

## APPENDIX

A generally accepted method originally described by Thomas et al. (3) was used to derive the absorbed dose to the blood per unit administered activity:

$$D_{\text{blood}}/A_0 = S_{\text{blood} \leftarrow \text{blood}} \cdot \tau_{\text{blood}} + S_{\text{blood} \leftarrow \text{remainder}} \cdot \tau_{\text{remainder}},$$

where  $\tau_{\text{source}}$  stands for the residence time in a source organ representing the integral of the time–activity curve in the source organ (cumulated activity) divided by the administered activity.  $S_{\text{target} \leftarrow \text{source}}$  is the mean absorbed dose to the target organ per unit cumulated activity in the source organ.

The blood contribution was determined with S values published by Akabani and Poston (14), which were scaled for the individual blood volume (BLV) of the patient. BLV can be estimated from the patient's weight, wt [kg], and height, ht [cm] (3):  $BLV = 31.9 \cdot ht + 26.3 \cdot wt - 2,402$  for males,  $BLV = 56.9 \cdot ht + 14.1 \cdot wt - 6,460$  for females. To cover the range of blood vessel radii, blood dose values for 0.2- and 5-mm vessel radii were calculated. The activity in the total blood was calculated from BLV and the blood activity concentration.

The remainder-to-blood S value was taken to be identical to  $S_{\text{total body} \leftarrow \text{total body}}$  listed in MIRD Pamphlet No. 11 (15) and the residence time in the remainder was calculated as the difference of the residence times in the total body and the total blood.

Therefore, the expression for the dose to the blood per unit administered activity becomes:

$$\frac{D_{\text{blood}}}{A_0} \approx S_{\text{blood} \leftarrow \text{blood}}^{5,200 \text{ mL}} \cdot \frac{5,200}{BLV} \cdot \tau_{\text{blood}} + S_{\text{total body} \leftarrow \text{total body}} \cdot (\tau_{\text{total body}} - \tau_{\text{blood}}). \quad \text{Eq. 1}$$

Refinements to the model described above have been introduced to account for (a) the contribution from penetrating radiation from activity in distant blood to the blood dose, (b) the mass dependency of the S value representing the radiation from the total body to the blood, and (c) a mean value  $S_{\text{blood} \leftarrow \text{blood}}$  representing an average for blood circulating in vessels of different diameters with different S values.

Akabani and Poston (14) deduced blood-to-blood S values for different sizes of blood vessels in Monte Carlo simulations. The values are the self-absorbed doses resulting from the number of transformations per milliliter of blood within the vessel. Energy deposition from penetrating radiation originating in the remaining blood circuit was not considered. The S value used in the standard method is simply scaled by the blood volume and, likewise, does not consider penetrating radiation from decays in distant blood vessels.

A term is added in the modified expression to include this contribution:

$$D_{\text{blood}}/A_0 = S_{\text{blood} \leftarrow \text{blood}} \cdot \tau_{\text{mL of blood}} + S_{\text{blood} \leftarrow \text{distant blood}} \cdot \tau_{\text{blood}} + S_{\text{blood} \leftarrow \text{remainder}} \cdot \tau_{\text{remainder}}.$$

The first term considers the self-absorbed dose from decays within the blood vessel. The S value is the unmodified value from (14) and  $\tau_{\text{mL of blood}}$  is the residence time for 1 mL of blood. The second term accounts for the penetrating radiation from distant blood.

Good approximations for the S values are  $S_{\text{blood} \leftarrow \text{distant blood}} \approx S_{\text{total body} \leftarrow \text{total body}}$  and  $S_{\text{blood} \leftarrow \text{remainder}} \approx S_{\text{total body} \leftarrow \text{total body}}$ . The expression for the dose to the blood per unit administered activity becomes:

$$D_{\text{blood}}/A_0 = S_{\text{blood} \leftarrow \text{blood}} \cdot \tau_{\text{mL of blood}} + S_{\text{total body} \leftarrow \text{total body}} \cdot \tau_{\text{total body}}.$$

$S_{\text{total body} \leftarrow \text{total body}}$  is available through MIRD Pamphlet No. 11 (15) or from the computer code OLINDA (16), with the latter allowing inclusion of the dependency of the S value on the patient's weight, wt:

$$S_{\text{total body} \leftarrow \text{total body}}^{\text{wt}} = S_{\text{total body} \leftarrow \text{total body}}^{73.7 \text{ kg}} \cdot (73.7 \text{ kg}/\text{wt})^{0.86}.$$

With  $S_{\text{total body} \leftarrow \text{total body}}^{73.7 \text{ kg}} = 0.00258 \text{ mGy}/(\text{MBq} \cdot \text{h})$  (16), the S value becomes:

$$S_{\text{total body} \leftarrow \text{total body}}^{\text{wt}} = 0.104/(\text{wt} [\text{kg}])^{0.86} \text{ mGy}/(\text{MBq} \cdot \text{h}).$$

The S value  $S_{\text{blood} \leftarrow \text{blood}}$  is dependent on the blood vessel radius. About 73% of the total blood is located in blood vessels with radii between 2.5 and 10 mm (14), 16% resides in capillaries, and 11% resides in larger vessels. A blood vessel radius of 5 mm is most representative for the major part of the blood. A procedure proposed by Akabani and Poston (14) to deduce a mean S value for the total blood would result in a value only a few percent less than that listed for a vessel radius of 5 mm. Therefore,

$$S_{\text{blood} \leftarrow \text{blood}} \approx S_{\text{blood} \leftarrow \text{blood}}^{5 \text{ mm}} = 3.22 \cdot 10^{-8} \text{ mGy}/(\text{Bq} \cdot \text{s}) = 116 \text{ mGy}/(\text{MBq} \cdot \text{h})$$

may be used in a conservative approach to quantitate the dose contribution from the activity in the blood.

The equation for the dose to the blood per unit administered activity becomes:

$$\frac{D_{\text{blood}}}{A_0} [\text{mGy}/\text{MBq}] = 116 \cdot \tau_{\text{mL of blood}} [\text{h}] + \frac{0.104}{(\text{wt} [\text{kg}])^{0.86}} \cdot \tau_{\text{total body}} [\text{h}], \quad \text{Eq. 2}$$

or in traditional units:

$$\frac{D_{\text{blood}}}{A_0} [\text{rad}/\text{mCi}] = 429 \cdot \tau_{\text{mL of blood}} [\text{h}] + \frac{0.385}{(\text{wt} [\text{kg}])^{0.86}} \cdot \tau_{\text{total body}} [\text{h}].$$

The modified expression accounts for activity in distant blood vessels and the influence of the individual patient mass. Using this approach, the blood volume estimate is no longer required.

**TABLE 3**  
Iodine Kinetics, Residence Times, and Specific Blood Dose Determined with Standard Procedure and Refined Method for Euthyroid Patients

No.	Sex	Weight (kg)	Height (cm)	Retention at 48 h			Effective half-time in remnant (h)	Residence time			Specific blood dose (mGy/MBq)			
				Blood (%)	Whole body (%)	Remnant (%)		Blood (h/L) fit (phys.)*	Whole body (h) fit (phys.)*	Remnant (h)	Standard method	Modified method		
											0.2 mm <sup>†</sup>	5 mm <sup>†</sup>		
1	M	100	176	0.30	1.7	0.01	192.5	0.32 (0.34)	13.3 (13.6)	0.02	0.049	0.068	0.064	
2	M	92	178	0.51	3.3	0.10	133.3	0.35 (0.40)	12.5 (12.8)	0.23	0.048	0.069	0.067	
3	F	92	158	0.34	4.7	0.60	107.1	0.35 (0.37)	13.9 (16.1)	1.19	0.054	0.074	0.070	
4	M	99	186	0.71	5.4	1.48	40.2	0.39 (0.44)	16.5 (19.1)	1.94	0.061	0.083	0.079	
5	M	85	178	0.30	8.0	0.47	139.0	0.30 (0.33)	19.3 (22.6)	1.19	0.065	0.082	0.079	
6	M	105	184	0.84	3.7	0.25	43.6	0.46 (0.47)	14.0 (14.3)	0.35	0.056	0.083	0.080	
7	F	67	163	0.20	1.5	0.24	27.8	0.38 (0.38)	12.8 (13.1)	0.36	0.053	0.075	0.080	
8	F	65	160	0.32	2.0	0.02	81.9	0.42 (0.43)	12.9 (13.0)	0.04	0.055	0.079	0.086	
9	F	62	159	0.19	2.2	1.37	18.8	0.43 (0.44)	12.9 (13.5)	2.58	0.055	0.080	0.088	
10	F	72	168	0.43	3.2	0.01	18.3	0.50 (0.54)	12.6 (13.2)	0.01	0.057	0.086	0.091	
11	F	76	175	0.29	2.6	0.28	66.2	0.49 (0.49)	14.1 (14.9)	0.41	0.060	0.089	0.093	
12	F	75	173	0.53	7.1	0.03	66.0	0.47 (0.48)	17.2 (19.0)	0.05	0.068	0.095	0.098	
13	F	87	155	0.47	5.0	0.26	51.1	0.55 (0.56)	15.6 (16.0)	0.37	0.068	0.100	0.099	
14	F	72	167	0.56	5.8	1.12	33.0	0.50 (0.58)	16.8 (19.0)	1.56	0.069	0.098	0.103	
15	F	61	164	0.36	2.0	0.25	69.4	0.55 (0.56)	13.1 (13.4)	0.40	0.061	0.093	0.103	
16	M	98	193	0.83	9.5	0.05	62.9	0.50 (0.51)	23.3 (25.0)	0.07	0.083	0.112	0.105	
17	F	64	160	0.13	1.3	0.26	90.9	0.50 (0.50)	16.7 (16.7)	0.51	0.069	0.098	0.107	
18	F	68	163	0.58	5.6	0.38	175.7	0.55 (0.55)	15.8 (17.4)	1.12	0.069	0.101	0.107	
19	F	86	160	0.89	7.9	0.84	46.7	0.62 (0.67)	20.1 (23.3)	1.15	0.083	0.119	0.117	
20	M	74	172	0.91	5.3	1.47	17.3	0.59 (0.70)	19.9 (20.6)	2.45	0.079	0.114	0.120	
21	F	70	162	0.78	7.4	0.26	34.3	0.62 (0.64)	17.7 (18.2)	0.32	0.077	0.113	0.120	
22	F	73	168	1.21	6.2	0.05	155.7	0.65 (0.67)	17.0 (17.5)	0.13	0.076	0.114	0.120	
23	F	57	165	0.43	4.1	0.32	57.8	0.61 (0.62)	15.7 (16.5)	0.49	0.072	0.107	0.121	
24	F	69	160	0.91	5.1	0.29	30.6	0.66 (0.68)	16.7 (17.0)	0.41	0.077	0.115	0.122	
25	F	72	165	0.77	21.9	0.01	81.8	0.56 (0.60)	22.4 (24.6)	0.02	0.086	0.119	0.124	
26	F	61	149	0.48	7.4	0.10	43.2	0.59 (0.63)	18.7 (18.9)	0.13	0.080	0.114	0.125	
27	F	69	179	1.56	10.4	0.64	30.4	0.71 (0.76)	19.2 (20.2)	0.84	0.084	0.125	0.136	
28	F	73	172	1.54	10.9	0.15	65.8	0.66 (0.74)	23.3 (27.7)	0.24	0.093	0.131	0.137	
29	F	49	165	0.50	8.1	3.39	19.0	0.65 (0.74)	18.2 (21.0)	6.62	0.080	0.118	0.143	
30	F	54	158	0.68	9.9	1.64	31.1	0.68 (0.81)	19.7 (24.8)	2.25	0.086	0.125	0.145	
31	F	121	167	4.21	28.7	0.36	143.1	1.00 (1.06)	29.3 (32.0)	0.94	0.124	0.182	0.166	
32	F	62	168	2.55	12.8	0.00	22.1	1.02 (1.37)	21.0 (21.7)	0.01	0.104	0.163	0.181	
33	F	60	163	0.56		0.08	33.3	0.65 (0.66)		0.10				
				(%)	(%)	(%)	(h)	(h/L)	(h)	(h)	(mGy/MBq)	(mGy/MBq)	(mGy/MBq)	
				Mean	0.78	6.9	0.51	67.6	0.55 (0.60)	17.3 (18.6)	0.86	0.072	0.104	0.109
				Median	0.56	5.5	0.26	51.1	0.55 (0.56)	16.8 (17.9)	0.40	0.069	0.100	0.106
				SD	0.78	5.7	0.70	48.8	0.16 (0.21)	3.9 (4.8)	1.27	0.017	0.026	0.028
				Minimum	0.13	1.3	0.00	17.3	0.30 (0.33)	12.5 (12.8)	0.01	0.048	0.068	0.064
				Maximum	4.21	28.7	3.39	192.5	1.02 (1.37)	29.3 (32.0)	6.62	0.124	0.182	0.181

Iodine Kinetics, Residence Times, and Specific Blood Dose Determined with Standard Procedure and Refined Method for Hypothyroid Patients

No.	Sex	Weight (kg)	Height (cm)	Retention at 48 h			Effective half-time in remnant (h)	Residence time			Specific blood dose (mGy/MBq)			
				Blood (%)	Whole body (%)	Remnant (%)		Blood (h/L) fit (phys.)*	Whole body (h) fit (phys.)*	Remnant (h)	Standard method	0.2 mm <sup>†</sup>	5 mm <sup>†</sup>	Modified method
1	F	52	150	0.09	1.0	0.22	24.0	0.42 (0.42)	11.4 (11.6)	0.35	0.051	0.076	0.088	
2	M	100	188	1.49	17.8	0.53	192.5	0.48 (0.52)	21.9 (23.5)	1.72	0.078	0.106	0.099	
3	F	64	167	0.51	3.8	0.45	33.4	0.48 (0.53)	15.5 (17.1)	0.59	0.064	0.092	0.101	
4	F	84	164	0.49	5.6	1.01	32.0	0.54 (0.55)	17.9 (20.8)	1.41	0.073	0.105	0.104	
5	F	89	163	0.58	7.0	1.11	35.0	0.61 (0.61)	17.1 (19.7)	1.55	0.075	0.110	0.108	
6	F	63	153	0.62	6.3	0.07	18.7	0.63 (0.66)	17.5 (18.1)	0.11	0.078	0.114	0.124	
7	F	83	163	0.51	5.3	0.15	192.5	0.64 (0.67)	22.1 (25.2)	0.52	0.089	0.126	0.125	
8	M	86	171	1.47	10.9	0.63	73.0	0.66 (0.66)	22.3 (22.9)	1.09	0.089	0.127	0.127	
9	M	79	180	1.81	17.3	0.53	87.3	0.59 (0.70)	26.8 (33.9)	0.93	0.097	0.131	0.133	
10	F	70	163	1.19	10.7	0.18	20.1	0.69 (0.83)	22.6 (25.9)	0.27	0.094	0.134	0.141	
11	F	59	148	0.34	6.2	2.14	25.8	0.77 (0.77)	16.8 (20.4)	3.11	0.084	0.129	0.142	
12	F	60	160	0.73	6.3	0.05	16.7	0.58 (0.59)	26.6 (28.2)	0.06	0.099	0.132	0.149	
13	F	49	152	0.40	5.6	0.72	26.9	0.75 (0.81)	18.2 (19.8)	0.83	0.086	0.129	0.153	
14	F	76	161	1.21	13.7	0.75	43.2	0.79 (0.87)	26.1 (27.2)	0.98	0.108	0.153	0.157	
15	F	55	160	0.70	6.6	1.64	16.0	0.89 (0.89)	18.2 (21.9)	3.11	0.092	0.144	0.164	
16	M	95	185	3.05	20.7	0.26	66.9	0.82 (0.97)	35.2 (44.7)	0.39	0.128	0.176	0.168	
17	F	51	165	1.24	12.2	0.01	20.3	0.79 (0.89)	23.4 (27.6)	0.01	0.101	0.146	0.174	
18	F	54	165	2.31	7.0	1.37	34.6	0.98 (1.40)	18.9 (22.6)	1.57	0.098	0.154	0.177	
19	F	64	150	1.13	8.5	0.15	16.4	1.13 (1.15)	18.6 (19.2)	0.27	0.106	0.172	0.186	
20	F	65	155	1.12	17.0	0.53	41.9	0.84 (0.87)	31.0 (34.3)	0.77	0.124	0.173	0.187	
21	F	60	174	2.63	12.0	2.01	20.9	1.02 (1.72)	22.9 (34.4)	2.84	0.109	0.168	0.188	
22	F	73	159	1.63	12.1			1.43 (1.43)	21.9 (33.4)		0.127	0.210	0.216	
23	F	56	160	2.85	20.6	0.01	17.4	1.10 (1.32)	27.7 (35.9)	0.02	0.128	0.191	0.218	
24	M	78	170	5.93	32.3	0.05	190.8	1.35 (1.60)	34.8 (41.8)	0.15	0.153	0.231	0.242	
25	F	75	160	3.33	28.8	2.15	22.7	1.44 (1.70)	32.8 (38.3)	2.84	0.157	0.240	0.250	
26	F	72	163	4.77	36.7	0.31	24.1	1.52 (1.80)	36.6 (45.2)	0.40	0.170	0.259	0.273	
27	F	87	163	7.55	45.1	0.09	26.6	2.20 (2.35)	45.8 (46.9)	0.15	0.222	0.349	0.353	
28	F	65	160	1.83		2.95	16.3	0.96 (1.39)		4.84				
29	F	94	172	1.06		4.33	29.7	0.89 (0.98)		5.95				
30	M	88	182	1.30		2.14	27.1	0.66 (0.81)		3.08				
				(%)	(%)	(%)	(h)	(h/L)	(h)	(h)	(mGy/MBq)	(mGy/MBq)	(mGy/MBq)	
				Mean	1.79	14.0	0.91	48.0	0.89 (1.02)	24.1 (28.2)	1.38	0.107	0.158	0.167
				Median	1.22	10.9	0.53	26.9	0.79 (0.87)	22.3 (25.9)	0.83	0.098	0.144	0.157
				SD	1.71	10.8	1.05	52.6	0.39 (0.47)	7.8 (9.5)	1.51	0.036	0.059	0.061
				Minimum	0.09	1.0	0.01	16.0	0.42 (0.42)	11.4 (11.6)	0.01	0.051	0.076	0.088
				Maximum	7.55	45.1	4.33	192.5	2.20 (2.35)	45.8 (46.9)	5.95	0.222	0.349	0.353

Missing values indicate invalid data due to technical failure or severe protocol violation.

\*Activity time function according to biexponential fit (fit) or with physical decay (phys.) after last measurement.

<sup>†</sup>Blood vessel radius.