Monte Carlo simulations of photon specific absorbed fractions in a mouse voxel phantom

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For preclinical assessments of several radiopharmaceuticals, photon specific absorbed fractions (SAFs), the absorbed fraction in the target organ per unit mass of the target organ, were evaluated in a mouse sophisticated model and a new set of photon SAFs were tabulated for photon energies from 10 keV to 4 MeV. In the present study, Digimouse voxel phantom was used as a sophisticated model and converted to an input file for EGS4 code, in conjunction with an EGS4 user code, UCSAF. The sources were assumed to be mono-energetic and distributed uniformly in the main organs with isotropic direction emission. The SAFs were evaluated in the Digimouse for eleven organs. Table 1 shows the photon SAFs in some organs of the Digimouse and source was in liver.

Table 1 Photon specific absorbed fractions (SAFs in 1/kg) in some organs of the Digimouse phantom (source = liver).

	Target organ									
Energy (MeV)	Skeleton	Heart	Bladder	Stomach	Spleen	Pancreas	Liver	Kidneys	Adrenal	Lungs
0.010	2.3×10^{1}	3.1×10^{1}	2.8×10^{-1}	8.2×10^{1}	1.8×10^{1}	3.1×10^{1}	3.2×10^{2}	2.9×10^{1}	1.3×10^{2}	7.3×10^{1}
0.015	3.2×10^{1}	3.8×10^{1}	2.7×10^{0}	8.0×10^{1}	2.6×10^{1}	3.5×10^{1}	2.1×10^{2}	3.4×10^{1}	1.1×10^{2}	6.6×10^{1}
0.02	2.8×10^{1}	2.8×10^{1}	4.4×10^{0}	5.2×10^{1}	2.2×10^{1}	2.6×10^{1}	1.1×10^{2}	2.6×10^{1}	6.8×10^{1}	4.2×10^{1}
0.03	1.4×10^{1}	1.1×10^{1}	2.8×10^{0}	2.0×10^{1}	9.3×10^{0}	1.1×10^{1}	3.8×10^{1}	1.1×10^{1}	2.4×10^{1}	1.6×10^{1}
0.05	3.9×10^{0}	3.5×10^{0}	9.7×10^{-1}	5.9×10^{0}	2.9×10^{0}	3.4×10^{0}	1.1×10^{1}	3.4×10^{0}	7.3×10^{0}	4.7×10^{0}
0.1	1.1×10^{0}	2.1×10^{0}	5.9×10^{-1}	3.4×10^{0}	1.7×10^{0}	2.0×10^{0}	6.6×10^{0}	2.0×10^{0}	4.5×10^{0}	2.6×10^{0}
0.2	8.5×10^{1}	2.3×10^{0}	6.6×10^{-1}	3.9×10^{0}	2.0×10^{0}	2.2×10^{0}	7.5×10^{0}	2.2×10^{0}	4.6×10^{0}	2.8×10^{0}
0.5	9.1×10^{-1}	2.5×10^{0}	7.0×10^{-1}	4.2×10^{0}	2.1×10^{0}	2.5×10^{0}	7.9×10^{0}	2.4×10^{0}	5.4×10^{0}	3.2×10^{0}
1	8.4×10^{-1}	2.4×10^{0}	6.6×10^{-1}	4.0×10^{0}	2.0×10^{0}	2.3×10^{0}	6.6×10^{0}	2.3×10^{0}	4.9×10^{0}	2.9×10^{0}
1.5	7.5×10^{-1}	2.1×10^{0}	6.3×10^{-1}	3.5×10^{0}	1.8×10^{0}	2.0×10^{0}	5.3×10^{0}	2.0×10^{0}	3.8×10^{0}	2.5×10^{0}
2	6.5×10^{-1}	1.9×10^{0}	5.9×10^{-1}	2.9×10^{0}	1.6×10^{0}	1.8×10^{0}	4.1×10^{0}	1.8×10^{0}	3.4×10^{0}	2.1×10^{0}
4	4.0×10^{-1}	1.1×10^{0}	4.6×10^{-1}	1.5×10^{0}	1.0×10^{0}	1.1×10^{0}	1.9×10^{0}	1.1×10^{0}	1.7×10^{0}	1.1×10^{0}

From the above table, comparison of the SAFs in different organs shows energy dependency of the photon SAFs for self-irradiation, i.e., the source organ is the target organ, (target = liver) and cross-irradiation, i.e., the source organ is not the target organ, (target ≠ liver). The photon SAFs in pancreas and kidneys (Table 1) for all energy have the same values although the mass of them are completely different with large difference. The mass of pancreas and Kidneys are 0.0465 g and 0.5149 g. From the SAFs results for cross-irradiation, e.g., pancreas and kidneys, it can be resulted that the photon SAFs for cross-irradiation do not always change with the differences in mass. It seems that the geometry including source size, target size and their distance significantly affect on the SAFs for cross-irradiation.

Table 2 Photon-only S values (Gy/Bq.s) for ^{131}I, ^{153}Sm and ^{188}Re sources in liver and spleen.

		the present study		Kolbert *et al.*	
		Source organ			
	target	Liver	Spleen	Liver	Spleen
^{131}I	Liver	4.9×10^{-13}	1.3×10^{-13}	5.8×10^{-13}	4.4×10^{-14}
	Spleen	1.3×10^{-13}	2.4×10^{-12}	4.2×10^{-14}	4.7×10^{-12}
^{153}Sm	Liver	1.6×10^{-13}	2.7×10^{-14}	1.7×10^{-13}	1.1×10^{-14}
	Spleen	2.7×10^{-14}	1.3×10^{-12}	1.1×10^{-14}	1.8×10^{-12}
^{188}Re	Liver	8.1×10^{-14}	1.9×10^{-14}	1.0×10^{-13}	6.5×10^{-15}
	Spleen	1.8×10^{-14}	4.6×10^{-13}	6.2×10^{-15}	9.2×10^{-13}

Photon-only S values, dose per unit cumulated activity (Gy/Bq.s), were calculated for the Digimouse phantom using the results of the photon SAFs in spleen and liver. Table 2 lists the S values for three radionuclides in comparison with Kolbert *et al.* results which were obtained in a mouse voxel phantom using point kernel method. Large differences can be observed between S values obtained from the different models. For different source-target configurations large variations can be observed between the different datasets.

In the present study, it was confirmed that the photon SAFs for self-irradiation depended on the photon energy and the mass of the target/source organ. The photon SAFs for cross-irradiation also was an energy dependent function but did not change by the mass of target and it might be affected by source size, target size, their shape and distance between the source and target. Organ dose evaluation should be performed in the phantom with the Monte Carlo method since the minor changes in the geometry had a large effect on photon-only S values and organ dose. From comparison of the results, it can be stated that minor changes in the source-target geometry are likely to change dramatically the resulting S values.