

EFFECTIVE DOSE AND EFFECTIVE DOSE EQUIVALENT IN NUCLEAR MEDICINE

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INTRODUCTION

For years many physicians and physicists have employed the concept of "total body dose" or "whole body dose," i.e., the total energy deposited in the body divided by the total mass of the body, in evaluating the risks of different nuclear medicine procedures. Although this concept may be considered useful for comparing doses received from different procedures, it does not take into account the typical non-uniformity in dose distribution among the several body organs. The effective dose equivalent (H_E), first described in ICRP Publication 26 (1), has been accepted by some as a better quantity to use in evaluating the total risk of a procedure, but its use has been criticized by others primarily because the tissue weighting factors were intended for use with the population of radiation workers, rather than of nuclear medicine patients (2). Nevertheless, the ICRP has suggested in Publication 52 (3) that the H_E may be used in nuclear medicine, and provided in Publication 53 (4) a compendium of dose estimates, including H_E values, for various nuclear medicine procedures undergone at various ages. The effective dose (E) of ICRP Publication 60 (5) is perhaps more suitable for use in nuclear medicine, with tissue weighting factors based on the entire population.

METHODS

Comparisons of H_E and E have previously been published (6). We have used the program MIRDOSE 3.1 to compute total body dose, H_E and E in the adult male and adult (nonpregnant) female for 62 radiopharmaceutical procedures, involving 19 different radionuclides, based on the best current biokinetic data available. The improvements in this latest version of MIRDOSE include mathematical phantoms for the pregnant female at 3-, 6-, and 9-months gestation, and a new model for bone and marrow dosimetry based on the work of Eckerman (7).

RESULTS

The computed values of total body dose, H_E and E are listed in Table 1, for both the adult male and adult female phantoms in MIRDOSE 3.1. As found by Johansson et al. (6), the average ratio of E to H_E is about 0.8, with a relatively narrow spread from 0.48 to 1.77. The ratio of E to total body dose, however, ranges from 1.1 to almost 100. All ratios greater than 10 occur for the iodines; the values for Tc-99m agents fall between 1.4 and 6.9. In view of the non-uniform distributions of most radiopharmaceuticals, we believe that the total body dose is not a useful quantity for evaluating risks, and should be replaced by the quantity effective dose, or the effective dose equivalent, as an interim method in those countries that have not as yet adopted the ICRP 60 (5) methodology.

REFERENCES

1. ICRP Publication 26, Annals ICRP 1 (3), 1-53 (1977).
2. J. W. Poston, *J. Nucl. Med* 34 (4), 714 (1993).
3. ICRP Publication 52, Annals ICRP 17 (4), 1-37 (1987).
4. ICRP Publication 53, Annals ICRP 18 (1-4), 1-377 (1987).
5. ICRP Publication 60, Annals ICRP 21 (1-3), 1-201 (1991).
6. L. Johansson et al., Proc. 5th Internat. Radiopharm. Dosimetry Symp., Oak Ridge, TN (1992).
7. K. Eckerman, Proc. 4th Internat. Radiopharm. Dosimetry Symp., Oak Ridge, TN (1986).

Table 1. Total body dose, effective dose equivalent (H_E) and effective dose (E) (mSv/MBq), and ratios for several radiopharmaceuticals.

Pharmaceutical	DOSES			RATIOS								
	FEMALES		MALES	FEMALES		MALES						
	Total Body	H_E	E	Total Body	H_E	E	H_E/TB	E/TB	E/H_E	H_E/TB	E/TB	E/H_E
Au-198 colloid	4.58E-01	1.72E+00	1.16E+00	3.59E-01	1.38E+00	9.14E-01	3.76	2.53	0.67	3.84	2.55	0.66
C-111 Tryptophane	3.60E-04	5.92E-04	5.03E-04	2.87E-03	5.16E-03	4.32E-03	1.64	1.40	0.85	1.80	1.51	0.84
C-111 Iomazenil	2.79E-03	1.54E-02	1.39E-02	2.20E-03	1.19E-02	1.06E-02	5.52	4.98	0.90	5.41	4.82	0.89
Co-57 B-12, Normal	1.91E+00	3.73E+00	2.90E+00	1.53E+00	2.94E+00	2.25E+00	1.95	1.52	0.78	1.92	1.47	0.77
Co-57 B-12, PA	2.68E-01	6.18E-01	5.99E-01	2.15E-01	5.00E-01	4.90E-01	2.31	2.24	0.97	2.33	2.28	0.98
Co-58 B-12, Normal	3.66E+00	7.08E+00	5.45E+00	2.96E+00	5.70E+00	4.35E+00	1.93	1.49	0.77	1.93	1.47	0.76
Co-58 B-12, PA	6.08E-01	1.61E+00	1.59E+00	4.93E-01	1.30E+00	1.30E+00	2.65	2.62	0.99	2.64	2.64	1.00
Co-60 B-12, Normal	5.61E+01	1.08E+02	8.01E+01	4.56E+01	8.67E+01	6.39E+01	1.93	1.43	0.74	1.90	1.40	0.74
Co-60 B-12, PA	7.49E+00	1.48E+01	1.24E+01	6.08E+00	1.19E+01	1.00E+01	1.98	1.66	0.84	1.96	1.64	0.84
F-18 FDG	1.51E-02	3.81E-02	3.10E-02	1.20E-02	2.98E-02	2.41E-02	2.52	2.05	0.81	2.48	2.01	0.81
F-18 Sodium Fluoride	1.10E-02	3.56E-02	3.10E-02	8.75E-03	2.70E-02	2.31E-02	3.24	2.82	0.87	3.09	2.64	0.86
Ga-67 Citrate	8.23E-02	1.23E-01	1.20E-01	6.62E-02	1.03E-01	1.00E-01	1.49	1.46	0.98	1.56	1.51	0.97
Hg-197 Chlormerodrin	3.84E-02	2.05E-01	1.13E-01	3.00E-02	1.81E-01	9.66E-02	5.34	2.94	0.55	6.03	3.22	0.53
I-123 Hippuran	3.52E-03	3.39E-02	2.90E-02	2.70E-03	2.38E-02	2.01E-02	9.63	8.24	0.86	8.81	7.44	0.84
I-123 IMP	1.43E-02	2.44E-02	2.34E-02	1.15E-02	1.91E-02	1.82E-02	1.71	1.64	0.96	1.66	1.58	0.95
I-123 mIBG	1.14E-02	2.56E-02	2.21E-02	9.12E-03	1.93E-02	1.66E-02	2.25	1.94	0.86	2.12	1.82	0.86
I-123 Sodium Iodide	9.72E-03	1.47E-01	2.43E-01	8.03E-03	1.20E-01	2.00E-01	15.1	25.0	1.65	14.9	24.9	1.67
I-125 HSA	2.61E-01	3.89E-01	2.91E-01	2.07E-01	3.07E-01	2.29E-01	1.49	1.11	0.75	1.48	1.11	0.75
I-125 mIBG	2.93E-02	6.71E-02	4.86E-02	2.28E-02	5.08E-02	3.63E-02	2.29	1.66	0.72	2.23	1.59	0.71
I-125 Sodium Iodide	1.61E-01	7.62E+00	1.35E+01	1.32E-01	6.37E+00	1.13E+01	47.3	83.8	1.77	48.3	85.6	1.77
I-131 Hippuran	9.71E-03	1.35E-01	1.17E-01	7.27E-03	1.00E-01	8.58E-02	13.9	12.0	0.87	13.8	11.8	0.86
I-131 HSA	5.89E-01	1.30E+00	9.35E-01	4.68E-01	1.07E+00	7.43E-01	2.21	1.59	0.72	2.29	1.59	0.69
I-131 MAA	1.80E-01	6.35E-01	6.06E-01	1.41E-01	4.96E-01	4.72E-01	3.53	3.37	0.95	3.52	3.35	0.95
I-131 mIBG	1.03E-01	2.51E-01	1.95E-01	8.12E-02	1.95E-01	1.49E-01	2.44	1.89	0.78	2.40	1.83	0.76
I-131 Sodium Iodide	2.32E-01	1.27E+01	2.24E+01	1.92E-01	1.04E+01	1.84E+01	54.7	96.6	1.76	54.2	95.8	1.77
I-131 Rose Bengal	1.02E-01	1.02E+00	1.33E+00	8.13E-02	9.02E-01	1.21E+00	10.0	13.0	1.30	11.1	14.9	1.34
In-111 DTPA	1.11E-02	5.75E-02	5.02E-02	8.75E-03	4.10E-02	3.56E-02	5.18	4.52	0.87	4.69	4.07	0.87
In-111 Platelets	1.92E-01	6.18E-01	3.95E-01	1.55E-01	5.13E-01	3.26E-01	3.22	2.06	0.64	3.31	2.10	0.64
In-111 RBCs	1.80E-01	2.47E-01	2.24E-01	1.48E-01	2.04E-01	1.85E-01	1.37	1.24	0.91	1.38	1.25	0.91
In-111 WBCs	2.04E-01	7.62E-01	4.88E-01	1.63E-01	6.38E-01	4.09E-01	3.74	2.39	0.64	3.91	2.51	0.64
In-111 Pentetate	3.77E-02	1.46E-01	1.03E-01	3.02E-02	1.18E-01	8.14E-02	3.87	2.73	0.71	3.91	2.70	0.69

Table 1 (continued). Total body dose, effective dose equivalent (H_E) and effective dose (E) (mSv/MBq), and ratios for several radiopharmaceuticals.

Pharmaceutical	DOSES				RATIOS			
	FEMALES		MALES		FEMALES		MALES	
	Total Body	H_E	Total Body	H_E	H_E /TB	E /TB	H_E /TB	E /TB
Kr-81m	5.72E-06	3.35E-05	3.39E-05	4.42E-06	2.65E-05	2.65E-05	5.86	5.93
N-13 Ammonia	1.99E-03	2.81E-03	2.56E-03	1.58E-03	2.22E-03	2.01E-03	1.41	1.29
P-32 Sodium Phosphate	1.96E+00	2.40E+00	2.29E+00	1.51E+00	1.93E+00	1.80E+00	1.22	1.17
Tc-99m Alb. uspheres	5.43E-03	1.78E-02	1.77E-02	4.30E-03	1.45E-02	1.45E-02	3.28	3.26
Tc-99m DISIDA	4.93E-03	3.00E-02	2.15E-02	3.99E-03	2.51E-02	1.78E-02	6.09	4.36
Tc-99m DMSA	4.76E-03	1.85E-02	1.07E-02	3.81E-03	1.62E-02	9.12E-03	3.89	2.25
Tc-99m DTPA - iv	2.85E-03	1.11E-02	9.66E-03	2.29E-03	8.19E-03	7.09E-03	3.89	3.39
Tc-99m DTPA Aerosol	2.20E-03	7.90E-03	7.50E-03	1.75E-03	6.06E-03	5.76E-03	3.59	3.41
Tc-99m Glucoheptonate	3.36E-03	1.35E-02	1.00E-02	2.69E-03	1.04E-02	7.42E-03	4.02	2.98
Tc-99m HDP	4.20E-03	7.45E-03	6.07E-03	3.40E-03	6.12E-03	4.80E-03	1.77	1.45
Tc-99m HEDP	2.95E-03	7.86E-03	6.55E-03	2.37E-03	6.10E-03	4.96E-03	2.66	2.22
Tc-99m HMPAO	4.69E-03	1.68E-02	1.29E-02	3.78E-03	1.38E-02	1.09E-02	3.58	2.75
Tc-99m HSA	5.30E-03	9.59E-03	7.54E-03	4.28E-03	7.85E-03	6.21E-03	1.81	1.42
Tc-99m MAA	5.22E-03	1.62E-02	1.54E-02	4.12E-03	1.27E-02	1.20E-02	3.10	2.95
Tc-99m MAG3	2.04E-03	1.64E-02	1.40E-02	1.60E-03	1.18E-02	9.99E-03	8.04	6.86
Tc-99m MDP	3.27E-03	7.64E-03	6.19E-03	2.64E-03	6.08E-03	4.75E-03	2.34	1.89
Tc-99m MIBI/stress	4.65E-03	1.55E-02	1.31E-02	3.77E-03	1.27E-02	1.07E-02	3.33	2.82
Tc-99m MIBI/rest	5.26E-03	1.83E-02	1.63E-02	4.26E-03	1.49E-02	1.33E-02	3.48	3.10
Tc-99m Pertechnetate	3.94E-03	1.32E-02	1.40E-02	3.18E-03	1.06E-02	1.14E-02	3.35	3.55
Tc-99m PYP	4.12E-03	7.46E-03	6.31E-03	3.34E-03	6.03E-03	4.95E-03	1.81	1.53
Tc-99m RBCs/in vitro	4.65E-03	9.19E-03	7.83E-03	3.75E-03	7.28E-03	6.11E-03	1.98	1.68
Tc-99m RBCs/in vivo	4.95E-03	8.95E-03	7.59E-03	3.99E-03	7.17E-03	5.99E-03	1.81	1.53
Tc-99m RBCs/heat	6.25E-03	5.55E-02	2.66E-02	4.94E-03	4.64E-02	2.24E-02	8.88	4.26
Tc-99m Sfr Cld/Normal	6.24E-03	1.69E-02	1.03E-02	4.99E-03	1.36E-02	8.04E-03	2.71	1.65
Tc-99m Sfr Cld/Disease	6.11E-03	2.60E-02	1.59E-02	4.88E-03	2.16E-02	1.32E-02	4.26	2.60
Tc-99m Sfr Cld/Oral	5.28E-03	3.00E-02	2.88E-02	4.72E-03	2.77E-02	2.68E-02	5.68	5.45
Tc-99m Teboroxime	4.75E-03	1.49E-02	1.23E-02	3.86E-03	1.24E-02	1.00E-02	3.14	2.59
Tc-99m WBC's	6.08E-03	2.39E-02	1.54E-02	4.87E-03	2.00E-02	1.29E-02	3.93	2.53
Tl-201 Chloride	6.79E-02	1.87E-01	1.65E-01	5.46E-02	3.16E-01	2.74E-01	2.75	2.43
Xe-127, 10 min breathhold	2.22E-04	2.92E-04	2.92E-04	1.80E-04	2.36E-04	2.36E-04	1.32	1.32
Xe-133, 10 min brteahold	2.59E-04	3.79E-04	3.86E-04	2.02E-04	2.98E-04	3.04E-04	1.46	1.49