

Estimation of Radiation Dosimetry for ^{68}Ga -HBED-CC (PSMA-11) in Patients with Suspected Recurrence of Prostate Cancer

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^{68}Ga -DKFZ-PSMA-11

Glu-NH-CO-NH-Lys-(Ahx)-[^{68}Ga (HBED-CC)]

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ABSTRACT

Introduction: To estimate the human radiation dosimetry for [⁶⁸Ga]Ga-HBED-CC (PSMA-11). **Methods:** Under an RDRC-approved research protocol, we evaluated the biodistribution and pharmacokinetics of [⁶⁸Ga]Ga-HBED-CC (PSMA-11) with serial PET imaging following intravenous administration to nine prostate cancer patients in whom clinical [¹¹C]acetate PET/CT exams had been independently performed under Expanded Access IND 118,204. List-mode imaging was performed over the initial 0-10 minutes post-injection with the pelvis in the field-of-view. Whole-body images were acquired, pelvis-to-head, at 15, 60, and 90-minutes post-injection. Additional images of the pelvis were acquired at 40-minutes and 115-minutes, and voided urine collected from each subject at 48-minutes and 120-minutes post-injection. Radiation dosimetry estimates were calculated from these data using the OLINDA software package. **Results:** Renal uptake was high and relatively invariant, ranging from 11% to 14% of the injected dose between 15 and 90-minutes post-injection. Radioactivity collected in the voided urine accounted for 14% of the injected dose over a period of 120-minutes. Lymph nodes and skeletal metastases suspicious for prostate cancer recurrence were detected in fewer patients using ¹¹C-acetate than using [⁶⁸Ga]Ga-HBED-CC (PSMA-11). **Conclusion:** Kidneys are the critical organ following [⁶⁸Ga]Ga-HBED-CC (PSMA-11) administration, receiving an estimated dose of 0.413 mGy/MBq. **Advances in Knowledge and Implications for Patient Care:** This study confirms that the kidneys will be the critical organ following intravenous administration of [⁶⁸Ga]Ga-HBED-CC (PSMA-11), and provided data consistent with the expectation that [⁶⁸Ga]Ga-HBED-CC (PSMA-11) will be superior to [¹¹C]acetate for defining sites of recurrence in prostate cancer patients presenting with biochemical relapse.

Introduction

The PSMA-targeted [⁶⁸Ga]Ga-HBED-CC (PSMA-11) radiopharmaceutical has been shown to be quite useful in imaging patients with prostate cancer to define the location and extent of disease [1-2]. However, despite its fairly extensive human use of [⁶⁸Ga]Ga-HBED-CC, until recently no estimates of the human radiation dosimetry for [⁶⁸Ga]Ga-HBED-CC were available in the published literature. Those recently published data [3,4] represent findings in a very limited number of subjects, in one case only four subjects [3], and the other case, five subjects who received a concurrent dosing with furosemide [4]. To independently assess [⁶⁸Ga]Ga-HBED-CC (PSMA-11) dosimetry, we have evaluated the radiopharmaceutical's biodistribution and pharmacokinetics with serial PET imaging following intravenous administration to nine prostate cancer patients in whom ¹¹C-acetate PET/CT exams had been clinically performed under Expanded Access IND 118,204 to assess disease recurrence.

Materials and Methods

Our use of [⁶⁸Ga]Ga-HBED-CC (PSMA-11) in PET/CT imaging was reviewed and approved by the Indiana University Radioactive Drug Research Committee and the Indiana University Institutional Review Board (IRB). Subjects were recruited from patients undergoing clinical imaging with ¹¹C-acetate (Expanded Access IND 118,204) due to suspected recurrence of prostate cancer that had previously been treated with surgery or radiation therapy (*i.e.*, all subjects were prostate cancer patients presenting with "biochemical failure"). All subjects provided written informed consent prior to

administration of the [⁶⁸Ga]Ga-HBED-CC radiopharmaceutical. The interval between [¹¹C]acetate and [⁶⁸Ga]Ga-HBED-CC PET/CT imaging averaged 21 ± 25 days (median 20 days; range 0-83 days). The reported serum PSA levels (Supplemental Data) were the most recent clinical values at the time of ⁶⁸Ga imaging, obtained an average of 61 ± 41 days prior to the [⁶⁸Ga]Ga-HBED-CC study (median 42 days; range 33-157 days).

Radiochemistry

The HBED-CC (PSMA-11) conjugate was purchased from ABX GmbH as commercial cGMP-grade product packaged at 10-µg per vial. The [⁶⁸Ga]Ga-HBED-CC (PSMA-11) radiopharmaceutical was prepared using ⁶⁸Ga from ITG Isotope Technologies Garching GmbH ⁶⁸Ge/⁶⁸Ga generators (30-mCi; 1.11 GBq). Briefly, the 4.0-mL 0.05M ultrapure HCl generator eluate was buffered to pH ~4.8 by addition of ultrapure NaOAc and reacted with the HBED-CC conjugate (10-µg) with heating at ~95°C for 5-minutes employing ITG's manually controlled iQS[®] Ga-68 Fluidic Labeling Module [5-8]. The complete synthetic protocol was as we have described for [⁶⁸Ga]Ga-DOTA-NOC, with the exceptions of using only a 5-minute reaction time, and the substitution of HBED-CC (PSMA-11) for DOTA-NOC [5]. Pre-release product quality control procedures included: half-life measurement for confirmation of radionuclidic identity; pH measurement; ITLC assessment of radiochemical purity; endotoxin testing; and a bubble point measurement to confirm the integrity of the single-use sterile 0.2-µm filter employed for terminal product sterilization. The ITLC determination of radiochemical purity employed ITLC-SG strips developed with 1:1 MeOH:1M NH₄OAc to quantify colloidal ⁶⁸Ga-hydroxide plus ionic ⁶⁸Ga, both of which remain at or near the origin while the [⁶⁸Ga]Ga-HBED-CC product migrates near the solvent front. Retrospective analysis of each production batch

included sterility testing, and measurement of ^{68}Ge breakthrough levels in the final product [5].

PET/CT Imaging and Image Analysis

Imaging was performed using a Siemens mCT extended FOV time-of-flight PET/CT (128 slice) camera. Following a low-dose pelvis-to-head CT scan for attenuation correction, the radiopharmaceutical was administered intravenously with the patient's pelvis in the PET field-of-view for a list-mode acquisition from 0-10 minutes, followed by a whole-body (pelvis to head) PET acquisition starting at 15-minutes post-injection. An image of the pelvis was again collected at 40-minutes, then the patient removed from the camera and urine collected. The patient then returned to the PET/CT camera for a second low-dose (attenuation correction only) CT scan, followed by whole-body (pelvis-to-head) PET acquisitions at 60-minutes and 90-minutes, with a final PET image of the pelvis collected at 115 minutes. Again the patient was removed from the camera and directed to void his bladder with collection of the excreted urine. The volume of the collected urine samples was measured, and the excreted radioactivity quantified by dose calibrator assay of a 20-mL sample. PET images were reconstructed using both filtered back-projection (FBP), and a standard clinical iterative algorithm, (3 iterations and 21 subsets); 3-D volumes-of-interest were drawn for the tissues of interest using the MIM PET Edge (v6.5) software package, and corresponding SUV_{mean} values extracted for calculation of radiopharmaceutical biodistribution as a percentage of the injected dose per tissue. Iterative vs. FBP reconstruction provided comparable SUV_{mean} values; the reported results (Table 1) are from the iterative reconstructions.

Radiation dosimetry estimates (Table 2) were obtained from the PET/CT biodistribution data (Table 1) using the OLINDA software package (Organ level Internal Dose

Assessment Code, Vanderbilt University, 2003). For these dose estimates, it was assumed that the urinary bladder was completely voided at 120-minutes post-injection, and that over the first 120-minutes the bladder contained the cumulative measured urine levels of radioactivity without intermediate voiding. The remaining unspecified radioactivity was assumed to be uniformly distributed in the remaining body volume.

Results and Discussion

The [⁶⁸Ga]Ga-HBED-CC (PSMA-11) radiopharmaceutical has been shown to be useful in the detection of tumor recurrence in prostate cancer patients previously treated with prostatectomy or radiation therapy [1,2], with lesion detectability appearing to be better than we can achieve with [¹¹C]acetate PET/CT. [⁶⁸Ga]Ga-HBED-CC (PSMA-11) has a relatively low molecular weight (1014 g/mole), and targets the cell surface prostate-specific membrane antigen (PSMA) with the urea fragment of the Glu-urea-Lys(Ahx)-HBED-CC conjugate [9]. The ⁶⁸Ga³⁺ ion is bound with high affinity in an octahedral N₂O₄ coordination sphere by the two phenolate O, two amino-acetate carboxylate O, and the two amino N donor atoms of the HBED chelator [9-12].

Radiochemical purity of the [⁶⁸Ga]Ga-HBED-CC (PSMA-11) averaged 98.9 ± 0.5% (*n* = 9), with ⁶⁸Ge breakthrough levels in the final product averaging 8.5 × 10⁻⁶ ± 7.9 × 10⁻⁶% (calculated for the time of dose expiration). Synthesis time, beginning-of-elution to dose release, averaged 42 ± 1 minutes. Patients reported no symptoms, nor exhibited any adverse reactions, following radiopharmaceutical administration (3.04 ± 0.09 mCi, 112.5 ± 3.3 MBq). The administered mass of the HBED-CC (PSMA-11) ligand averaged 3.2 ±

0.4 μg , assuming all the HBED-CC (PSMA-11) in the reaction mixture remained present in the final product solution.

The PET/CT biodistribution findings for [^{68}Ga]Ga-HBED-CC are shown in Table 1, with a patient-by-patient tabulation provided in the Supplemental Data. Observed SUV_{mean} values at 60-minutes for kidneys, liver, spleen, and parotids (30.1 ± 6.6 ; 3.3 ± 0.6 ; 5.2 ± 2.5 ; and 9.4 ± 2.0 , respectively) are in general agreement with the SUV values of 31.7; 5.1; 7.2; and 12.9 reported by Dietlein, *et al.* [13].

Radiation dosimetry estimates, calculated from the Table 1 data using the OLINDA software package, are shown in Table 2. The kidneys are the critical organ, with an absorbed dose of 0.413 mGy/MBq (1.53 Rad/mCi). The total body dose is estimated to be 0.0143 mGy/MBq (0.0529 Rad/mCi), with an effective dose equivalent of 0.044 mSv/MBq (0.163 Rad/mCi). Afshar-Oromich, *et al.* [3] similarly conclude that the kidneys are the critical organ, arriving at an estimated renal dose of 0.26 mGy/MBq in their study of four subjects that included additional renal clearance data between 2 and 5 hours. Differences in administered mass of PSMA-11 may also result in some changes in renal retention of the radiotracer, but are not possible to directly compare from the published data [3]. Pfoh, *et al.* [4], report a renal adsorbed dose of only 0.121 mGy/MBq, but those data are not directly comparable, since that study was performed with concurrent administration of furosemide at an unspecified dose to promote urine production and urinary clearance.

Comparison of images obtained with [^{68}Ga]Ga-HBED-CC and ^{11}C -acetate demonstrated enhanced ^{68}Ga identification of lymph nodes and skeletal lesions suspicious for metastatic recurrent prostate cancer, supporting clinical use of [^{68}Ga]Ga-HBED-CC

(PSMA-11) as an alternative to [¹¹C]acetate in assessment of prostate cancer patients presenting with biochemical failure. As examples, Figures 1 and 2 illustrate these findings in two of the subjects. While this comparison was not the study objective, and the sample size is small, our results favor clinical use of [⁶⁸Ga]Ga-HBED-CC (PSMA-11) over [¹¹C]acetate, as would be expected based on the reported clinical experience with [⁶⁸Ga]Ga-HBED-CC (PSMA-11) [1,2].

Conclusions

Radiation dosimetry estimates were calculated for [⁶⁸Ga]Ga-HBED-CC (PSMA-11) from nine prostate cancer patients in whom clinical [¹¹C]acetate PET/CT exams had been previously performed under Expanded Access IND118,204. Kidneys are the critical organ following [⁶⁸Ga]Ga-HBED-CC (PSMA-11) administration, receiving an estimated dose of 0.413 mGy/MBq.

Disclosure

The authors have no conflicts-of-interest or relevant financial activities to disclose.

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Supplemental Data

A patient-by-patient tabulation of the biodistribution findings, and complete OLINDA output, is available in the online publication.

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Table 1. Observed Biodistribution of ^{68}Ga Following Intravenous Administration of ^{68}Ga -HBED-CC (PSMA-11) (3.04 ± 0.09 mCi, 112.5 ± 3.3 MBq; Injected HBED-CC = 3.2 ± 0.4 μg) to Adult Males (95.8 ± 20.3 kg) Previously Treated for Prostate Cancer and Presenting with Biochemical Failure (average serum PSA value of 2.3 ± 3.8 ng/mL; range 0.16 – 11.3 ng/mL; median 0.52 ng/mL).

	Tissue Uptake of ^{68}Ga as a Percentage of Injected Dose (\pm Std. Dev.; $n = 9$)						
	15 Minutes	40 Minutes	48 Minutes	60 Minutes	90 Minutes	115 Minutes	120 Minutes
Lacrimal Glands (L + R)	0.0090 \pm 0.0044			0.0066 \pm 0.0050	0.0075 \pm 0.0049		
Parotid Glands (L + R)	0.79 \pm 0.26			0.87 \pm 0.30	0.92 \pm 0.35		
Submandibular Glands (L + R)	0.25 \pm 0.15			0.29 \pm 0.19	0.30 \pm 0.19		
Liver	9.24 \pm 2.14			6.54 \pm 1.43	5.98 \pm 1.39		
Kidneys (L + R)	11.23 \pm 2.20			14.02 \pm 3.73	14.21 \pm 4.54		
Spleen	1.64 \pm 0.80			1.25 \pm 0.63	1.06 \pm 0.55		
Pancreas	0.12 \pm 0.07			0.091 \pm 0.064	0.086 \pm 0.063		
Urinary bladder	0.85 \pm 0.36	2.84 \pm 1.04		1.22 \pm 0.49	2.97 \pm 1.32	6.53 \pm 1.83	
Voided Urine			4.18 \pm 1.68				9.43 \pm 2.55

Table 2. Radiation Dosimetry Estimates* for [⁶⁸Ga]Ga-HBED-CC (PSMA-11)

Target Organ	Organ Doses (rem/mCi)	Organ Doses (mSv/MBq)
Adrenals	6.42E-02	1.74E-02
Brain	3.72E-02	1.01E-02
Breasts	3.74E-02	1.01E-02
Gallbladder Wall	6.06E-02	1.64E-02
LLI Wall	4.70E-02	1.27E-02
Small Intestine	5.07E-02	1.37E-02
Stomach Wall	5.05E-02	1.37E-02
ULI Wall	5.04E-02	1.36E-02
Heart Wall	4.60E-02	1.24E-02
Kidneys	1.53E+00	4.13E-01
Liver	1.46E-01	3.95E-02
Lungs	4.29E-02	1.16E-02
Muscle	4.29E-02	1.16E-02
Pancreas	7.35E-02	1.99E-02
Red Marrow	3.80E-02	1.03E-02
Osteogenic Cells	5.06E-02	1.37E-02
Skin	3.67E-02	9.93E-03
Spleen	2.15E-01	5.81E-02
Testes	4.07E-02	1.10E-02
Thymus	4.13E-02	1.12E-02
Thyroid	4.04E-02	1.09E-02
Urinary Bladder Wall	2.48E-01	6.71E-02
Total Body	5.29E-02	1.43E-02
Effective Dose Equivalent	1.63E-01	4.40E-02
Effective Dose	9.53E-02	2.58E-02

*Calculated with OLINDA using the biodistribution data for the nine male subjects reported in Table 1, assuming no voiding of the urinary bladder until 2-hours post-injection.

Figure 1. Example of PET images (right) and fused PET/CT images (left) obtained with ^{68}Ga -HBED-CC (PSMA-11) (top) and ^{11}C -acetate (bottom). The ^{11}C acetate image was obtained 48-days prior to ^{68}Ga imaging. Serum PSA was 1.7 ng/mL at the time of the acetate study. The red arrows indicates PSMA-avid retroperitoneal lymph nodes that are not acetate-avid (yellow arrows). The acetate PET image was reconstructed from data collected at 10 minutes post-injection. The ^{68}Ga image was reconstructed from data collected at 15 minutes post-injection. Lymph node uptake in the ^{68}Ga -images showed slight increase with time (SUV_{mean} values of 6.0, 7.8, and 8.8 (lymph node A) and 5.3, 7.3 and 9.6 (lymph node B) in images collected at 15, 60, and 90-minutes post-injection, respectively).

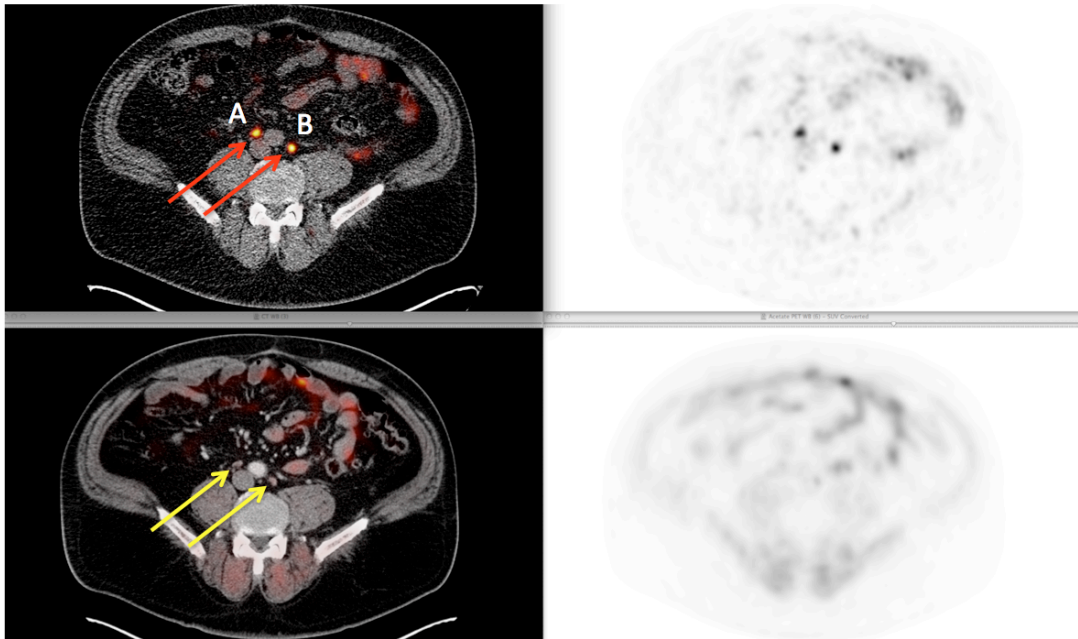
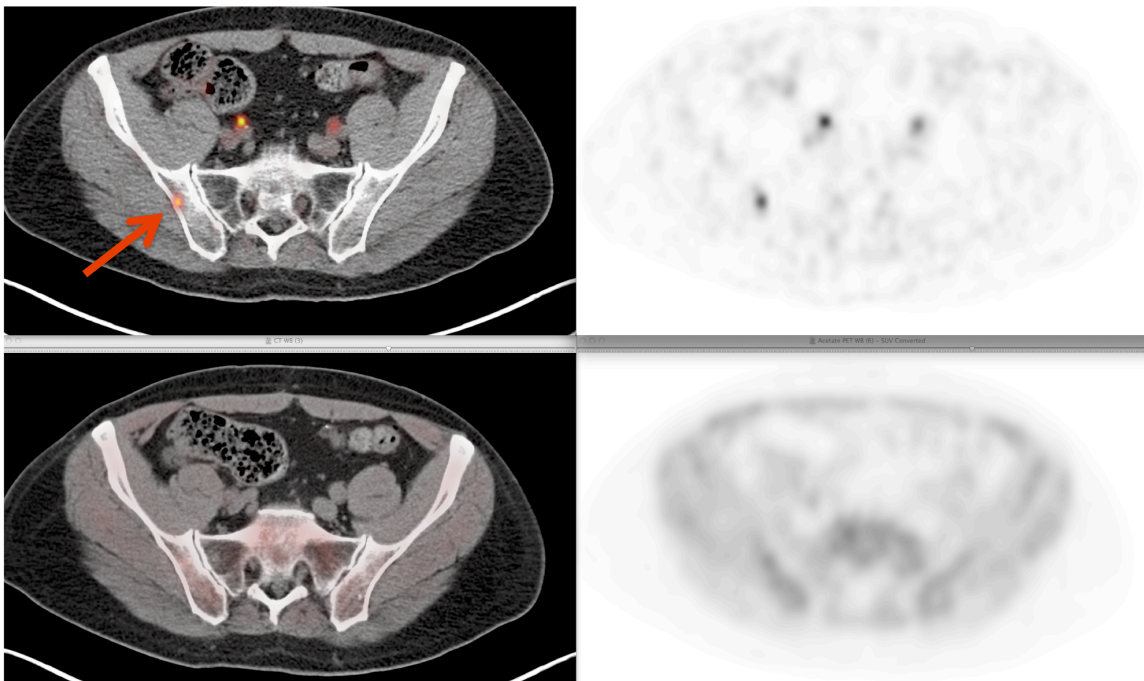


Figure 2. Additional example of PET images (right) and fused PET/CT images (left) obtained with ^{68}Ga -HBED-CC (PSMA-11) (top) and ^{11}C -acetate (bottom). The ^{11}C acetate image was obtained 23-days prior to ^{68}Ga imaging. Serum PSA was 11.1 ng/mL at the time of the acetate study. Red arrow indicates PSMA-avid bone metastasis in right ilium that was not seen on the ^{11}C -acetate exam. Ureters are noted on the PSMA study. The acetate image was reconstructed from data collected at 10 minutes post-injection, and the ^{68}Ga image reconstructed from data collected at 15 minutes post-injection. Tumor uptake in the ^{68}Ga -images was again relatively invariant with time (SUV_{mean} values of 3.5, 3.7, 3.9, 2.4, 1.8, 1.7, 1.7 and 2.2 in images collected at 0-3, 4-6, 7-9, 15, 40, 60, 90, and 115-minutes post-injection, respectively).



Observed Distribution of ⁶⁸Ga by PET/CT Following Intravenous Administration of ⁶⁸Ga-HBED-CC (PSMA-11) (% Injected Dose per Organ or Tissue)

	Time Post-Injection (min)	Patient 1	Patient 2	Patient 3	Patient 4	Patient 5	Patient 6	Patient 7	Patient 8	Patient 9	Mean	Std Dev
Injected Dose (mCi)		3.18	3.12	2.94	2.95	2.94	3.06	3.01	3.07	3.13	3.04	0.09
Injected HBED-CC (µg)		2.82	3.45	3.36	3	3.09	3.27	3.55	3.73	2.36	3.18	0.42
Serum PSA (ng/mL)		0.3	0.3	0.52	1.7	11.3	5.5	0.33	0.16	0.65	2.31	3.77
Patient Body Mass (kg)		97.7	106.1	118	122.6	70.05	81.65	112.49	68.94	84.5	95.78	20.35
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R lacrimal	15	0.001	0.003	0.007	0.006	0.006	0.003	0.008	0.002	0.005	0.005	0.002
L lacrimal	15	0.002	0.001	0.005	0.007	0.005	0.004	0.007	0.002	0.005	0.004	0.002
TOTAL Lacrimal	15	0.003	0.004	0.012	0.013	0.011	0.007	0.015	0.005	0.011	0.0090	0.0044
R parotid	15	0.400	0.264	0.422	0.707	0.297	0.636	0.298	0.217	0.292	0.39	0.17
L parotid	15	0.343	0.298	0.477	0.564	0.240	0.478	0.377	0.390	0.404	0.40	0.10
TOTAL Parotid	15	0.743	0.562	0.899	1.271	0.537	1.115	0.675	0.607	0.696	0.79	0.26
R submandibular	15	0.090	0.256	0.089	0.223	0.103	0.104	0.177	0.000	0.080	0.12	0.08
L submandibular	15	0.088	0.204	0.085	0.226	0.132	0.088	0.215	0.024	0.099	0.13	0.07
TOTAL Submandibular	15	0.178	0.460	0.174	0.449	0.235	0.191	0.392	0.024	0.179	0.25	0.15
Liver	15	10.045	9.431	7.729	8.382	7.854	13.670	6.116	9.372	10.544	9.24	2.14
R kidney	15	5.611	5.626	4.561	3.808	6.361	5.539	6.023	7.109	6.505	5.68	1.01
L kidney	15	5.388	6.090	3.821	3.684	6.104	4.939	5.843	7.066	7.028	5.55	1.23
TOTAL Kidney	15	11.000	11.716	8.381	7.491	12.465	10.478	11.866	14.175	13.533	11.23	2.20
Spleen	15	0.744	1.395	1.265	1.255	2.641	2.579	2.064	2.331	0.457	1.64	0.80
Pancreas	15	0.203	0.260	0.041	0.081	0.088	0.145	0.084	0.094	0.046	0.12	0.07
Urinary bladder	15	0.857	0.746	0.844	1.320	1.120	0.463	1.390	0.572	0.375	0.85	0.36
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R lacrimal	60	0.001	0.002	0.003	0.001	0.007	0.003	0.008	0.003	0.001	0.003	0.003
L lacrimal	60	0.001	0.002	0.001	0.002	0.007	0.005	0.008	0.002	0.001	0.003	0.002
TOTAL Lacrimal	60	0.002	0.004	0.004	0.003	0.014	0.008	0.016	0.006	0.002	0.0066	0.0050
R parotid	60	0.414	0.274	0.403	0.764	0.361	0.756	0.331	0.276	0.244	0.42	0.20
L parotid	60	0.298	0.407	0.493	0.689	0.285	0.544	0.517	0.346	0.456	0.45	0.13
TOTAL Parotid	60	0.712	0.682	0.896	1.453	0.646	1.300	0.848	0.622	0.700	0.87	0.30
R submandibular	60	0.099	0.293	0.079	0.243	0.120	0.118	0.240	0.000	0.070	0.14	0.10
L submandibular	60	0.073	0.232	0.089	0.264	0.167	0.104	0.282	0.021	0.101	0.15	0.09
TOTAL Submandibular	60	0.173	0.525	0.168	0.507	0.288	0.222	0.523	0.021	0.171	0.29	0.19
Liver	60	6.914	5.992	5.999	6.320	5.920	7.876	3.695	7.584	8.598	6.54	1.43
R kidney	60	7.094	6.837	5.441	4.376	7.704	7.400	6.155	10.116	9.401	7.17	1.80
L kidney	60	6.820	7.552	4.238	4.106	7.322	6.694	5.849	9.754	9.350	6.85	1.96
TOTAL Kidney	60	13.914	14.390	9.679	8.482	15.027	14.094	12.003	19.870	18.751	14.02	3.73
Spleen	60	0.517	1.014	1.000	1.043	2.097	1.741	1.509	1.999	0.321	1.25	0.63
Pancreas	60	0.217	0.165	0.027	0.062	0.064	0.108	0.026	0.097	0.050	0.091	0.064
Urinary bladder	60	1.396	1.464	0.780	1.464	2.206	0.892	1.312	0.758	0.662	1.22	0.49
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R lacrimal	90	0.001	0.002	0.001	0.002	0.006	0.004	0.009	0.004	0.005	0.004	0.0025
L lacrimal	90	0.002	0.001	0.001	0.004	0.006	0.005	0.009	0.002	0.005	0.004	0.0025
TOTAL Lacrimal	90	0.003	0.003	0.002	0.006	0.012	0.008	0.017	0.006	0.011	0.008	0.005
R parotid	90	0.425	0.326	0.428	0.923	0.371	0.789	0.331	0.292	0.300	0.46	0.23
L parotid	90	0.313	0.389	0.387	0.732	0.280	0.588	0.544	0.336	0.524	0.45	0.15
TOTAL Parotid	90	0.738	0.715	0.815	1.655	0.651	1.377	0.875	0.628	0.824	0.92	0.35
R submandibular	90	0.102	0.305	0.072	0.271	0.114	0.129	0.251	0.001	0.080	0.15	0.10
L submandibular	90	0.095	0.199	0.077	0.275	0.167	0.107	0.306	0.020	0.111	0.15	0.09
TOTAL Submandibular	90	0.197	0.503	0.148	0.546	0.281	0.236	0.557	0.020	0.191	0.30	0.19
Liver	90	6.208	5.369	5.686	5.588	5.506	6.619	3.384	6.947	8.524	5.98	1.39
R kidney	90	7.098	6.773	5.439	4.114	7.581	7.265	5.572	10.905	10.235	7.22	2.20
L kidney	90	6.949	7.459	4.052	3.909	7.224	7.035	5.339	10.668	10.234	6.99	2.38
TOTAL Kidney	90	14.047	14.232	9.491	8.023	14.805	14.300	10.911	21.574	20.468	14.21	4.54
Spleen	90	0.422	0.857	0.802	0.885	1.860	1.402	1.357	1.709	0.282	1.06	0.55
Pancreas	90	0.217	0.142	0.024	0.052	0.057	0.092	0.023	0.112	0.054	0.086	0.063
Urinary bladder	90	3.083	4.362	1.097	2.003	4.811	3.058	4.383	1.773	2.120	2.97	1.32
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Urinary Bladder	40	2.49	2.77	3.64	3.59	3.53	2.11	4.43	1.17	1.83	2.84	1.04
Urinary Bladder	115	8.12	7.16	6.15	5.82	7.81	4.78	8.80	2.92	7.20	6.53	1.83
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Voided Urine	48	4.7	4.4	5.5	5.2	5.4	2.1	6.2	1.5	2.6	4.18	1.68
Voided Urine	120	10.6	10.5	11.1	9	10.6	6.4	12.5	4.3	9.9	9.43	2.55

OLINDA – Organ Level INTERNAL Dose Assessment Code (copyright Vanderbilt University, 2003)

NOTE: This code gives doses for stylized models of average individuals – results should be applied with caution to specific human subjects.

NOTE: Users should always carefully check input data (shown below) and critically review the reported results.

Organ Doses (mSv/MBq), Nuclide: Ga-68 (6.76E01 min), Adult Male

Target Organ	Alpha	Beta	Photon	Total	EDE Cont.	ED Cont.
Adrenals	0.00E000	7.18E-03	1.02E-02	1.74E-02	0.00E000	4.34E-05
Brain	0.00E000	7.18E-03	2.88E-03	1.01E-02	0.00E000	2.52E-05
Breasts	0.00E000	7.18E-03	2.94E-03	1.01E-02	1.52E-03	5.06E-04
Gallbladder Wall	0.00E000	7.18E-03	9.20E-03	1.64E-02	0.00E000	0.00E000
LLI Wall	0.00E000	7.18E-03	5.52E-03	1.27E-02	0.00E000	1.52E-03
Small Intestine	0.00E000	7.18E-03	6.52E-03	1.37E-02	0.00E000	3.42E-05
Stomach Wall	0.00E000	7.18E-03	6.48E-03	1.37E-02	0.00E000	1.64E-03
ULI Wall	0.00E000	7.18E-03	6.44E-03	1.36E-02	0.00E000	3.41E-05
Heart Wall	0.00E000	7.18E-03	5.26E-03	1.24E-02	0.00E000	0.00E000
Kidneys	0.00E000	3.72E-01	4.04E-02	4.13E-01	2.48E-02	1.03E-02
Liver	0.00E000	2.91E-02	1.05E-02	3.95E-02	2.37E-03	1.98E-03
Lungs	0.00E000	7.18E-03	4.42E-03	1.16E-02	1.39E-03	1.39E-03
Muscle	0.00E000	7.18E-03	4.42E-03	1.16E-02	0.00E000	2.90E-05
Ovaries	0.00E000	7.18E-03	5.86E-03	1.30E-02	3.26E-03	2.61E-03
Pancreas	0.00E000	1.04E-02	9.49E-03	1.99E-02	1.19E-03	4.97E-05
Red Marrow	0.00E000	4.91E-03	5.35E-03	1.03E-02	1.23E-03	1.23E-03
Osteogenic Cells	0.00E000	8.82E-03	4.86E-03	1.37E-02	4.10E-04	1.37E-04
Skin	0.00E000	7.18E-03	2.75E-03	9.93E-03	0.00E000	9.93E-05
Spleen	0.00E000	4.55E-02	1.26E-02	5.81E-02	3.49E-03	1.45E-04
Testes	0.00E000	7.18E-03	3.82E-03	1.10E-02	0.00E000	0.00E000
Thymus	0.00E000	7.18E-03	3.99E-03	1.12E-02	0.00E000	2.79E-05
Thyroid	0.00E000	7.18E-03	3.73E-03	1.09E-02	3.27E-04	5.46E-04
Urinary Bladder Wall	0.00E000	5.63E-02	1.08E-02	6.71E-02	4.03E-03	3.35E-03
Uterus	0.00E000	7.18E-03	6.60E-03	1.38E-02	0.00E000	3.45E-05
Total Body	0.00E000	9.64E-03	4.65E-03	1.43E-02	0.00E000	0.00E000
Effective Dose Equivalent (mSv/MBq)					4.40E-02	
Effective Dose (mSv/MBq)						2.58E-02

Organ Doses (rem/mCi), Nuclide: Ga-68 (6.76E01 min), Adult Male

Target Organ	Alpha	Beta	Photon	Total	EDE Cont.	ED Cont.
Adrenals	0.00E000	2.66E-02	3.76E-02	6.42E-02	0.00E000	1.61E-04
Brain	0.00E000	2.66E-02	1.07E-02	3.72E-02	0.00E000	9.31E-05
Breasts	0.00E000	2.66E-02	1.09E-02	3.74E-02	5.62E-03	1.87E-03
Gallbladder Wall	0.00E000	2.66E-02	3.41E-02	6.06E-02	0.00E000	0.00E000
LLI Wall	0.00E000	2.66E-02	2.04E-02	4.70E-02	0.00E000	5.64E-03
Small Intestine	0.00E000	2.66E-02	2.41E-02	5.07E-02	0.00E000	1.27E-04
Stomach Wall	0.00E000	2.66E-02	2.40E-02	5.05E-02	0.00E000	6.06E-03
ULI Wall	0.00E000	2.66E-02	2.38E-02	5.04E-02	0.00E000	1.26E-04
Heart Wall	0.00E000	2.66E-02	1.95E-02	4.60E-02	0.00E000	0.00E000
Kidneys	0.00E000	1.38E000	1.50E-01	1.53E000	9.16E-02	3.82E-02
Liver	0.00E000	1.07E-01	3.87E-02	1.46E-01	8.77E-03	7.31E-03
Lungs	0.00E000	2.66E-02	1.63E-02	4.29E-02	5.15E-03	5.15E-03
Muscle	0.00E000	2.66E-02	1.63E-02	4.29E-02	0.00E000	1.07E-04
Ovaries	0.00E000	2.66E-02	2.17E-02	4.82E-02	1.21E-02	9.65E-03
Pancreas	0.00E000	3.84E-02	3.51E-02	7.35E-02	4.41E-03	1.84E-04
Red Marrow	0.00E000	1.82E-02	1.98E-02	3.80E-02	4.56E-03	4.56E-03
Osteogenic Cells	0.00E000	3.26E-02	1.80E-02	5.06E-02	1.52E-03	5.06E-04
Skin	0.00E000	2.66E-02	1.02E-02	3.67E-02	0.00E000	3.67E-04
Spleen	0.00E000	1.68E-01	4.66E-02	2.15E-01	1.29E-02	5.38E-04
Testes	0.00E000	2.66E-02	1.41E-02	4.07E-02	0.00E000	0.00E000
Thymus	0.00E000	2.66E-02	1.48E-02	4.13E-02	0.00E000	1.03E-04
Thyroid	0.00E000	2.66E-02	1.38E-02	4.04E-02	1.21E-03	2.02E-03
Urinary Bladder Wall	0.00E000	2.08E-01	3.98E-02	2.48E-01	1.49E-02	1.24E-02
Uterus	0.00E000	2.66E-02	2.44E-02	5.10E-02	0.00E000	1.27E-04
Total Body	0.00E000	3.57E-02	1.72E-02	5.29E-02	0.00E000	0.00E000
Effective Dose Equivalent (rem/mCi)					1.63E-01	
Effective Dose (rem/mCi)						9.53E-02

Number of Disintegrations in Source Organs:

Adrenals	0.00E000	MBq-h/MBq or uCi-h/uCi
Brain	0.00E000	MBq-h/MBq or uCi-h/uCi
Breasts	0.00E000	MBq-h/MBq or uCi-h/uCi
Gallbladder Contents	0.00E000	MBq-h/MBq or uCi-h/uCi
LLI	0.00E000	MBq-h/MBq or uCi-h/uCi
Small Intestine	0.00E000	MBq-h/MBq or uCi-h/uCi
Stomach	0.00E000	MBq-h/MBq or uCi-h/uCi
ULI	0.00E000	MBq-h/MBq or uCi-h/uCi
Heart Contents	0.00E000	MBq-h/MBq or uCi-h/uCi
Heart Wall	0.00E000	MBq-h/MBq or uCi-h/uCi
Kidneys	2.66E-01	MBq-h/MBq or uCi-h/uCi
Liver	1.30E-01	MBq-h/MBq or uCi-h/uCi
Lungs	0.00E000	MBq-h/MBq or uCi-h/uCi
Muscle	0.00E000	MBq-h/MBq or uCi-h/uCi
Ovaries	0.00E000	MBq-h/MBq or uCi-h/uCi
Pancreas	2.36E-03	MBq-h/MBq or uCi-h/uCi
Red Marrow	0.00E000	MBq-h/MBq or uCi-h/uCi
Cortical Bone	0.00E000	MBq-h/MBq or uCi-h/uCi
Trabecular Bone	0.00E000	MBq-h/MBq or uCi-h/uCi
Spleen	2.00E-02	MBq-h/MBq or uCi-h/uCi
Testes	0.00E000	MBq-h/MBq or uCi-h/uCi
Thymus	0.00E000	MBq-h/MBq or uCi-h/uCi
Thyroid	0.00E000	MBq-h/MBq or uCi-h/uCi
Urinary Bladder Contents	4.86E-02	MBq-h/MBq or uCi-h/uCi
Uterus/Uterine Wall	0.00E000	MBq-h/MBq or uCi-h/uCi
Remainder	1.24E000	MBq-h/MBq or uCi-h/uCi

Target Organ Masses:

Adrenals	1.63E001 g
Brain	1.42E003 g
Breasts	3.51E002 g
Gallbladder Wall	1.05E001 g
LLI Wall	1.67E002 g
Small Intestine	6.77E002 g
Stomach Wall	1.58E002 g
ULI Wall	2.20E002 g
Heart Wall	3.16E002 g
Kidneys	2.99E002 g
Liver	1.91E003 g
Lungs	1.00E003 g
Muscle	2.80E004 g
Ovaries	8.71E000 g
Pancreas	9.43E001 g
Red Marrow	1.12E003 g
Osteogenic Cells	1.20E002 g
Skin	3.01E003 g
Spleen	1.83E002 g
Testes	3.91E001 g
Thymus	2.09E001 g
Thyroid	2.07E001 g
Urinary Bladder Wall	4.76E001 g
Uterus	7.90E001 g
Total Body	7.37E004 g

* Mass modified by user

Radiation Weighting Factors:

Alpha:	5.00E00
Beta:	1.00E00
Photon:	1.00E00

** Weighting factor modified by user