1st International & 28th National Conference on Nuclear Science & Technology 2022 (ICNST22)
Nuclear Science & Technology Research Institute

Microdosimetric Study on the effect of nanoparticles on absorbed dose in thyroid cells for Auger electron decay mode

Sadremomtaz A[1*], Kazemiyan M. [2]

[1,2]Physics department, Basic science faculty, University of guilan ,Institute,4193833697, Rasht, Iran
[*] *Email: sadremomtaz@yahoo.co.uk*

Abstract

Targeted Auger electron therapy is a promising strategy that aims to deposit DNA-damaging radiation selectively while sparing normal cells. according to their low range, subcellular localization of Auger-emitters becomes crucial. Auger elecrtons can be produced directly by Auger emitters or by using an external beam interacting with a contrast agent. usually Gold nano-particles are used as contrast agents. nanoparticles can also enhance the absorbed dose and can be used as radiopharmaceuticals carriers too. in this study, a previously constructed model of thyroid follicle was used. ^{131}I, ^{123}I, and ^{125}I were chosen as sources, and Nanoparticles (Nps) were defined in the media and their dose enhancement factor in subcellular level was calculated. results showed when the source is located in the nucleus itself, S values increase with a factor of 9.57 when Np's concentration is 50 mg/g.

Keywords: Nano particles, Microdosimetry, MCNP, Auger electeron, TRT, MIRD

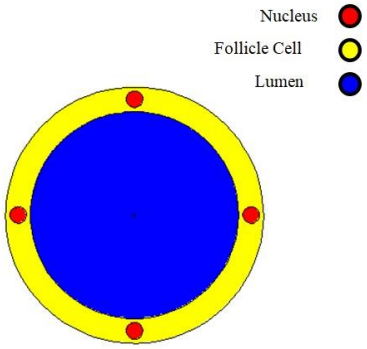
Introduction

Targeted radionuclide therapy (TRT) is a promising treatment for solid tumors and micro-metastases Cell-level [1] absorbed-dose calculations for internal radionuclides generally are based on the Medical Internal Radiation Dose (MIRD) schema, with the assumption that activity is uniformly distributed within the cell or subcellular region [2]. In such cases, it is implicitly assumed that all irradiated tumor cells will receive the same average tumor dose. However, various experimental studies for several radiopharmaceuticals that were performed have revealed that the distribution of activity in tumors is highly non-uniform. The heterogeneous distribution of radioactivity has been one of the main reasons for the widespread usage of beta emitters which by their long irradiation range are capable of cross irradiating nontargeted tumor cells. Although the importance of the crossfire effect, it comes with the price of increased normal tissue damage. The therapeutic advantages of Auger emitters in such cases have been extensively discussed in the literature [3] in this study, the relation between S-values caused by AE emitters and gold nano-particles concentration was investigated.

materials and methods

According to josefsson et al [4] the model of thyroid follicle of a human consisted of a centrally placed follicle lumen represented by a sphere. A single layer of follicle cells represented by a concentric spherical shell surrounded the follicle lumen. Six follicle cell nuclei were centrally placed within the follicle cells, symmetrically.

The follicle cell nuclei were the target volumes and an average value was calculated for the six nuclei. The dimensions of the single follicle model were: follicle lumen diameters 150 μm; follicle cell thickness 6 μm; follicle cell nucleus diameter 4 μm, respectively. The model consisted of unit density liquid water homogeneously The radiohalogens were homogenously distributed 1) within the follicle lumen (L), 2) follicle cells (f), 3) the follicle cell nuclei (N), and and in all the calculations the follicle cell nuclei were the targets. The radiohalogens studied were 124I, 123I, 125I. The nuclear decay data used in all the MC calculations was taken from ICRP 107[5].



(a)

Figure 1. Geometry of simulation

To evaluate the effect of NPs being present in the media, the study was performed in 3 conditions : 1) in absence of nano-partilcles 2)in presence of nano-particles with concentration of 30 mg/g. 3)in presence of nano-particles with concentration of 30 mg/g. MCNP5 code wase used to perform the simulation and parralel computing techniques administrated. S-values were calculated in follicle cell nucleis using tally: *f8. this tally gives the results in MeV/gr, in order to converting

the results into Gy, 1.6×10^{-14} as a coefficient was multiplied to output. in first step the results in absence of NPs and for three radioistioes meaning ^{131}I, ^{123}I and ^{125}I were compared with those in josefsson et al. Table 1 shows result of validation of the study.

Table 1. camparison between this study and josefsson et al

Radio-isotopes	source	S-values do to AE (Gy/pp)		
		this study	josefsson et al	diff (%)
^{131}I	L	2.05E-08	2.13E-09	8.62
	f	7.19E-08	7.28E-08	1.24
	N	1.55E-04	1.63E-04	4.91
^{125}I	L	5.13E-08	5.49E-08	6.56
	f	2.12E-06	2.15E-06	1.40
	N	4.91E-03	4.70E-03	4.47
^{123}I	L	3.36E-08	3.39E-08	8.85
	f	1.26E-06	1.29E-06	2.33
	N	2.79E-03	2.82E-03	1.06

Results and discussion

After expriment validation, NPs were added to the geometry. two concentration were considered namely 30 mg/g and 50 mg/g. corresponding tallies can be seen in table 2 and 3.

Table 2. DEF for GNPs with 30 mg/g concentration

Radio-isotopes	source	S-values due to AE (Gy/pp)		
		30 mg/g Nps	without Nps	DEF
^{131}I	L	1.13E-08	2.05E-08	0.55
	f	5.10E-08	7.19E-08	0.71
	N	7.13E-04	1.55E-04	4.6
^{125}I	L	3.35E-08	5.13E-08	0.61
	f	1.66E-06	2.12E-06	0.77
	N	2.40E-02	4.91E-03	5.1
^{123}I	L	1.18E-08	3.36E-08	0.35
	f	6.43E-07	1.26E-06	0.51
	N	2.01E-02	2.79E-03	7.2

Table 2. DEF for GNPs with 50 mg/g concentration

Radio-isotopes	source	S-values due to AE (Gy/PP)		
		50 mg/g Nps	without Nps	DEF
^{131}I	L	4.92E-09	2.05E-08	0.24
	f	4.24E-08	7.19E-08	0.59
	N	1.31E-03	1.55E-04	8.45
^{125}I	L	1.69E-08	5.13E-08	0.3
	f	1.17E-06	2.12E-06	0.55
	N	4.22E-02	4.91E-03	8.6
^{123}I	L	6.38E-09	3.36E-08	0.19
	f	3.53E-07	1.26E-06	0.28
	N	2.23E-02	2.79E-03	8

Data in table 2 and table 3 show that when Auger emitters are placed outside the cell nucleus adding Nps causes a decreasing factor in S values. it can be explained by very short range of Auger electrons in human body medium. when Nps are added, the medium absorbing ability for almost all of radiations increases. This prevents AE electrons from traveling from the source to target, so when source is in lumen or follicle cell, adding nanoparticles reduces the probability of AE electrons successful reaching to target and that is the main concern during a therapy with AE emitter. but in the other hand table 2 and table 3 show when AE electrons emitter reaches to Nucleus cell, presence of NPs can increase absorbed dose and in this situation DEF has a direct relation with Nps concentration.

Different S-values from different radioisotopes show the importance of decaye porobability although all AE electrons belonged to different radioisotopes in this study, have approximately same energy, but differences in frequency of AE decay in these radioisotopes, causes different S-values.

Conclusions

AE electrons have lower energy levels from beta particles and as a result their range in tissue is very short, so they deposit almost all of their energy in the vacinity of where they are emitted. this can cause a inhomogenous dose distribution. but also when they are correclty localized in cancreouse cell (i.e close to DNA) they can cause an extremely damage to malignant cells and spare the healthy cells at the same time. using simultaneously AE emitters and nano particles can help to achieve to a maximum level of treatment success. this study shows when AE emitters are placed in cell nuclei, with increasing the amount of Np's concentraion S-value increases to. the maximum DEF wase achieved whe cell nucleus was chosen as source and nanoparticles with concentration 50 mg/g were added, the value of DEF in this situation went up to 8.

References

[1] Guilia Tamborino et al, *Cellular dosimetry of [^{177}Lu]Lu-DOTA-[Tyr^3]octreo radionuclide therapy: the impact of modeling assumptions on the correlation with in vitro cytotoxicity*, EJNMMI Physics (2020)

[2] Tian Yuan et al, *Influence of Nanuniform Activity Distribution on Cellular Dosimetry*, Cancer Biotherapy & Radiopharmaceuticals, Volume 23, N:2 (2008)

[3] C bousis et al , *Monte carlo single-Cell dosimetry of Auger-electron emitting radionuclides*, physics in medicine and biology, Vol:55 pp:2555-2572 (2010)

[4] A. josefsson et al , *Dosimetric analysis of ^{123}I, ^{125}I and ^{131}I in thyroid follicle models* , EJNMMI Physics (2014)

[5] Valentin J: *ICRP Publication 107: nuclear decay data for dosimetric calculations.* Oxford: Published for the International Commission on Radiological Protection by Elsevier (2009)