Effectiveness Evaluation of Skin Covers against Intravascular Brachytherapy Sources Using VARSKIN3 Code

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ABSTRACT

Background and Objective: The most common intravascular brachytherapy sources include ^{32}P, ^{188}Re, ^{106}Rh and ^{90}Sr/^{90}Y. In this research, skin absorbed dose for different covering materials in dealing with these sources were evaluated and the best covering material for skin protection and reduction of absorbed dose by radiation staff was recognized and recommended.

Method: Four materials including polyethylene, cotton and two different kinds of plastic were proposed as skin covers and skin absorbed dose at different depths for each kind of the materials was calculated separately using the VARSKIN3 code.

Results: The results suggested that for all sources, skin absorbed dose was minimized when using polyethylene. Considering this material as skin cover, maximum and minimum doses at skin surface were related to ^{90}Sr/^{90}Y and ^{106}Rh, respectively.

Conclusion: polyethylene was found the most effective cover in reducing skin dose and protecting the skin. Furthermore, proper agreement between the results of VARSKIN3 and other experimental measurements indicated that VRASKIN3 is a powerful tool for skin dose calculations when working with beta emitter sources. Therefore, it can be utilized in dealing with the issue of radiation protection.

Keywords

Beta emitter radionuclides, Intravascular Brachytherapy, Skin covers, VARSKIN3 code, Radiation Protection

Introduction

Coronary artery disease is most commonly treated using bypass surgery or percutaneous transluminal coronary angioplasty (PTCA). A major problem with PTCA, however, is high incidence of rest enosis and recurrence of artery blockage at the site of treatment. To prevent incidence of restenosis and recurrence of artery blockage, a new approach called intravascular brachytherapy has been developed. This method may be divided into two categories: temporary implants (sealed sources or liquid-filled balloons) and permanent implants (radioactive stents). In Temporary implantation, radioactive source is located inside or close to the treatment site for a certain period of time and will be removed when irradiation time is completed. Temporary implantation is administered with low dose rate (LDR), and high dose rate (HDR) technique. In this kind of implantation, needles, plastic stents or special applicators are used to handle the desired location. In permanent implanta-

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tion, also called seed implant, radioactive seed is positioned inside or near the tumor and will permanently remain in the desired position. In this method, the radioactive seeds are loaded directly into the tumor site using special equipments. After a few weeks or months (depending on the half-life of the radioactive seed), the exposure rate of implanted seeds reduces to a negligible level. The inactive seeds remain in the patient's body without any subsequent side effects. Each method has its own advantages and limitations [1-3]. The dose received by the target tissue depends on the shape of the radioactive source and its physical properties such as half-life, energy spectrum and type of decay. Various types of sources are used in intravascular brachytherapy. The most common gamma emitter sources are 192Ir and 125I and the most frequently used Beta-emitters include 32P, 90Sr/90Y, 188Re and 106Rh [4, 5]. Since the surrounding healthy tissues undergo less damage due to short-range of beta rays, it is more appropriate to use beta emitter sources in this treatment method. Regarding the widespread use of these kinds of sources, their production in radioisotope laboratories is very important. One of the most important issues during production of these radioisotopes in laboratory is to observe principles of radiation safety and radiation protection in order to achieve the ALARA slogan. One of the most important parts of the body always exposed to radiation damage in radionuclide laboratories is the skin, which must be protected by some suitable covering materials. In this study, some covering materials are proposed as skin cover, When working with beta-emitter sources used in the intravascular brachytherapy and skin absorbed dose for each suggested cover was calculated using VARSKIN3 code, a special code for skin dose calculations. Finally the best covering material to protect the skin and to reduce the radiation dose received to relevant staff has been recommended.

Material And Methods

As previously mentioned, VARSKIN3 code was used in this study to calculate the skin absorbed dose. This code, which is specially developed for radiation protection purposes, is used to calculate the dose received by the skin as a result of contaminations caused by beta-emitter materials. Dose calculations by this code are based on solving multiple integrals on the volume and the area of the interested region. It should be noted that all calculations are automatically made by a kernel code that is developed by FORTRAN programming language. The user only inserts the physical and geometrical parameters required for the desired conditions using a graphic user interface (GUI) which is developed by Visual Basic programming language. To obtain more information about the mathematical equations and dose calculation methods utilized in this software, the reader is referred to related guidelines published in the user manual of mentioned software [6]. This code has six different geometries for source shape modeling; Point, Disk, Spherical, Rectangular, Cylindrical, and Syringe geometry (the last one is similar to Cylindrical geometry but the only difference is that the radiation is emitted from the surface of the cylindrical side); each of these models are used in special circumstances. Point source is used in cases that radioactive contamination is limited to a very small area of skin. In VARSKIN3 code, point source is considered as a cylinder with radius and height of 1µm. The disk geometry is recommended in the cases that modeling of liquid skin contamination is desired. In this code the disk source is considered as a cylinder with 1 µm thickness. Spherical geometry is the simplest three-dimensional model in dose calculations of this code, because only one parameter, the diameter, is required to fully specify the source geometry. In this geometry it is assumed that the surrounding space of the sphere is surrounded by air and the source is only abutted on the skin surface or the skin cover at the lowest point.

Cylindrical model requires the knowledge of two parameters, height and diameter of the cylinder. This model, also assumes that the surrounding space of the cylinder is encircled by air; but the cylinder base is entirely in contact with skin or skin cover. Rectangular model requires the knowledge of three parameters, length, width and height of the Rectangle. The time for dose calculations in this model is two to five times longer than the two previous volume models. In addition, the accuracy of dose calculations in this model is lower than the previous volumetric ones. This code consists of two libraries for radioactive nucleuses; one library includes 838 radioactive nucleuses and the other contains nucleuses added by the user. Adding a new source to code library is performed by Sademode 2 program and all of the physical characteristics of the source should be given to the software. Finally radioactive nucleus is selected from the user library; however, it should be noted that if the daughter nucleus is also a radioactive material, it should be added by the user and it will not be done automatically. This code uses two different models for dose calculations; average dosimetry and point particle dosimetry. In Average dosimetry model, the average dose at space between two different depths determined by the user is calculated. This dosimetry model is closer to the actual conditions because all of the utilized dosimeters have a finite volume. In this model, the average dose is calculated over some volume of tissue that is specified by a cylinder. The Cylinder diameter is equal to the area over which dose is averaged and is limited from top and bottom with two arbitrary skin depths. Furthermore, the code is able to define various types of cover materials with different thicknesses on the skin. Additionally, it is possible to consider the air gap between the skin and the cover in the calculations. In this research, four common Beta-emitter radionuclides, used in intravascular brachytherapy, were considered as a source. The activity of each source was assumed to be 1 µCi. Characteristics of mentioned sources are shown in table 1 [7, 8]. Afterwards, the dose received by various depths of the skin was evaluated by average dosimetry model in the presence of various covering materials listed in table 2 [6, 9]. Dimensions of the source were equal to 1×1 mm, thickness of the skin cover in all cases was 1 mm and the air gap between the skin and its cover was assumed to be zero. The dimensions of the cylinder used in average dosimetry were considered equal to dimensions of GR200A TLD model manufactured by PTW Company in order to be closer to actual calculation circumstances. Characteristics of this type of TLD are shown in table 3 [10].

After selecting the desired parameters including geometry and type of the source, desired cover material as well as the other pa-

Table 1: Physical characteristics of the sources used in this research.

Radionuclide	^{32}P	^{188}Re	^{106}Rh	^{90}Sr	^{90}Y
Maximum energy of the emitted beta particle (MeV)	1.71	2.12	0.92	0.54	2.282
The half-life	14.28 Days	16.98 Hours	2.17 Hours	28.5 Years	2.671 Days

Table 2: Characteristics of skin covers used in this study.

Cover	Plastic type1	Plastic type2	Cotton	Polyethylene
Density (g / cm³)	0.036	0.6	0.3	0.93

Table 3: Physical Characteristics of GR200A TLD model

TLD Model	Ingredient	Geometry	Dimensions (mm)	
GR200A	LiF (Mg, Cu, P)	Cylindrical	Height (0.8)	Diameter (4.5)

rameters mentioned above, the irradiation time was determined and calculations began. Since the aim of this research was to evaluate the radiation dose received by skin surface of a radiation worker during one working day in a radioisotope laboratory; irradiation time was set to 8 hours. It is noteworthy that the dose calculation time is significantly affected by the activity of selected sources as well as the thickness and type of cover materials assigned for skin.

Results

Figures 1 to 4 show variations of the skin absorbed dose as a function of depth in presence of various covers for 32P, 188Re, 106Rh and 90Sr/90Y sources, respectively. In all of the presented results, the source geometry was considered to be the cylindrical one because it is the most accurate model in dose calculations related to the volumetric sources. In addition, most of the sources used in brachytherapy are made in the form of a tablet or cylinder. In this geometric model, dose calculations are more sensitive to changes in the cylinder thickness than its diameter. In all cases, a 4.5 mm diameter cylinder with 0.8 mm thick (just equal to GR200 A TLD dimensions) was used for dosimetry and at each stage the cylinder moved 0.1 mm downwards. It should be mentioned that the maximum depth of dosimetry from skin surface is equal to the maximum range of beta particle emitted by the source. Therefore, the maximum depth of dosimetry is different for various sources. In addition, in case of 90Sr/90Y, at first dose calculations related to yttrium and strontium were performed separately and then the dose center of gravity in each non-uniform dose volumes was measured by means of the relevant analytic equations and, finally, the dose curve was obtained as a function of the skin depth. It should be noted that in all graphs, because of their proximity to each other, dose values are shown exponentially to allow better comparison between obtained results.

As expected, the absorbed dose in all cases drops exponentially as the depth increases because the beta particle energy decreases as the depth increases. Eventually, after a certain depth- depending on the applied source and cover- dose rate changes are negligible which may be justified by the low range of beta particle at large depths. In addition, the dose gradient in regions near the surface is very high and decreases as the distance from the surface increases. Maximum absorbed dose by skin for various skin covers and sources are shown in table 4.

Discussion and Conclusion

In this research, the effectiveness of skin covers in protecting the skin against radioisotopes used for intravascular brachytherapy was studied using VARSKIN3 code. The results showed that the polyethylene is the most effective material in reducing the skin dose and protecting it against each of the four radionuclides. Moreover, theoretically obtaining this result seems reasonable because while studying beta ray attenuation in the medium, the most important physical quantity is density thickness. With increasing the density thickness, beta rays are attenuated to a greater level because of an increase in the number of electrons per unit of area [11]. Among these four covers, polyethylene has the highest density and consequently, the same thicknesses, density thickness of polyethylene cover was the greatest of all other covers and, therefore, will

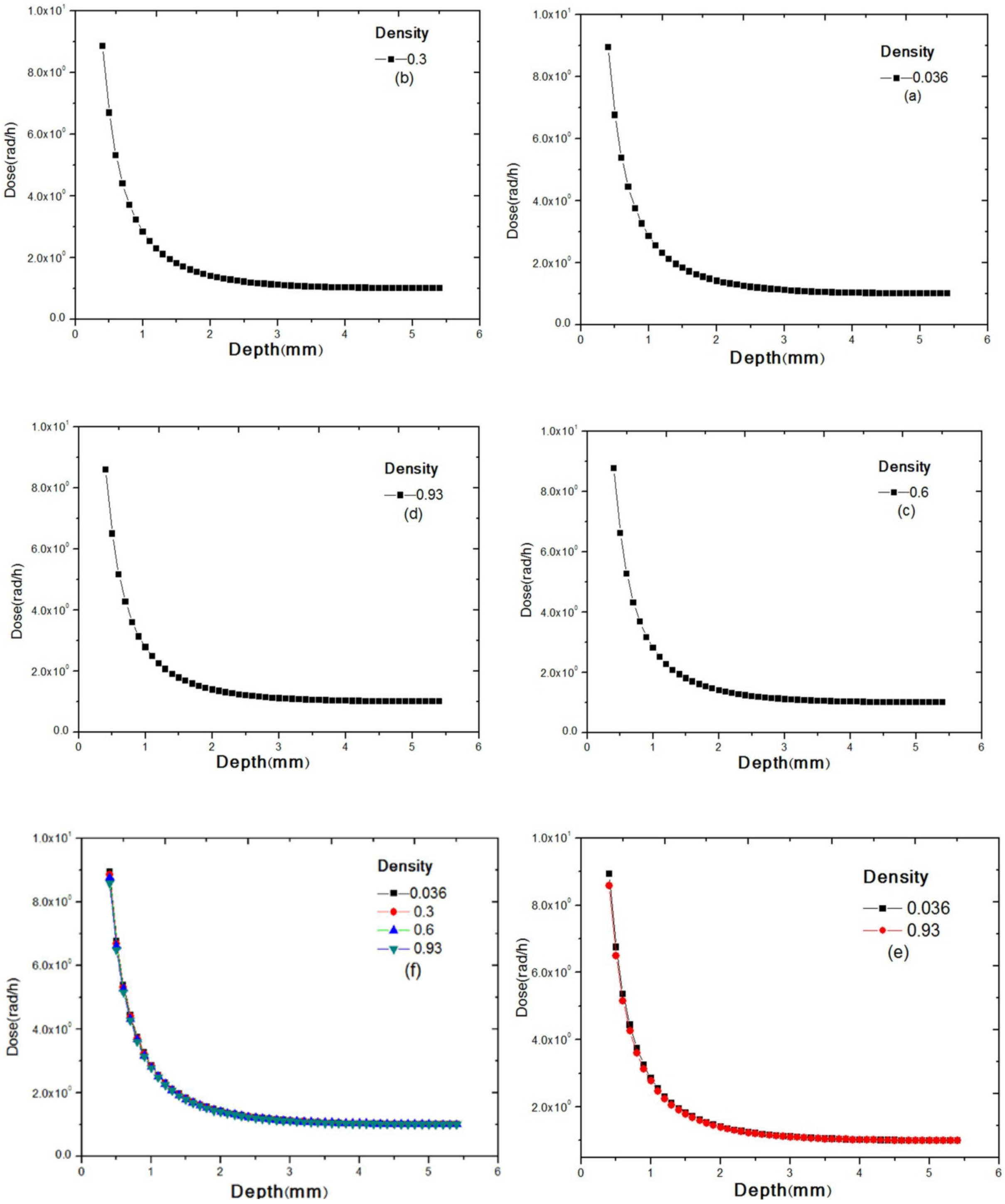

Figure 1: Diagram of the dose absorbed by the skin in terms of skin depth coverage for every 32P source: (a) plastic type I (b) Cotton (c) Plastic Type II (d) Polyethylene (e) Plastic Type I and polyethylene drawn separately and (f) all of the covers drawn separately.

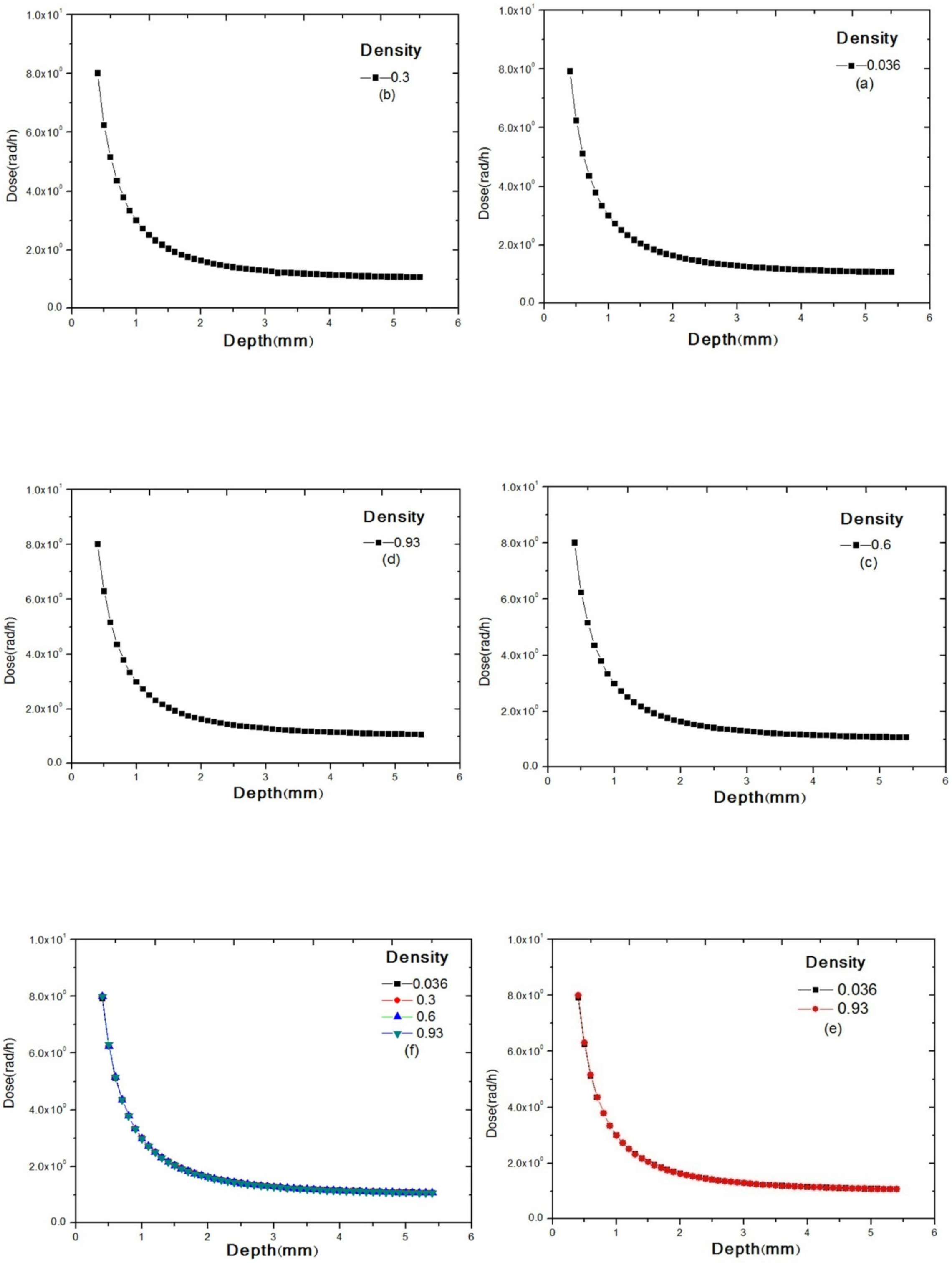

Figure 2: Diagram of the dose absorbed by the skin in terms of skin depth coverage for every 188Re source: (a) plastic type I (b) Cotton (c) Plastic Type II (d) Polyethylene (e) Plastic Type I and polyethylene drawn separately and (f) all of the covers drawn separately.

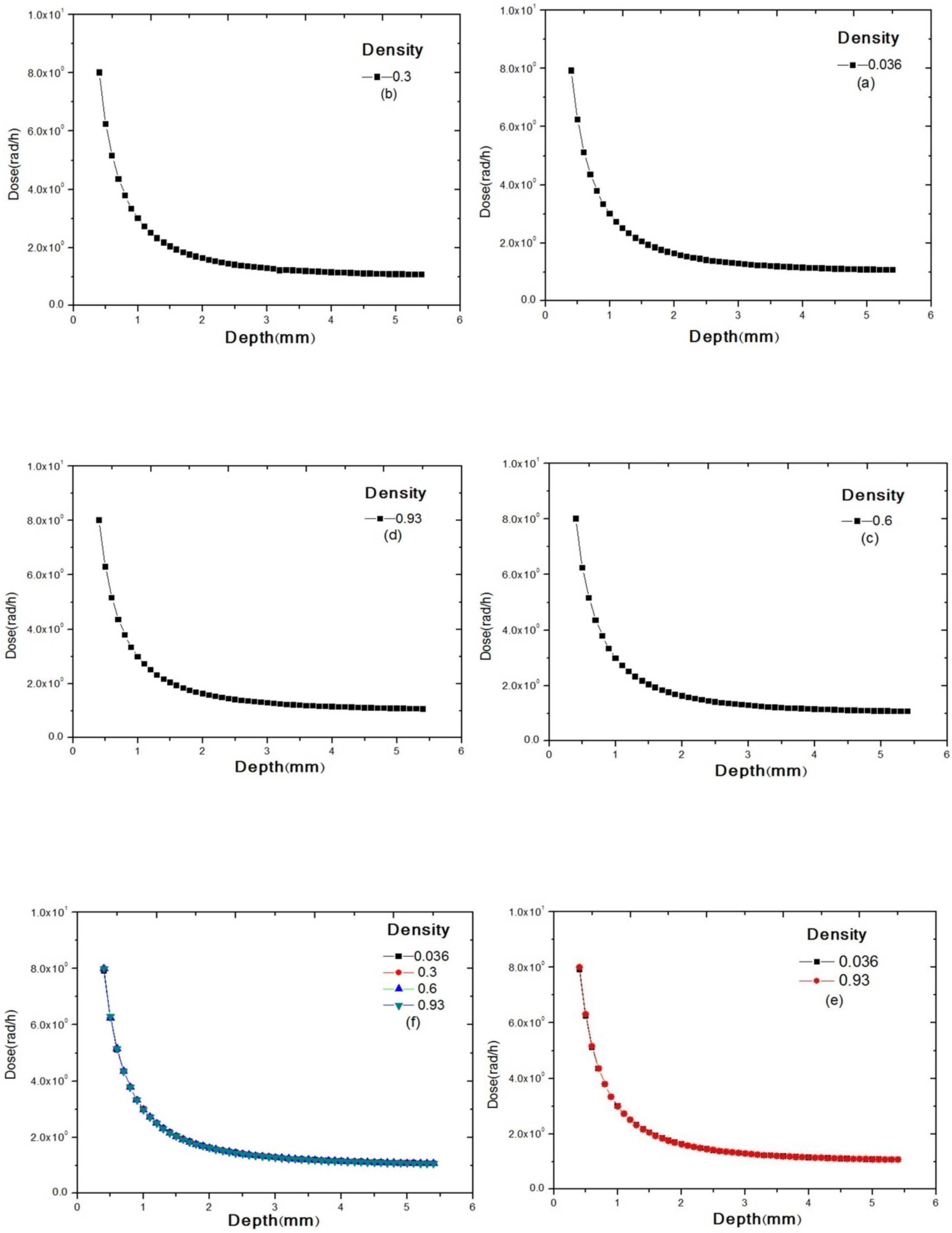

Figure 3: Diagram of the dose absorbed by the skin in terms of skin depth coverage for every 106Rh source: (a) plastic type I (b) Cotton (c) Plastic Type II (d) Polyethylene (e) Plastic Type I and polyethylene drawn separately and (f) all of the covers drawn separately.

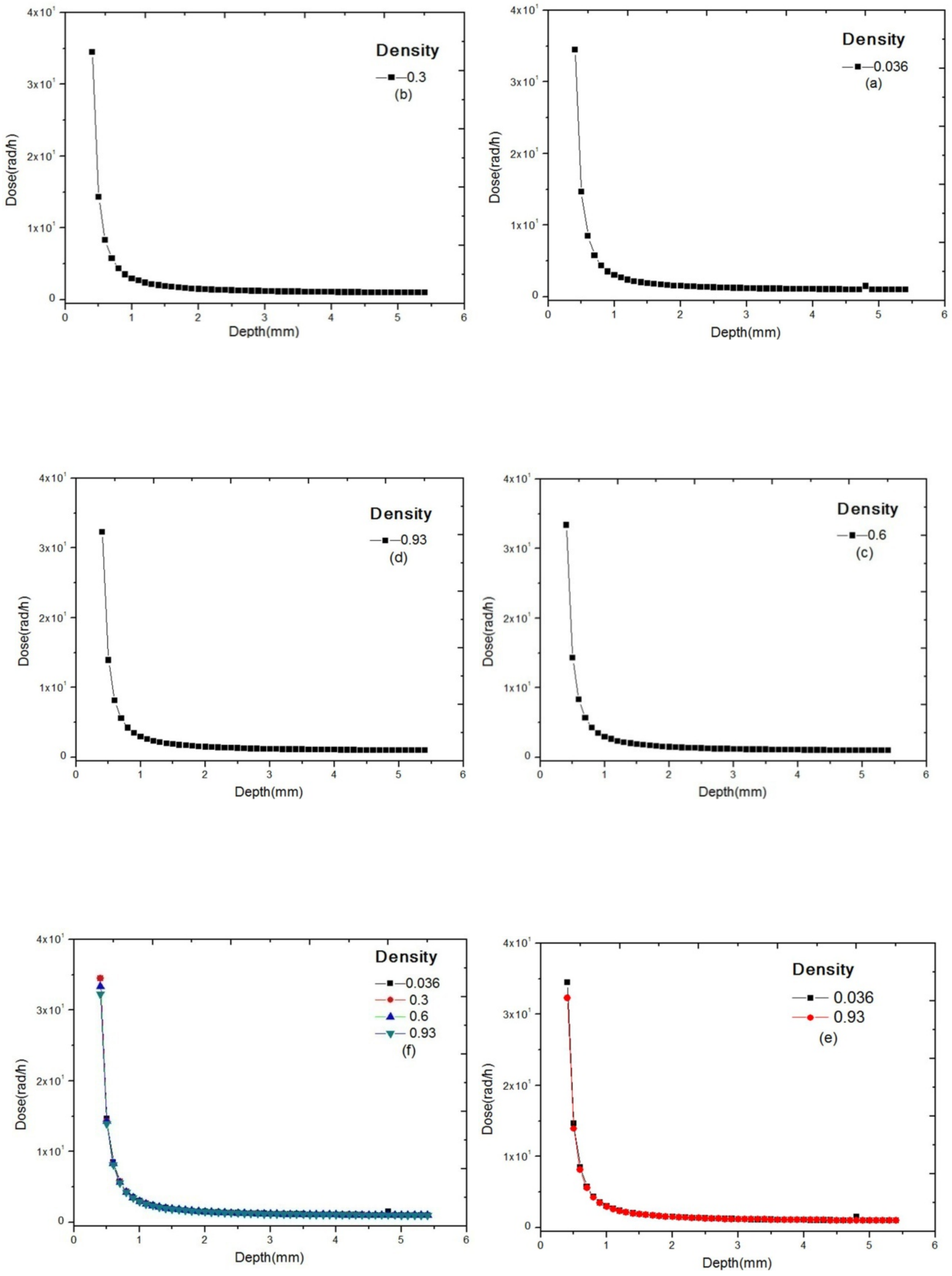

Figure 4: Diagram of the dose absorbed by the skin in terms of skin depth coverage for every 90Sr /90Y source: (a) plastic type I (b) Cotton (c) Plastic Type II (d) Polyethylene (e) Plastic Type I and polyethylene drawn separately and (f) all of the covers drawn separately.

Table 4: maximum absorbed dose by skin for various combination of sources and covers (in unit of rad/µCi-h)

Cover/source	^{32}P	^{188}Re	^{106}Rh	^{90}Sr/^{90}Y
Plastic type 1	2.19	2.33	2.07	3.54
Plastic type 2	2.17	2.25	2.08	3.51
Cotton	2.18	2.28	2.08	3.54
Polyethylene	2.15	2.22	2.08	3.47

be the most effective cover in energy reduction and attenuation of beta rays. The highest dose at skin surface protected by polyethylene cover was obtained during the use of 90Sr/90Y and the lowest dose belonged to 106Rh. This result was expectable regarding to beta ray energy emitted from these sources. In order to investigate the validity of this study and evaluate the performance accuracy of the VARSKIN3 code in estimating skin dose due to beta rays, the maximum dose received by skin surface by sources 32P, 90Sr and 90Y was compared with the results of other studies reported in this field [12-14]. In all of these studies the maximum dose received by skin surface is reported through using an infinitely thin surface source that has doped uniformly by 1 µCi activity per square centimeter. In order to estimate the amount of dose reaching the skin by VARSKIN3 code, a disk source model with a diameter of 2 cm and 14.3 µCi activity (activity concentration of 1 µCi per unit area) was used and the dose rate at skin surface was compared to the results reported by these papers, as shown in table 5.

Furthermore, the results of the work done by Chabot *et al* [15] were compared with the results of VARSKIN3 code. In the study done by Chabot, skin absorbed dose for 1 µCi activity of a point source of 90Sr /90Y in the presence of various skin covers has been reported. One of the skin covers was cotton with 0.37 mm thickness and 0.7 g/cm^3 density and the other cover was a combination of a layer of cotton with the same thick and a plastic layer with a 0.4 mm thickness and 1.1 g/cm^3 density. In the first case, the sizes of the air gaps were 0.2 cm and 1cm and in the second case were 1 cm and 5 cm, respectively. This data was given to the code as input, and its results were compared with the results of Chabot *et al* (table 6).

As is obvious, there is a reasonable agreement between the results of the present study and the empirical results of the above-mentioned papers. This supports validity of the performed simulation and generally confirms the performance accuracy of the VARSKIN3 code in skin dose calculations. It should be mentioned that the difference between the results of VARSKIN3 code and empirical results in table 5 is due to the backscatter correction made by VARSKIN3 code. Finally, it can be

Table 5: Depth dose coefficient in unit of rad-cm2/µCi-h reported by this work and other references.

Method	^{32}P	^{90}Sr	^{90}Y
VARSKIN3	6.63	5.46	6.84
Delacroix	9.15	6.99	9.18
Kocher and Eckermann	8.87	6.79	8.87
Piechowski	7	5.9	7.5

Table 6: Comparison between the results of Chabot and Varskin3 for 1 µCi point source of $^{90}Sr/^{90}Y$ located on various cover materials.

Radionuclide	Air gap(cm)	Cover	Chabot et al (rem/h)	VARSKIN3 (rem/h)
$^{90}Sr/^{90}Y$	0.2	cotton	3.543	3.26
	1	cotton	0.596	0.531
	1	cotton + plastic	0.337	0.326
	5	cotton + plastic	0.018	0.0167

concluded that VARSKIN3 code is a powerful tool for skin dose calculations when working with beta emitter sources. One of the remarkable features of this code is its high speed and ease of use which gives it an advantage over more complex codes such as MCNP when calculating skin dose.

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Conflict of Interest

None

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