Available online at http://www.ijabbr.com

International journal of Advanced Biological and Biomedical Research

Volume 1, Issue 9, 2013: 1094-1100

Assessment the effect of kidney internal structure on gamma absorbed dose of radiopharmaceutical ^{111}In-DTPA

Mohammad Mirzaei

Physics department, Faculty of Shahid Chamran, Technical and Vocational University, Kerman, Iran

ABSTRACT

Large quantities of radiopharmaceuticals prescribed for treatment and diagnosis are excreted through kidney. Therefore, radiation unwanted dose is created in kidney. As a result, exact calculation of prescribed radiopharmaceuticals amount is important. Monte Carlo method is used for simulation of radiation transport in body due to random nature of radiation. In this research, for the first time kidney is considered integrated and for the second time it is considered that it has three areas; gamma absorbed dose is calculated and compared in cortex and medulla kidney using MCNPX code to identify a more accurate way to prescribe radioisotope. The results showed that gamma absorbed dose in medulla is 2 times as much as dose in integrated kidney and gamma dose in cortex is about 62% as much as dose in integrated kidney. Internal structure of kidney should be considered in simulation to achieve a more accurate prescribed dose.

Key words: Gamma absorbed dose, Cortex, ^{111}In, Medulla

INTRODUCTION

Radiolabeled somatostatin analogs such as ^{111}In-DTPA octreotide (DTPA is diethylenetriaminepentaacetic acid) are most successful in detecting and imaging tumors expressing somatostatin receptors(konijenenberg. 2007). Research on the basic interaction of radiation with biological systems has contributed to human society through various application in medicine, pharmaceutical and in other technological developments(Zarei 2013). History of using radiopharmaceuticals in medicine for diagnosis and treatment date back to1950s (Mowlavi.2008). Dosimetery calculations should be done with very high accuracy to control and destroy cancer cells in such a way that it has minimal damage surrounding healthy tissue, (Mowlavi et al.2006). When radiopharmaceuticals is taken to a patient for treatment or diagnosis, radiation absorbed dose can be a limiting factor in various organs since radiation damages both cancer and healthy cells (Mirzaei et al.2012). Therefore selected administration dose should have maximal therapeutics effects and minimal side effects(Mirzaei et al. 2013a). For example, prescribing excessive amounts of iodine-131 in treatment

Corresponding Author E-mail: m.mirzaei@tvu.ac.ir

of hyperthyroidism can lead to hypothyroid (Kalantar et al.2011). It is believed that absorb of radon gamma ray can lead to cancer(Mansourbahmani et al.2013). When a patient has taken radiopharmaceutical for diagnosis and treatment, a large amount of radiopharmaceutical is excreted through kidney and urinary tract. Thus, radiopharmaceutical density in kidney is caused unwanted dose and side effects in patient's kidney(Mirzaei. 2013b). It is shown that toxicity related to small molecule of radioisotope in kidney has caused limitation in prescribed dose (Wessels et al.2008).

Each kidney is consisted of some areas shown in Figure (1)**.**

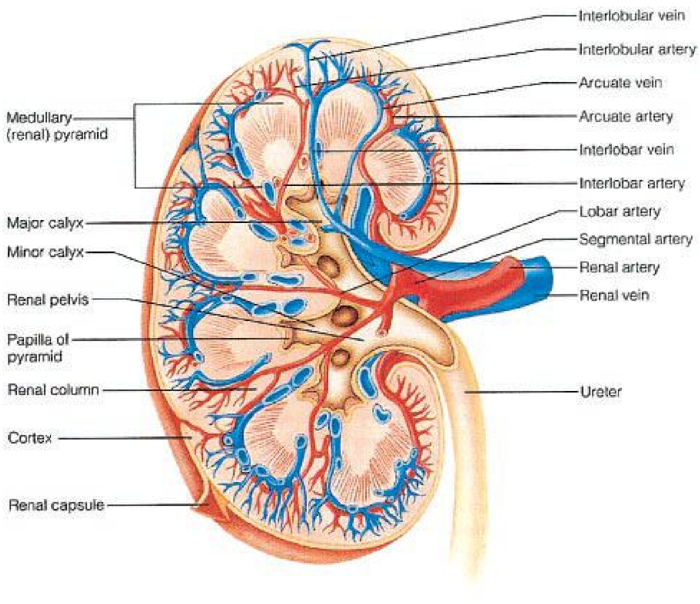

Figure (1): kidney components

Kidney cortex is in the form of layer that has completely surrounded the central area. Some appendixes called renal columns are raised from kidney cortex to central part of kidney. Central part (medulla) of kidney is formed from approximately 10 conical objects called renal pyramids. Tip of renal pyramids is toward kidney center and its base is toward kidney cortex. Tip of pyramids is called renal papilla. Renal papilla is surrounded by minor calyx. (Minor calyx is received urine; they are the beginning part of tract. Ultimately, they make ureters. Some minor calyx (three to seven) is connected to each other to form a major calyx; two or three major calyx is connected to each other to form renal pelvis, the funnel-shaped upper end of the ureter. Methods usually used to estimate absorbed dose of organs is based on uniformity assumption of activity in organs. Renal toxicity is a great limitation in treatment with radiopharmaceuticals. Passing prescribed radiopharmaceutical through kidney and urinary tract is created a big challenge to calculate appropriate dose. In Mird[1] pamphlet- 5, kidneys have considered in ellipsoidal shape that radiopharmaceutical is equally distributed in them and gamma absorption fraction is calculated and recorded in the tables and the fraction of gamma absorption is considered unit. While kidney has internal organs and radiopharmaceutical is not uniform distributed in.

[1] Committee on Medical Internal Radiation Dose

Materials and Methods: The data gamma rays of the ^{111}In have been taken from the LBNL Isotopes Project website (http://ie.lbl.gov/toi) whose last version has been released by Blachot (Blachot 1996).

The gamma spectrum of ^{111}In is shown in Figure (2).

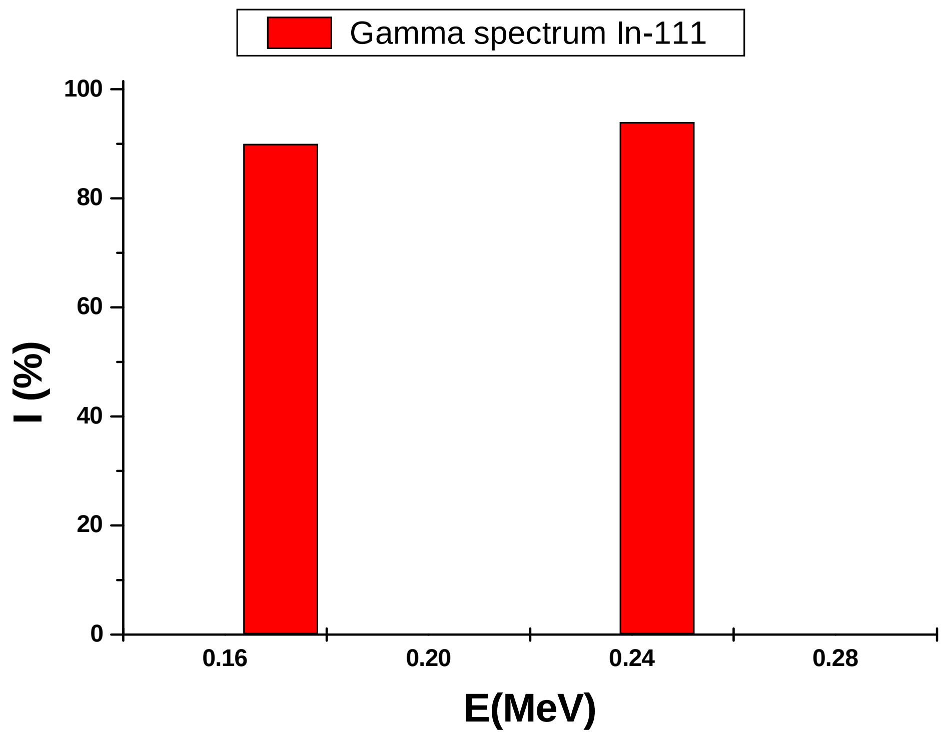

Figure (2): gamma spectrum isotope ^{111}In

Data related to energy and frequency is used to define radiation source in input file of MCNPX[2] code. Before radiotherapy, MCNP code can be used to calculate appropriate dose in order to minimize absorbed dose of healthy organs. This dose includes a library of data related to cross section of radiation absorption of all elements. In this research, MCNPX code is used for simulation of electrons transport. Based on Monte Carlo method, this code is used for transport of particles, different applications, discrete and continuous energy, time-dependent and time-independent. In this code, it is possible to define radiation source deliberately. Some source specifications such as energy, time, position and direction may have independent probability distribution (Soniua et al.2006.).MCNPX code which is so powerful in radiation transport is used to calculate absorbed dose ("Los Alamos National Laboratory" .2002).A computer with dual-core CPU and speed of 3 GHz is used to run the MCNPX code. Each run takes 60 minutes in order to reduce errors. Therefore, accuracy is obtained from 0.0001 levels. Body and kidney size are calculated for babies, children aged one, five, ten and fifteen year and adults based on pamphlet data of

[2] Monte Carlo N-particle Transport code

ORNL/Tm8381/V1 (Cristy and Eckerman. 1987). Anatomical studies of kidney have shown that radiopharmaceuticals absorption amount is not the same in different components of kidney(Mirzaei.2013 b). It is supposed that total radiation source is distributed in kidney in integrated kidney model. Therefore, gamma absorbed dose are obtained for entire kidney. In this research, for the first time kidney is considered ellipsoidal shape and for the second time has been considered that it is consisted of three areas, pelvis, medulla and cortex. It is supposed that radiopharmaceutical is distributed in medulla. Then, gamma absorbed dose is calculated in medulla and cortex using MCNPX code and is compared with integrated kidney results. Identifying patients' necessary dosimetery parameters using Monte Carlo Method or other measuring methods before using radioactive sources for their treatment is one of the suggestions of American Association of Physicists Medicine (Briesmeister . 2000).Size of kidney internal components, pelvis, medulla and cortex, are obtained from Mird pamphlet, 19 (Bouchet et al 2003). Kidney substance and its surrounding tissue are considered with density 1.04 g/cm^3 and soft tissue based on ICRP[3] committee ("ICRP ".1988). Phantoms used in this research are shown in Figures (3,4).

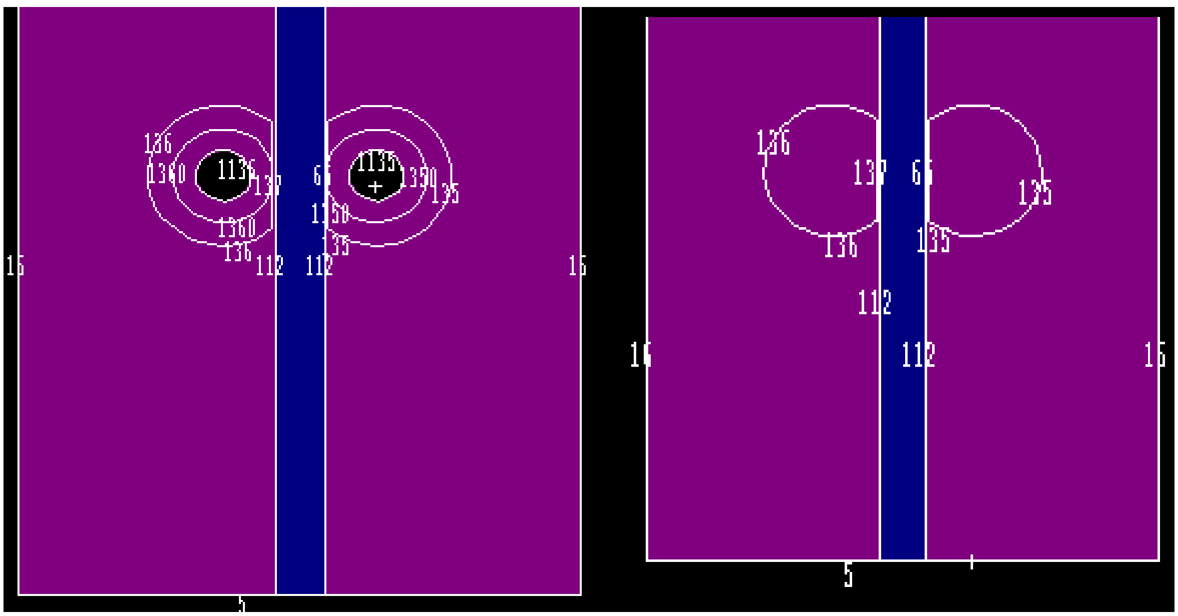

Figure (3): phantom used in this research from front view, three-part kidney and integrated kidney

[3] International Commission on Radiological Protection

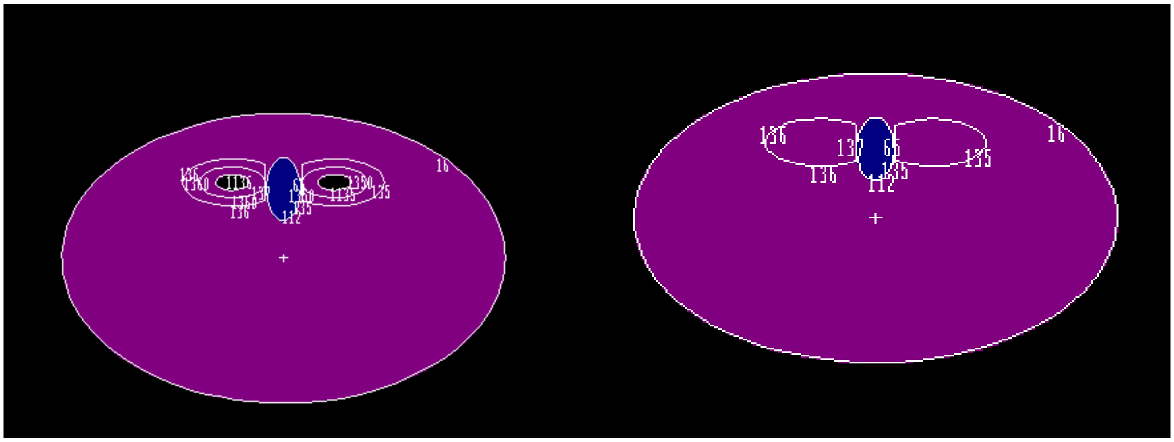

Figure (4): phantom used in this research from top view, three-part kidney and integrated kidney

First, kidney is considered integrated ellipsoidal shape that ^{111}In-DTPA is uniform distributed in; input file was prepared for tally F6, for gamma radiation of radioisotope ^{111}In in babies, children age one, five, ten and fifteen year and adults. After execution MCNPX code, gamma absorbed dose was obtained from output files with regard to kidney mass. Then, it was supposed that kidney was consisted of three areas, pelvis, medulla and cortex, ^{111}In-DTPA was uniform distributed in medulla, input file was prepared for tally F6, for gamma radiation of radioisotope ^{111}In for babies, one, five, ten and fifteen-year children and adults. After execution MCNPX code, gamma absorbed dose in cortex and medulla was obtained from output files with regard to their mass.

Results and Discussion: After execution MCNPX code, gamma absorbed dose was extracted from output file with regard to kidney mass. Next, ratio of gamma absorbed dose in cortex to gamma absorbed dose in integrated were calculated and recorded in table (1) in order to compare the results in integrated kidney and three-part kidney.

Table 1: Ratio of cortex gamma absorbed dose in kidney with three areas model to gamma absorbed dose in integrated kidney

Dose in cortex/Dose in integrated kidney					
newborn	1y	5y	10y	15y	adult
0.629	0.616	0.627	0.629	0.621	0.620

However, results of simulation comparison of three-part kidney with integrated kidney shown in table (1) have indicated that gamma does in cortex is less than in integrated kidney. Ratio of cortex dose to integrated kidney is about 62%. Then, ratio of medulla gamma absorbed dose in three-part kidney model to gamma absorbed dose in integrated were calculated and recorded in table(2).

Table 2: Ratio of medulla gamma absorbed dose in three-part kidney model to gamma absorbed dose in integrated kidney

Dose in medulla/Dose in integrated kidney					
newborn	1y	5y	10y	15y	adult
1.956	1.924	1.930	1.921	1.841	1.908

Moreover, table (2) has shown that gamma dose in medulla is twice times as much as dose in integrated model. Thus, much more dose is absorbed in medulla that will cause a lot of side effects.

Conclusion: To achieve maximum quality in imaging with minimum side effects, the most appropriate amount of ^{111}In-DTPA should be taken to patient. It is necessary to calculate gamma absorbed dose using MCNPX code to prescribe appropriate dose of radiopharmaceutical. The more accurate simulation results are, the more accurate the calculation of radiopharmaceuti-cal amount will be.

This research has been showed that if the amount of prescribed ^{111}In-DTPA is calculated according to integrated model, gamma dose absorbed in medulla will be approximately 2 times as much as calculated amount and will lead to renal toxicity.

It is recommended that simulation results of three-part kidney are replaced with integrated kidney to prevent from renal toxicity.

REFERENCES

Blachot J (1996). LBNL Isotopes Project - LUNDS University. ‹Table of Radioactive Isotopes. Version 2.1. The website: http://ie.lbl.gov/toi/nuclide.asp?iZA=490111

Bouchet LG, Bloch WE, Blanco HP, Wessels BW, Siegel JA, Rajon DA, Clairand I,Sgouros G (2003). Absorbed Fractions and Radionuclide S Values for Six Age-Dependent Multiregion Models of the Kidney .MIRD PAMPHLET NO. 19.J Nucl Med :44:1113-1147.

Briesmeister JF (2000). MCNP A general Monte Carlo N-particle transport code, Version 4C, Los Alamos.

Cristy M, Eckerman KF (1987).specific absorbed fractions of energy at various ages from internal photon source.

ICRP,(1988). Radiation Dose to Patients from Radiopharmaceuticals.ICRP Publication 53.Ann.ICRP 18(1-4).

Kalantar Hormozi M, Nabipour I, Assadi M, Asadipouya K, Zendehboudi S, Ranjbar Omrani G. (2011). Subclinical Hypothyroid. ISMJ; 14 (1):51-60.

Konijnenberg M, Melis M, Valkema R, Krenning E, Jong M (2007).Radiational dose distribution in human kidneys by octreotides in peptide receptor radionuclide therapy. J Nucl Med; 48:134-142.

Los Alamos National Laboratory (2002).MCNPX Users manual. version 2.4.0.

Mansourbahmani M, Moussavi AH, Vakili A, Rezaie MR, Dehghan HR, Rezvan Najad E (2013). Study of Existing Radon In Milk and Its Effect on Body Organs. Int J Adv Biol Biom Res; 1(8): 802-812.

Mirzaei M, Mowlavi AA, Mirshekarpour H, Mohammadi S (2012). Absorbed dose calculation from gamma and gamma rays of I-131 in ellipsoidal thyroid and other organs of neck with MCNPX code, Iranian South Med J, 3:201-7.

Mirzaei M, Mirshekaipour H(2013a). Comparison of absorbed fraction of Gamma and Beta rays of I-124 and I-131radio-isotopes in thyroid gland with Monte Carlo Simulation. Int J Adv Biol Biom Res; 1(9):993-998.

Mirzaei M(2013b). Studying the effect of kidney internal structure on beta absorbed dose of radiopharmaceuticals Hg-203, Ho-166 and Y-90 using Monte Carlo. Int J Adv Biol Biom Res; 1(9):1040-1046.

Mowlavi AA , Mokhtarinejad E (2006). Dose Calculation Due to a ^{125}I Source Model 6711 and Determination of Its Dosimetry Parameters in Water and Soft Tissue Phantom, Iranain Journal of Medical Physics, Vol.3 ,No.12.

Mowlavi AA (2008).Monte Carlo Dose Calculation of ^{90}Sr/^{90}Y Source in Water Phantom, Iranian Journal of Medical Physics, Vol.5, No.1 (18-19).

Soniua M, Eman M, Magda SH, Ibrahem I, Esmat AA (2006). Monte carlo dose calculations for breast radiotherapy using co-60 gamma rays .Journal of Nuclear and radiation Physics 1[1]: 61-72.

Wessels BW, Konijnenberg MW, Dale RG, Breitz HB, Cremonesi M, Meredith AJ, Green AJ, Bouchet LG, Brill AB, Bloch WE, Sgouros G, Thomas S (2008). The Effect of Model Assumptions on Kidney Dosimetry and Response—Implications for Radionuclide Therapy.J Nucl Med 49:1884-1899.

Zarei M, Kalifzadeh F(2013). Effects of using radiation processing in nutrition science and their restriction: a review. Int J Adv Biol Biom Res; 1(3):222-231.