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Studying the effect of kidney internal structure on beta absorbed dose of radiopharmaceuticals Hg-203, Ho-166 and Y-90 using Monte Carlo

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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; beta 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 beta absorbed dose in medulla is 4 times as much as dose in integrated kidney and beta dose in cortex is 0.004 to 0.012 times 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: Absorbed dose, Medulla, Cortex, Monte Carlo method

INTRODUCTION

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 a 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). For example, prescribing excessive amounts of iodine-131 in treatment of hyperthyroidism can lead to hypothyroid (Kalantar et al.2011). 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. It is shown that toxicity related to small molecule of radioisotope in kidney has caused limitation in prescribed dose (Wessels et al.2008).

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

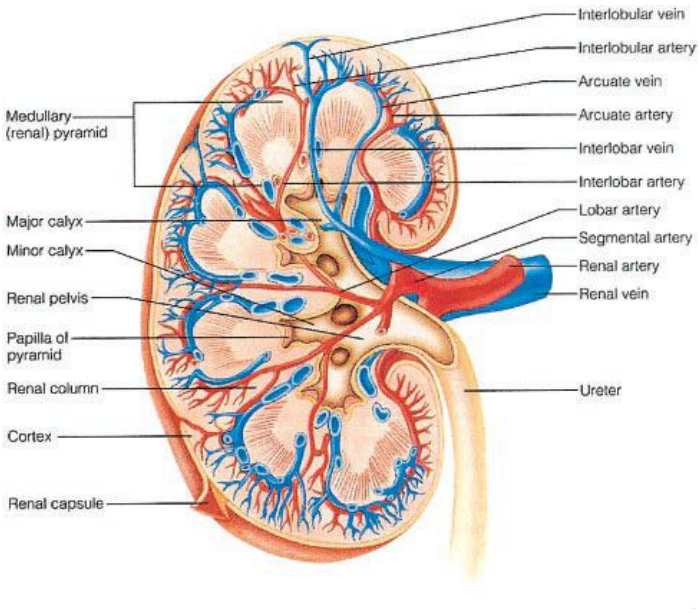

Figure (1): kidney components

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 beta absorption is considered unit. While kidney has internal organs and radiopharmaceutical is not uniform distributed in.

Materials and Methods: First, beta data of radioisotopes Hg-203, Ho-166 and Y-90 was downloaded from TORI site (Firestone and Ekström.1999). Then, their spectrums were calculated using point to point method. The spectrum is shown in Figure (2).

[1] Committee on Medical Internal Radiation Dose

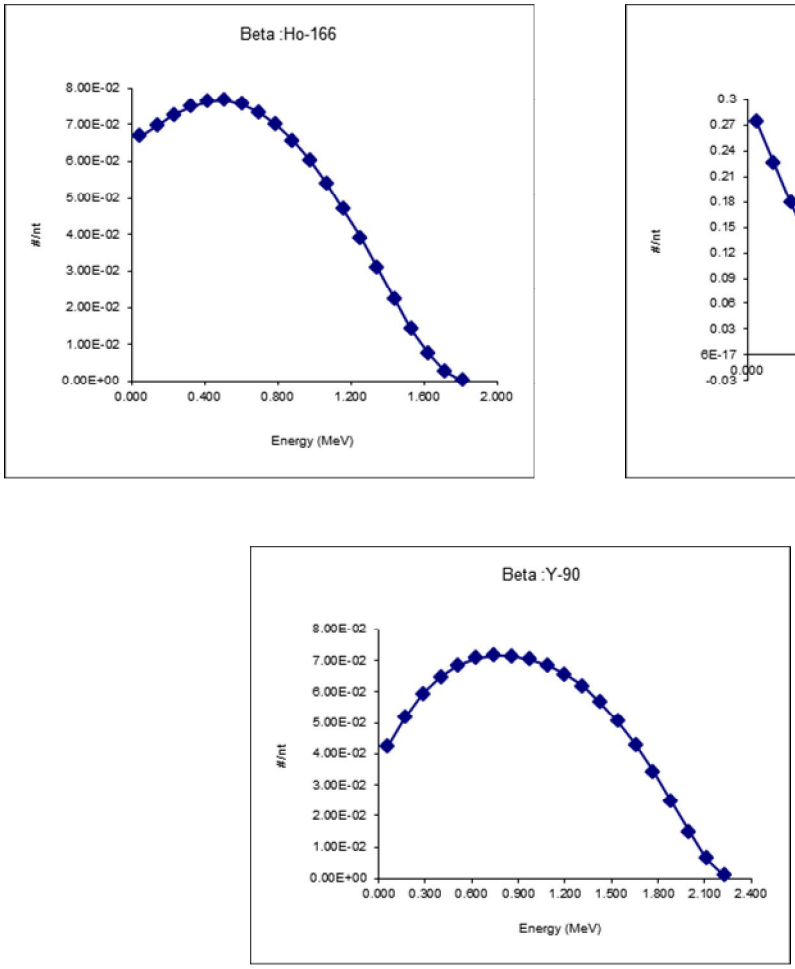

Figure (2): beta spectrum isotopes, Ho-166, Hg-203, and Y-90

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. It is supposed that total radiation source is distributed in kidney in integrated kidney model. Therefore, beta 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, beta 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 Figure (3).

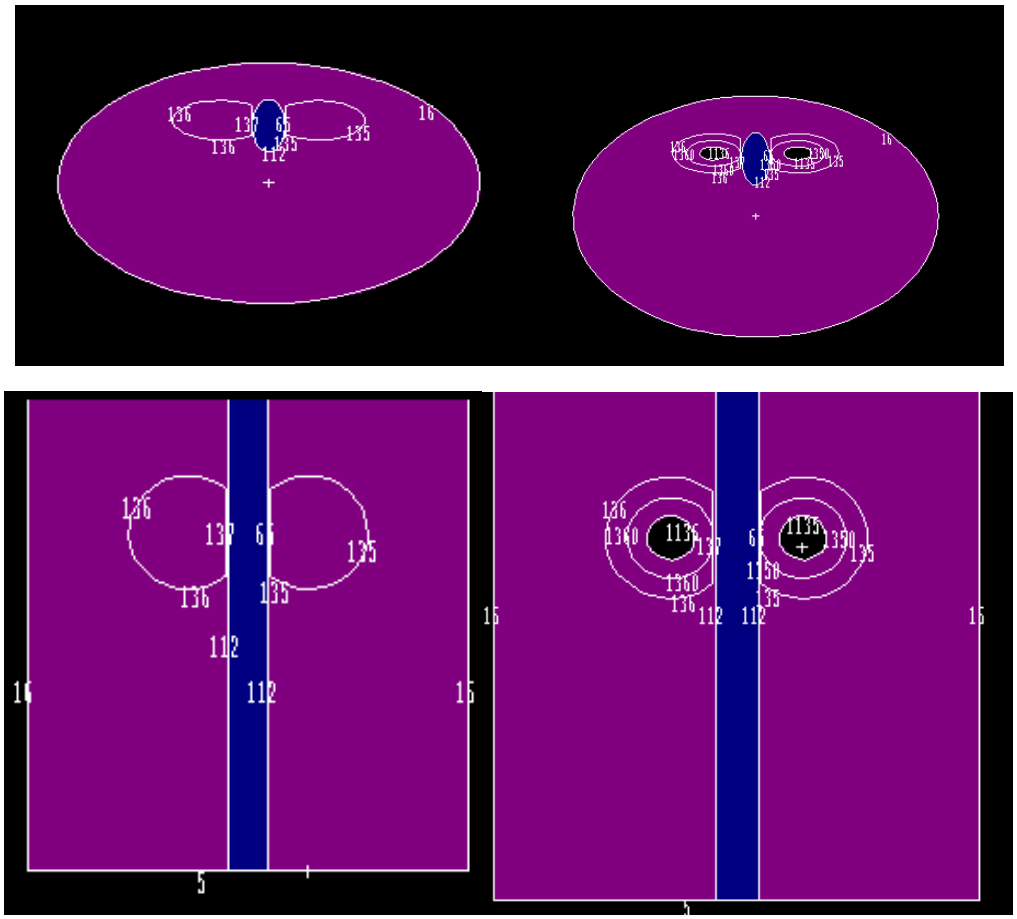

Figure (3): phantom used in this research from front and top view, integrated kidney and three-part kidney

[3] International Commission on Radiological Protection

First, kidney is considered integrated ellipsoidal shape that radiopharmaceutical is uniform distributed in; input file was prepared for tally F8, for beta radiation of radioisotopes Hg-203, Ho-166, Y-90 and for babies, children age one, five, ten and fifteen year and adults. After execution MCNPX code, beta absorbed energy was obtained from output files; beta absorbed dose was calculated with regard to kidney mass. Then, it was supposed that kidney was consisted of three areas, pelvis, medulla and cortex, radiopharmaceutical was uniform distributed in medulla, input file was prepared for tally F8, for beta radiation of radioisotopes, Hg-203, Ho-166 and Y-90 for babies, one, five, ten and fifteen-year children and adults. After execution MCNPX code, beta absorbed energy in cortex and medulla was obtained from output files; beta absorbed dose in cortex and medulla was calculated with regard to their mass.

RESULTS AND DISCUSSION

After execution MCNPX code, beta absorbed energy was obtained from output files; beta absorbed dose was calculated with regard to kidney mass. Next, ratio of beta absorbed dose of various isotopes in cortex to beta 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 beta absorbed dose in kidney with three areas model to beta absorbed dose in integrated kidney

Dose in cortex/Dose in integrated kidney			
	Ho-166	Y-90	Hg-203
newbon	1.21E-02	1.07E-01	7.29E-03
1y	8.81E-03	9.75E-02	5.34E-03
5y	7.83E-03	1.10E-01	4.60E-03
10y	7.34E-03	1.02E-01	4.43E-03
15y	6.85E-03	9.47E-02	4.08E-03
adult	7.11E-03	9.72E-02	4.22E-03

However, results of simulation comparison of three-part kidney with integrated kidney shown in table (1) have indicated that beta does in cortex is less than in integrated kidney. Ratio of cortex dose to integrated kidney is varied from 0.004 to 0.012; it means that a very small proportion of the radiation is reached to cortex.

Moreover, ratio of medulla beta absorbed dose in three-part kidney model to beta absorbed dose in integrated were calculated and recorded in table(2).

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

Dose in medulla/Dose in integrated kidney			
	Ho-166	Y-90	Hg-203
newborn	3.98	3.79	3.99
1y	3.98	4.22	3.99
5y	3.98	4.23	3.99
10y	3.97	4.24	3.98
15y	3.98	4.26	3.99
adult	3.99	4.25	3.99

Moreover, table (2) has shown that beta dose in medulla is four 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 therapeutic effect with minimum side effects, the most appropriate amount of radiopharmaceutical should be taken to patient. It is necessary to calculate absorbed dose using MCNPX code to prescribe appropriate dose of radiopharmaceutical. The more accurate simulation results are, the more accurate the calculation of radiopharmaceutical amount will be. This research has been showed that if the amount of prescribed radioisotope is calculated according to integrated model, beta dose absorbed in medulla will be approximately 4 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.

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