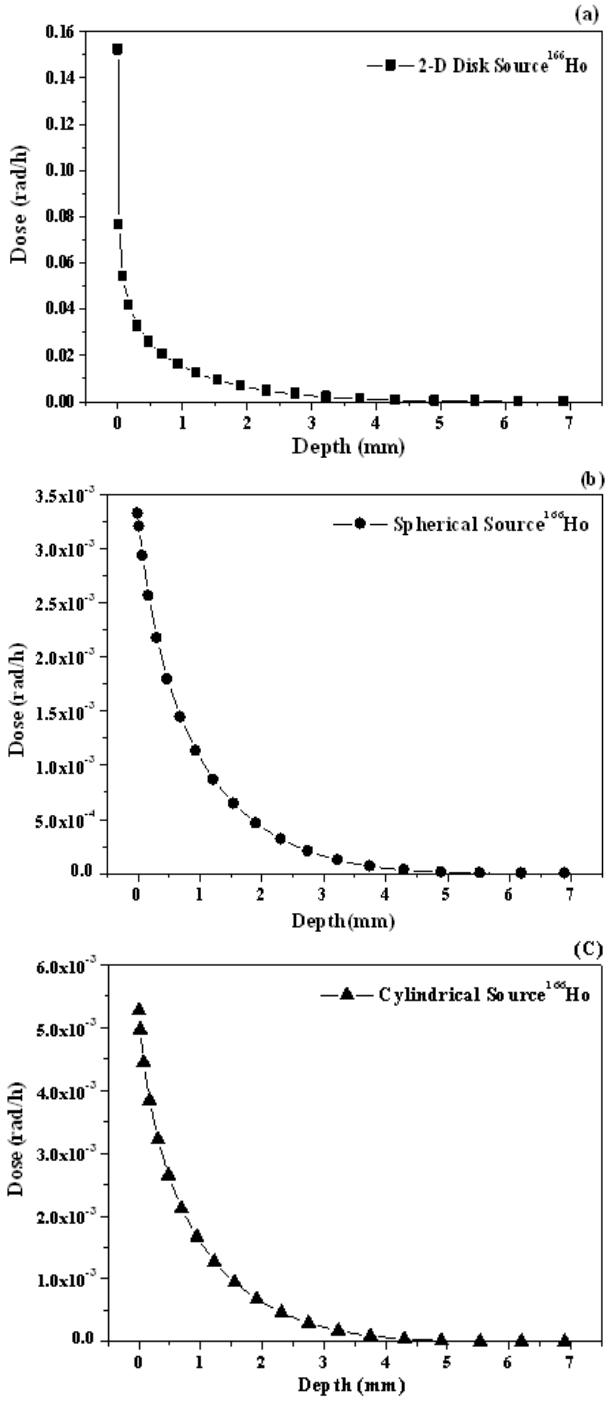

Figure 2. The absorbed depth dose variation for tree kind of ^{166}Ho source geometry with activity 1μCi (a) 2-D disk, (b) Spherical and (c) Cylindrical.

The result showed that skin absorbed depth dose variation was like an exponential function because of the short range of beta ray. It could be seen that dose gradient

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was very high near the skin surface considering the computational results shown in figure 2 for the same activity, the disk source induces skin dose more than the other cylindrical and spherical shapes. But, depth dose after 0.306 mm was falling down strongly for the disk and less than the others. Also, calculation using cylinder source geometry was more accurate than the spherical source geometry, since the air surrounding the bottom hemisphere does shielded the source particles as efficiently as the source material, and a larger area of skin was irradiated resulting in consisting higher doses.

Lee et al. used ^{166}Ho source for curing four women and one man, as well as several animal models with superficial squamous-cell, basal cell carcinoma and Bowen's disease in their experimental research [12]. They have seen successful tumor destruction in all of the subjects. Figure 3 shows that our results are in good agreement with their experimental data. These computational and experimental results are demonstrated that ^{166}Ho radionuclide is very useful for skin cancer treatment. One of the benefits 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 and rapid depth dose fall off.

CONCLUSION

Our computational results showed that 2-D disk source induced damage to skin cells more than cylindrical and spherical shape of sources. These computational and experimental results showed that ^{166}Ho radionuclide could be used effectively for skin cancer therapy. VARSKIN2 code is a very useful tool for skin dosimetry, and it is fast, accurate and user friendly. It can be used for dose optimization calculation especially in beta source over the human skin.

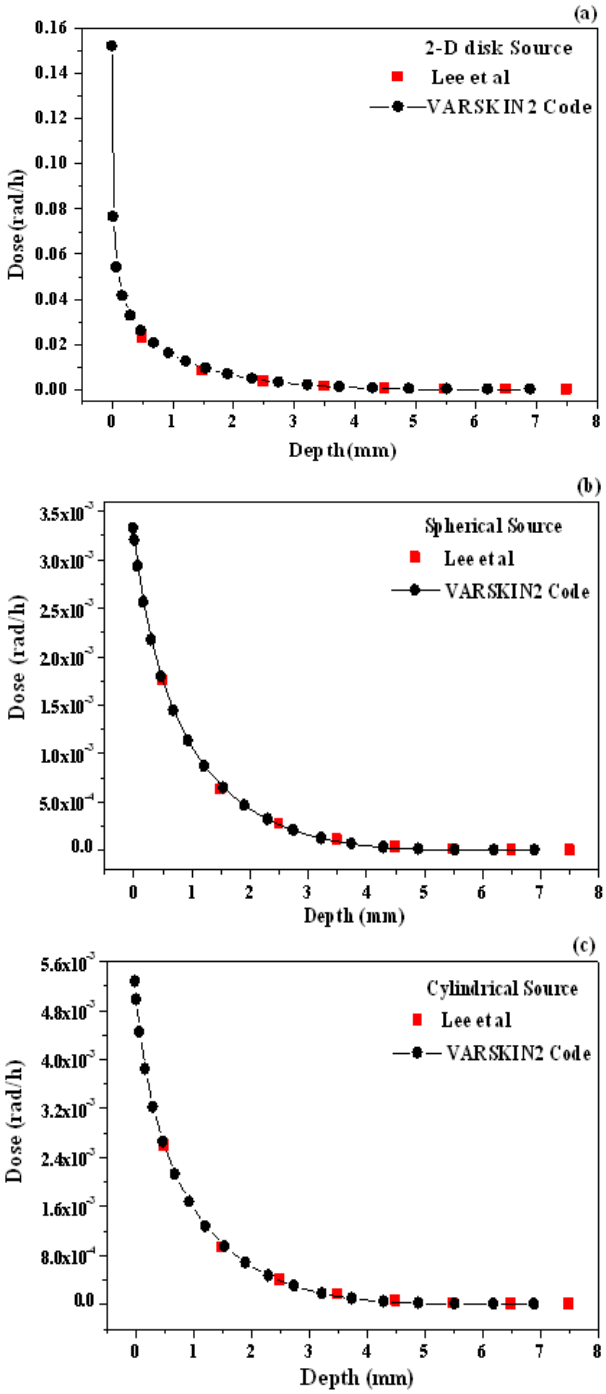

Figure 3. VARSKIN2 result of absorb depth dose variation for 1μCi of ^{166}Ho which compared with the experimental result of Lee *et al.* [12] (a) 2-D disk (b) Spherical (c) Cylindrical sources.

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