MCNP dosimetry study for prediction of Sn-117m radiopharmaceuticals production yield

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1. Introduction

Sn-117m is one of the most promising therapeutic radiopharmaceuticals in the field of nuclear medicine. In contrast to most other therapeutic beta emitters, Sn-117m decays with the emission of 3 major mono-energetic conversion electrons (127, 129, and 152 keV; abundance, 65%, 12%, and 26%, respectively) as shown in table 1. These non-energetic emitters enable to localize to a certain distance (290 um) of targeted tumor regions with high effective dose as shown as figure 1. Therefore, it is suitable for therapeutic radionuclide of highly selective targeting and uptakes in tissues. In this study, we have investigated therapeutic radiation physical effects on Sn-117m rituximab, and calculated radiation doses on mouse tumor model for prediction of its production yield.

Table 1. Radiation energy and intensity of Sn-117m

Radiations	E(i)(keV)	y(i)(Bq-s)-1
gamma1	156	2.11E-02
gamma2	159	8.64E-01
gamma3	314	4.23E-06
Kalpha1_X-ray	25.3	3.52E-01
Kalpha2_X-ray	25	1.88E-01
Kbeta_X-ray	28.5	1.19E-01
L_X-ray	3.44	7.34E-02
Auger-K	21	1.07E-01
Auger-L	2.95	9.19E-01
ce-K,gamma1	127	6.49E-01
ce-L,gamma1	152	2.62E-01
ce-M,gamma1	155	5.64E-02
ce-N+,gamma1	156	1.35E-02
ce-K,gamma2	129	1.17E-01
ce-L,gamma2	154	1.48E-02
ce-M,gamma2	158	2.89E-03
ce-N+,gamma2	158	6.48E-04

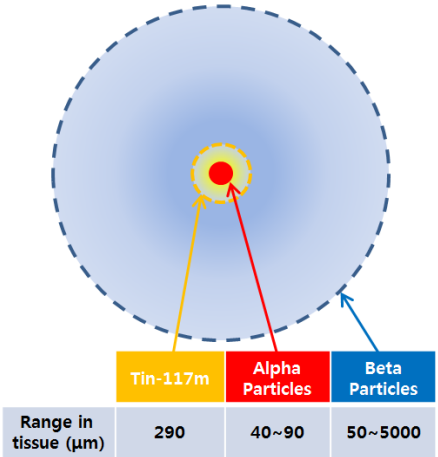

Fig. 1. A schematic comparison of energy types for therapeutic radionuclides

2. Methods

For the purpose of radionuclide dosimetry, absorbed doses for internal radionuclides (Sn-117m and Iodine-131) were calculated using mouse digital phantom and Monte Carlo simulation code, MCNPX V2.7. The mean dose per cumulated activity, S-values (mGy/Bq*-s) were simulated for different source target organ pairs for a number of radio-nuclides of interest organ regions. Commonly, the simulation based small animal dosimetry methods were calculated with digital mouse and rat phantoms of fixed normal models without blood and tumor. In this study, we added designed customizable digital phantom for xenograft tumor and blood in dosimetry study. The digital phantom based on anatomic data from 35g of MOBY(mouse whole-body) and Sn-117m and I-131 were used in the same therapeutic applications, which are leukemia and lymphomas. For this reason, we designed simulation tools for the blood and the tumor comparison between Sn-117m and I-131. In addition, the xenograft tumor mass of 2.2 g were additionally coded to the right flank of the voxel based mouse model. The internal blood of aorta was coded to calculate the inner-distributed blood dose.

The masses of included organs are shown in Table 2, and an illustration of the mouse model is shown in Fig. 2. The phantom matrix dimensions are 128×128×400 voxels, with a cubic voxel is equal to 0.29 mm.

Table 2. Masses of Organs Included in Mouse phantom

Organ	Mass(g)
Total body	35.000
Intestine	1.512
Stomach	0.449
Brain	0.624
Kidney	0.424
Heart	0.097
Liver	2.313
Spleen	0.137
Lung	0.177
Thyroid	0.002
Bone	3.441
Blood(Aorta)	0.274
REM Body	25.620
Tumor	2.200

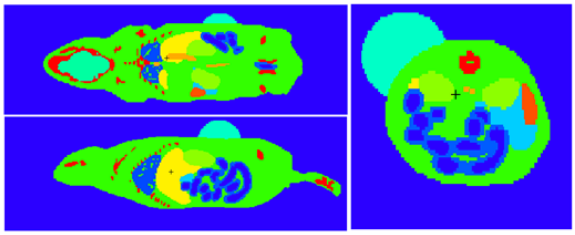

Fig. 2. Designed moby based MCNPX mouse voxel phantoms

4. Results

The mean dose per cumulated activities (S-values) were calculated by monte carlo simulation code(MCNP) with digital phantom. The voxel-based mouse models were designed from MOBY digital phantom, and tumors and other specific organs were defined by our developed program tool. The mass and the shape of organs and their locations have considerable effects on S-values. The absorbed fractions of targeted organs were calculated by considering all physical conditions such as type of radiation, energy, and branching ratio of particulate radiation and gamma ray energies and abundances. The final simulated S-value results are shown in Fig. 3.

Here, we calculated the S-value ratio of Sn-117m and I-131, and it represented as 10 organs, the blood, xenograft tumor, and remained body in table 3.

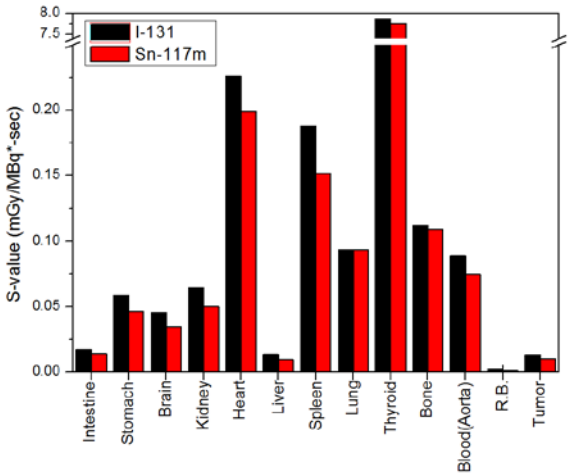

Fig. 3. Simulated S-value of Sn-117m and I-131

Table 3. S-value ratio of Sn-117m and I-131

Organ	S-value ratio$_{(Sn\text{-}117m/I\text{-}131)}$ (%)
Intestine	80.4
Stomach	79.8
Brain	75.8
Kidney	78
Heart	87.8
Liver	71.7
Spleen	80.9
Lung	100.3
Thyroid	98.8
Bone	97.1
Blood(Aorta)	83.8
REM Body	53
Tumor	76.2

4. Conclusions

We used the Monte Carlo method to evaluate s-value parameter for prediction of Sn-117m radio-pharmaceuticals production compared with I-131. In this study, we developed a customizable digital mouse phantom, because principal therapeutic applications of Sn-117m and I-131 are leukemia, lymphomas, solid tumor and metastatic bone pain. These applications are needed S-values of blood, tumor and bone for radiopharmaceuticals research.

The results of this study, lower S-values of Sn-117m compared with I-131, can support to estimate Sn-117m radiopharmaceuticals production yield. It can further be applied to evaluate pharmacokinetics and pharmacodynamics research with dose calculation.

In addition, the results can be used to determine proper administrative injection dose for radiopharmaceuticals.

REFERENCES

[1] S. C. Srivastava, Paving the Way to Personalized Medicine: Production of Some Promising Theragnostic Radionuclides at Brookhaven National Laboratory, Semin Nucl Med, Vol. 42, pp.151-163, 2012.

[2] S. C. Srivastava, Therapeutic Nuclear Medicine, Springer, New York, pp. 11-50, 2014

[3] Krishnamurthy GT, Swailem FM, Srivastava SC, et al, Tin-117m(4+)DTPA: Pharmacokinetics and imaging characteristics in patients with metastatic bone pain. J Nucl Med, Vol 38, pp 230-237, 1997

[4] Kasis AI, Sastry KSR, A delstein SJ. Intracellular distribution and radiotoxicity of chromium-51 in mammalian cells: Auger-electron dosimetry. J Nucl Med. Vol 26, pp 59-67, 1985