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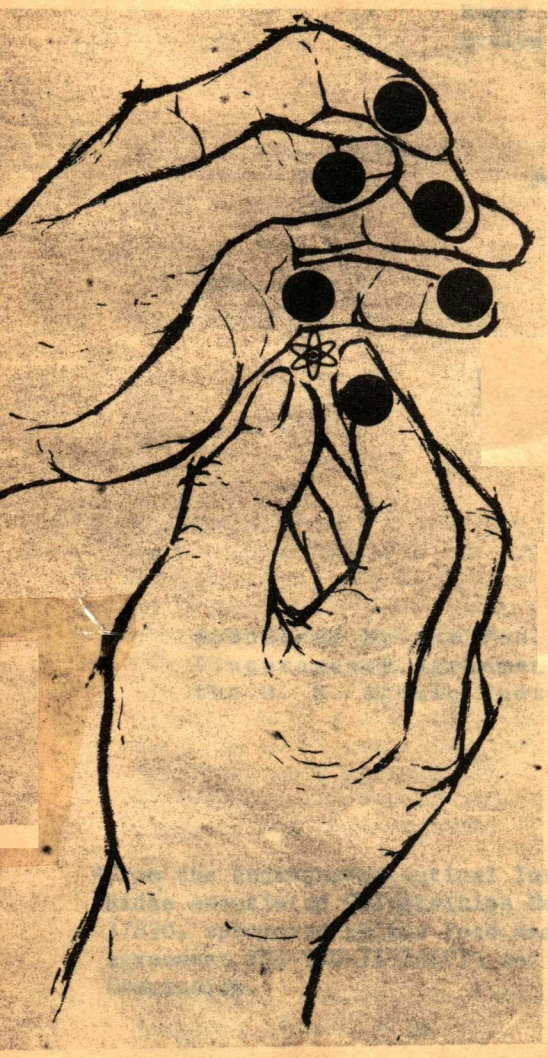

EFFECTIVE ABSORBED ENERGIES

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EFFECTIVE ABSORBED ENERGIES*

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EFFECTIVE ABSORBED ENERGIES

Abstract: *This report provides the "effective absorbed energies" for 14 radionuclides commonly used in nuclear medicine.*

The average radiation dose, $\bar{D}$, to the whole body or a specific organ from a radionuclide in the body may be calculated by using the equations suggested by the Society of Nuclear Medicine's Internal Radiation Dose (MIRD) Committee (1):

$$\bar{D}_{(t \leftarrow s)} = \frac{\tilde{A}_s}{m_t} \sum \Delta_i \phi_{i(t \leftarrow s)}$$

where $\tilde{A}$ = cumulated activity (μCi-hr)

m = mass (g)

Δ = equilibrium dose constant for type i radiation (g-rad/ Ci-hr)

ϕ = absorbed fraction for type i radiation

subscript t -- indicates target organ

subscript s -- indicates source organ

The summed terms, $\Sigma \Delta_i \phi_i$ $(t \leftarrow s)$ are called the "effective absorbed energy" and have a specific value for each radionuclide and target-source combination. We have calculated this value for 14 radionuclides commonly used in nuclear medicine (Table 1) by using several target-source organ combinations. The organs were selected because of their tendency to contain high concentrations of the radionuclide or their radiosensitivity. The equilibrium dose constant (Δ) was obtained for each radiation from either MIRD pamphlet No. 4 or No. 6 (3, 4). Most values of ϕ for penetrating radiation were obtained by interpolating tabulated values prepared by the MIRD Committee (2). When absorbed fractions were not available, we calculated the value by using the reciprocity principle which states that the ratio of absorbed fractions is equal to the ratio of the organ masses:

$$\frac{\phi_{(t \leftarrow s)}}{\phi_{(s \leftarrow t)}} = \frac{m_t}{m_s}$$

Tables 2-15 provide the "effective absorbed fraction" for the 14 radionuclides listed in Table 1.

REFERENCES

1. Loevinger R, Berman M: A schema for absorbed dose calculations for biologically-distributed radionuclides. *J Nucl Med* 9: Supplement No. 1, 7-14, MIRD Pamphlet No. 1, 1968.

2. Snyder WS, Ford MR, Warner GG, Fisher HL: Estimates of absorbed fractions for monoenergetic photon sources uniformly distributed in various organs of a heterogeneous phantom. *J Nucl Med* 10: Supplement No. 3, 5-52, MIRD Pamphlet No. 5, 1969.

3. Dillman LT: Radionuclide decay schemes and nuclear parameters for use in radiation-dose estimation. *J Nucl Med* 10: Supplement No. 2, 7-32, MIRD Pamphlet No. 4, 1969.

4. Dillman LT: Radionuclide decay schemes and nuclear parameters for use in radiation-dose estimation. *J Nucl Med* 11: Supplement No. 4, 7-32, MIRD Pamphlet No. 6, 1970.

TABLE I. RADIONUCLIDES

CARBON-11

FLUORINE-18

IRON-59

COBALT-57

COBALT-60

GALLIUM-67

SELENIUM-75

STRONTIUM-85

TECHNETIUM-99m

INDIUM-111

IODINE-125

IODINE-131

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YTTERBIUM-169

TABLE 2. CARBON-11

EFFECTIVE ABSORBED ENERGY

$$\sum_i \Delta_i \Phi_i \quad \left(\frac{g \cdot rad}{uCi \cdot hr}\right)$$

Target \ Source	Total Body	Kidney	Ovaries	Testes
Total Body	1.577*	1.728*	1.878*	1.858*
Kidney	3.11E-3	9.98E-1*	2.55E-3	3.28E-4
Ovaries	1.33E-4†	7.79E-5†	9.01E-1*	—
Testes	5.23E-4†	4.32E-5†	—	9.35E-1*

The digits following the symbol E indicate the power of ten by which the number is to be multiplied. Example: 2.31E-2 is equivalent to 2.31×10^{-2} or 0.0231.

* Includes both penetrating and nonpenetrating radiation.

† Calculated by the reciprocity method.

TABLE 3. FLUORINE-18
EFFECTIVE ABSORBED ENERGY

$$\sum_i \Delta_i \Phi_i \quad \left(\frac{g \cdot rad}{uCi \cdot hr}\right)$$

Target \ Source	Total Body	Skeleton	Ovaries	Testes
Total Body	1.234*	1.213*	1.523*	1.504*
Ribs	9.07E-3	1.33E-2	1.29E-3	2.11E-4
Pelvis	1.19E-2	1.98E-2	4.84E-2	1.21E-2
Spine	1.62E-2	3.70E-2	7.30E-3	5.50E-4
Skull	6.41E-3	1.66E-2	—	—
Skeleton	1.02E-1	7.65E-1*	6.97E-2	8.38E-2
Ovaries	1.27E-4†	6.07E-5†	5.64E-1*	—
Testes	5.36E-4†	3.16E-4†	—	6.10E-1*

The digits following the symbol E indicate the power of ten by which the number is to be multiplied. Example: 2.31E-2 is equivalent to 2.31×10^{-2} or 0.0231.

* Includes both penetrating and nonpenetrating radiation.

† Calculated by the reciprocity method.

TABLE 3. FLUORINE-18 EFFECTIVE ABSORBED ENERGY

TABLE 4. IRON-59

EFFECTIVE ABSORBED ENERGY $\sum_i \Delta_i \phi_i$ $\left(\frac{g \cdot rad}{uCi \cdot hr}\right)$

Target \ Source	Total Body	Liver	Kidney	Spleen	Skeleton	Ovaries	Testes
Total Body	1.046*	1.187*	1.196*	1.177*	9.94E-1*	1.342*	1.316*
Liver	2.25E-2	6.10E-1*	5.37E-2	1.59E-2	1.04E-2	1.02E-2	1.63E-3
Kidney	3.93E-3	8.07E-3	4.16E-1*	1.83E-2	2.18E-3	2.54E-3	4.05E-4
Spleen	2.26E-3	1.33E-3	1.16E-2	4.27E-1*	1.31E-3	7.83E-4	2.1 E-4
Rib	1.06E-2	1.94E-2	1.41E-2	2.13E-2	1.31E-2	1.45E-3	2.63E-4
Pelvis	1.33E-2	4.39E-3	9.44E-3	4.12E-3	1.98E-2	4.82E-2	1.07E-2
Spine	1.76E-2	1.73E-2	4.68E-2	1.99E-2	3.85E-2	6.94E-3	1.01E-3
Skull	6.70E-3	7.47E-4	3.67E-4	7.87E-4	1.98E-2	—	—
Skeleton	1.11E-1	5.81E-2	7.96E-2	6.14E-2	5.25E-1*	7.18E-2	8.63E-2
Ovaries	1.37E-4†	4.89E-5†	7.76E-5†	3.91E-5†	6.25E-5†	3.00E-1*	—
Testes	5.76E-4†	3.37E-5†	5.34E-5†	4.53E-5†	3.52E-4†	—	3.55E-1*

The digits following the symbol E indicate the power of ten by which the number is to be multiplied. Example: 2.31E-2 is equivalent to 2.31×10^{-2} or 0.0231.

* Includes both penetrating and nonpenetrating radiation.

† Calculated by the reciprocity method.

TABLE 5. COBALT-57

EFFECTIVE ABSORBED ENERGY $\sum_i \Delta_i \phi_i$ $\left(\frac{g \cdot rad}{uCi \cdot hr}\right)$

Target \ Source	Total Body	Liver	Kidney	Spleen	Skeleton	Ovaries	Testes
Total Body	1.41E-1*	1.62E-1*	1.62E-1*	1.62E-1*	1.40E-1*	1.87E-1*	1.84E-1*
Liver	3.19E-3	9.16E-2*	6.83E-3	1.84E-3	1.23E-3	9.55E-4	4.98E-5
Kidney	4.96E-4	1.07E-3	6.72E-2*	2.30E-3	2.43E-4	2.46E-4	1.47E-5
Spleen	2.80E-4	1.59E-4	1.51E-3	6.90E-2*	9.00E-5	8.00E-5	9.00E-6
Rib	1.86E-3	3.60E-3	2.26E-3	3.85E-3	2.75E-3	1.50E-4	7.80E-6
Pelvis	2.26E-3	7.47E-4	1.71E-3	6.70E-4	3.71E-3	1.11E-2	2.54E-3
Spine	3.35E-3	3.70E-3	9.13E-3	4.06E-3	7.35E-3	1.42E-3	1.03E-4
Skull	9.24E-4	2.36E-5	1.06E-5	2.81E-5	3.12E-3	—	—
Skeleton	1.95E-2	1.09E-2	1.39E-2	1.10E-2	9.00E-2*	1.49E-2	1.70E-2
Ovaries	1.80E-5†	4.60E-6†	7.00E-6†	4.00E-6†	1.20E-5†	5.37E-2*	—
Testes	7.70E-5†	1.00E-6†	1.90E-6†	1.90E-6†	6.30E-5†	—	6.00E-2*

The digits following the symbol E indicate the power of ten by which the number is to be multiplied. Example: 2.31E-2 is equivalent to 2.31×10^{-2} or 0.0231.

*** Includes both penetrating and nonpenetrating radiation.**

† Calculated by the reciprocity method.

TABLE 5. CONTINUED

EFFECTIVE ABSORBED ENERGY $\sum_i \Delta_i \Phi_i$ $\left(\frac{\text{g-rad}}{\mu\text{Ci-hr}}\right)$

Target \ Source	Total Body	Liver	GI(Stom)	GI(SI)	GI(ULI)	GI(LLI)	Ovaries	Testes
Total Body	1.41E-1*	1.62E-1*	1.68E-1*	1.81E-1*	1.69E-1*	1.73E-1*	1.87E-1*	1.84E-1*
Liver	3.19E-3	9.16E-2*	3.35E-3	2.94E-3	4.40E-3	3.51E-4	9.55E-3	4.98E-5
GI(Stom)	6.93E-4	8.41E-4	7.62E-2*	1.04E-3	1.50E-3	4.61E-4	3.11E-4	3.20E-5
GI(SI)	3.15E-3	2.73E-3	4.59E-3	9.01E-2*	2.28E-2	9.71E-3	1.73E-2	7.67E-4
GI(ULI)	7.14E-4	1.01E-3	1.51E-3	5.37E-3	6.95E-2*	1.15E-3	2.40E-3	1.54E-4
GI(LLI)	4.72E-4	4.47E-5	3.12E-4	1.58E-3	7.34E-4	6.56E-2*	1.98E-3	1.05E-3
Ovaries	1.80E-5†	4.50E-5†	6.80E-6†	8.97E-5†	5.07E-5†	6.31E-5†	5.37E-2*	—
Testes	7.70E-5†	1.00E-6†	3.00E-6†	1.71E-5†	1.40E-5†	1.45E-4†	—	6.00E-2*

The digits following the symbol E indicate the power of ten by which the number is to be multiplied. Example: 2.31E-2 is equivalent to 2.31×10^{-2} or 0.0231.

*** Includes both penetrating and nonpenetrating radiation.**

† Calculated by the reciprocity method.

TABLE 6. COBALT-60

EFFECTIVE ABSORBED ENERGY $\sum_i \Delta_i \phi_i$ $\left(\frac{g \cdot rad}{uCi \cdot hr}\right)$

Target \ Source	Total Body	Liver	Kidney	Spleen	Skeleton	Ovaries	Testes
Total Body	1.87*	2.15*	2.17*	2.14*	1.76*	2.48*	2.42*
Liver	4.80E-2	9.59E-1*	1.12E-1	3.33E-2	2.17E-2	2.17E-2	3.64E-3
Kidney	8.40E-3	1.69E-2	5.39E-1*	3.92E-2	4.51E-3	5.44E-3	8.65E-4
Spleen	4.80E-3	2.68E-3	2.48E-2	5.67E-1*	2.84E-3	1.63E-3	4.60E-4
Rib	2.19E-2	4.10E-2	2.98E-2	4.34E-2	2.77E-2	3.20E-3	5.96E-4
Pelvis	2.74E-2	9.39E-3	1.99E-2	8.81E-3	4.29E-2	1.02E-1	2.25E-2
Spine	3.64E-2	3.63E-2	1.00E-1	4.07E-2	8.16E-2	1.43E-2	2.13E-3
Skull	1.41E-2	1.68E-3	8.20E-4	1.72E-3	4.29E-2	2.80E-4	—
Skeleton	2.34E-1	1.23E-1	1.68E-1	1.28E-1	7.67E-1*	1.52E-1	1.80E-1
Ovaries	2.84E-4†	1.04E-4†	1.66E-4†	8.10E-5†	1.32E-4†	2.96E-1*	—
Testes	1.20E-3†	7.50E-5†	1.14E-4†	9.90E-5†	6.76E-4†	—	4.12E-1*

The digits following the symbol E indicate the power of ten by which the number is to be multiplied. Example: 2.31E-2 is equivalent to 2.31×10^{-2} or 0.0231.

*** Includes both penetrating and nonpenetrating radiation.**

† Calculated by the reciprocity method.

TABLE 6. CONTINUED

EFFECTIVE ABSORBED ENERGY $\sum_i \Delta_i \phi_i$ $\left(\frac{g \cdot rad}{uCi \cdot hr}\right)$

Target \ Source	Total Body	Liver	GI(Stom)	GI(SI)	GI(ULI)	GI(LLI)	Ovaries	Testes
Total Body	1.78*	2.15*	2.24*	2.42*	2.28*	2.31*	2.48*	2.42*
Liver	4.80E-2	9.59E-1*	5.62E-2	5.12E-2	8.02E-2	1.02E-2	2.17E-2	3.64E-3
GI(Stom)	1.00E-2	1.30E-2	6.81E-1*	1.71E-2	2.51E-2	8.77E-3	7.90E-3	1.11E-3
GI(SI)	5.38E-2	4.86E-2	7.19E-2	9.10E-1*	3.81E-1	1.60E-1	2.64E-1	1.84E-2
GI(ULI)	1.14E-2	1.60E-2	2.53E-2	8.89E-2	5.88E-1*	2.20E-2	3.90E-2	3.50E-3
GI(LLI)	9.55E-3	1.46E-3	5.91E-3	2.51E-2	1.50E-2	5.11E-1*	3.06E-2	1.69E-2
Ovaries	2.84E-4†	1.04E-4†	1.73E-4†	1.37E-3†	8.25E-4†	9.76E-4†	2.96E-1*	—
Testes	1.20E-3†	7.50E-5†	1.05E-4†	4.12E-4†	3.20E-4†	2.33E-3†	—	4.12E-1*

The digits following the symbol E indicate the power of ten by which the number is to be multiplied. Example: 2.31E-2 is equivalent to 2.31×10^{-2} or 0.0231.

*** Includes both penetrating and nonpenetrating radiation.**

† Calculated by the reciprocity method.

TABLE 7. GALLIUM-67

EFFECTIVE ABSORBED ENERGY

$$\sum_i \Delta_i \phi_i \quad \left(\frac{\text{g-rad}}{\text{uCi-hr}}\right)$$

Target \ Source	Total Body	Liver	Spleen
Total Body	2.12E-1*	2.4IE-1*	2.40E-1*
Liver	4.42E-3	1.40E-1*	2.55E-3
Spleen	3.93E-4	2.4 E-4	1.06E-1*

The digits following the symbol E indicate the power of ten by which the number is to be multiplied. Example: 2.31E-2 is equivalent to 2.31×10^{-2} or 0.0231.

* Includes both penetrating and nonpenetrating radiation.

TABLE 8. SELENIUM-75

EFFECTIVE ABSORBED ENERGY $\sum_i \Delta_i \phi_i$ $\left(\frac{\text{g-rad}}{\text{uCi-hr}}\right)$

Target \ Source	Total Body	Pancreas	Liver	Kidney	Ovaries	Testes
Total Body	3.22E-1*	4.40E-1*	3.81E-1*	3.80E-1*	4.52E-1*	4.42E-1*
Pancreas	3.62E-4	7.43E-2*	7.80E-4	1.19E-3	1.0 E-4	—
Liver	9.04E-3	2.24E-2	1.72E-1*	2.00E-2	3.12E-3	2.5 E-4
Kidney	1.39E-3	5.23E-3	3.23E-3	9.70E-2*	8.3 E-4	8.3 E-5
Ovaries	5.30E-5†	1.44E-5†	1.49E-5†	2.53E-5†	5.74E-2*	—
Testes	2.24E-4†	—	5.10E-6†	1.09E-5†	—	7.71E-2*

The digits following the symbol E indicate the power of ten by which the number is to be multiplied. Example: 2.31E-2 is equivalent to 2.31×10^{-2} or 0.0231.

* Includes both penetrating and nonpenetrating radiation.

† Calculated by the reciprocity method.

TABLE 9. STRONTIUM-85

EFFECTIVE ABSORBED ENERGY

$$\sum_i \Delta_i \Phi_i \quad \left(\frac{g \cdot rad}{uCi \cdot hr}\right)$$

Target \ Source	Total Body	Skeleton	Ovaries	Testes
Total Body	4.06E-1*	4.01E-1*	5.56E-1*	5.45E-1*
Ribs	5.07E-3	8.41E-3	6.68E-4	1.08E-4
Pelvis	6.47E-3	1.18E-2	2.49E-2	6.21E-3
Spine	8.59E-3	2.10E-2	3.76E-3	2.84E-4
Skull	3.49E-3	9.69E-3	—	—
Skeleton	5.54E-2	1.64E-1*	3.56E-2	4.29E-2
Ovaries	6.74E-5†	3.10E-5†	5.44E-2*	—
Testes	2.85E-4†	1.62E-4†	—	8.17E-2*

The digits following the symbol E indicate the power of ten by which the number is to be multiplied. Example: 2.31E-2 is equivalent to 2.31×10^{-2} or 0.0231.

* Includes both penetrating and nonpenetrating radiation.

† Calculated by the reciprocity method.

TABLE 10. TECHNETIUM-99m

EFFECTIVE ABSORBED ENERGY

$$\sum_i \Delta_i \Phi_i \left(\frac{g \cdot rad}{uCi \cdot hr}\right)$$

Target \ Source	Total Body	Kidney	Bladder	Ovaries	Testes
Total Body	1.31E-1*	1.52E-1*	1.66E-1*	1.78E-1*	1.74E-1*
Kidney	4.75E-4	5.58E-2*	8.7 E-4	2.55E-4	1.7 E-5
Bladder	9.09E-4	1.37E-4	6.90E-2*	3.46E-3	3.01E-3
Ovaries	1.77E-5†	7.7 E-6†	5.98E-5†	4.19E-2*	—
Testes	7.45E-5†	2.2 E-6†	2.25E-4†	—	4.84E-2*

The digits following the symbol E indicate the power of ten by which the number is to be multiplied. Example: 2.31E-2 is equivalent to 2.31×10^{-2} or 0.0231.

* Includes both penetrating and nonpenetrating radiation.

† Calculated by the reciprocity method.