EXPERIMENTAL EVALUATION OF ORGAN DOSES FROM EXPOSURE TO Tc-99m, I-123 and I-131

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1. INTRODUCTION

Recently the MIRD committee formulated a new quantity "S" defined as the absorbed dose per unit cumulated activity. This quantity has been tabulated in MIRD PAMPHLET No 11 for various radionuclides and source-target configurations of a standard man (1). We have partly calculated the corres-pon[illegible]lues by an alternative method using direct attenuation and build-up equations for point sources and partly studied experimentally the quantity "S" for Tc-99m, I-123 and I-131.
The calculation aproach adopted offers the possibility both to examin the dose-gradients in the target organs and to calculate the average "absorbed dose per unit cumulated activity" as given by MIRD, and further to normalize a real case to correlate the standard situation from which the "MIRD" values are evaluated.

2. CALCULATIONS

We have chosen an alternative way of calculating the absorbed dose in the target organs which is based on the expression (2):

$$D(r) = \int_0^t A_0 e^{-\lambda t} dt \cdot \Delta \cdot \frac{\mu en}{\rho} \, \frac{1}{4\pi r^2} \cdot e^{-\mu r} \cdot B(\mu r) \qquad 1.$$

This equation gives us the absorbed dose at a point from a point isotropic source within an infinite homogeneous medium where B(ur) is based on Bergers formula for calculation of the energy absorption build-up factor (2).
The organ in question is divided into a number of small volume elements which are approximated to points. The calculation proceeds until each volume element in the target organ has achieved a contribution from each volume element in the source organ. The absorbed dose can be written as

$$D(r_k \leftarrow r_h) = \frac{\sum_{i=1}^{n} D(r_i)}{n} \qquad 2.$$

Where n is the product of the number of volume elements in the target and source organs.

3. THE PHANTOM MODEL

The phantom model is in all important aspects in agreement with the mathematical description according to MIRD Pamphlet No 5. The soft-tissue is simulated by perspex and water and the skeleton by aluminium. The volume of the skeleton is corrected so that the electron density is in agreement

with that of the theoretical MIRD phantom.
Every organ (except the lungs) is constructed in one target version and one source version. The target organ version is divided into a number of planes parallel to the xy-plane where the mathematical equation of the organ is fulfilled in each plane. The lungs are constructed of corkplates with a density of 0.28 g/cm^3.
All the source- and target organs are fixed on the Al-tube which simulates the backbone.

4. MEASUREMENT OF ABSORBED DOSE

The absorbed dose measurements were performed using extruded LiF-TL-dosemeters packed in sealed thin plastic bags.
The dosemeters were placed in planes parallel to the xy-plane at various depth z in the target organ of interest.
The experimental set up is then inserted into the waterfilled phantom body. The radionuclide in question is injected into the sourceorgan and the dosemeters are exposed for time t. Then the phantom is emptied of water and the dosemeters are evaluated.

5. EVALUATION OF AVERAGE ABSORBED DOSE

Consider a mass element dm=P(z)*dz*density, where P(z) is the cross- sectional area of the plane parallel to the xy-plane at height z in the target organ.
Then the average absorbed dose D(z) in the mass element dm can be expressed as:

$$\bar{D}(z) = \frac{\left(\frac{\mu en}{\rho}\right)_{H_2O}}{\left(\frac{\mu en}{\rho}\right)_{LiF}} \cdot \frac{k}{CE} \cdot \frac{\sum R(i)}{n} \qquad 3.$$

Where R(i) represent the response from dosemeter i on the plane at level z, k is the calibrationconstant (rad/scale reading) for the whole group of dosemeters and CE is the correctioncoefficient for the energy dependence of the dosemeters. The weighted average absorbed dose for the whole organ is calculated from equation 4 given below. This corresponds to the theoretical absorbed dose $D(r_k \leftarrow r_h)$ according to MIRD.

$$\bar{\bar{D}}(r_k \leftarrow r_h) = \frac{\sum \bar{D}(z) \cdot P(z)}{\sum P(z)} \qquad 4.$$

Where the sum is taken over all measured depths in the target organ.
The absorbed dose per unit cumulated activity (rad/Ci-h) is derived from the expression .

$$S(r_k \leftarrow r_h) = \frac{\bar{\bar{D}}(r_k \leftarrow r_h)}{A_0 \int_0^t e^{-\lambda t} dt} \qquad 5.$$

6. RESULTS AND DISCUSSION

The variation of absorbed dose and absorbed dose per unit cumulated activity of the radionuclides Tc-99m, I-123 and I-131 have been determined both by experiments and calculations using bladder, liver and kidneys as source organs and kidneys, liver, lungs and ovaries as target organs. The overall uncertainty in the experimental determination of "S" was estimated to be about 20 % or less.

6.1 Comparison of absorbed dose per unit cumulated activity

The theoretical values given by MIRD (SM) and our calculated (SC) and experimental (SE) values are thus compared for various configurations of source and target organs. In table 1 the "S" values for kidneys and ovaries with Tc-99m in the liver are given and in table 2 the "S" values for liver, lungs and ovaries with the kidneys as source organs are given for both I-123 and I-131. As can be seen from these tables both our calculated and measured values are in good agreement with the values obtained by Monte Carlo calculations by MIRD committee. Our method of calculation can also be used for any radionuclide to normalize the "S"-values given by MIRD to various body shapes which differ significantly from the standard situation. This is achieved in the following way SN=SQ*(SM/SC) where SN is the normalized value and SQ is the calculated value for the case in question.

6.2 The variation of absorbed dose within the target organ

In order to get an idea of the significance of the variation in absorbed dose within the target organ we have calculated the unweighted average absorbed dose $\bar{D}$, and the range R between maximum and minimum values of absorbed dose and the ratio $R/\bar{D}$.
The results of these calculations are given in Table 3 for the liver and the ovaries with the kidneys as source organs. It can be noted from this table that $\bar{D}$ for I-123 is only about half of that for I-131. The relative spread however is the same in the liver for the radionuclides considered but within the ovaries it is slightly higher for I-123 than for I-131.

Target organ	Sourceorgan: Liver		
	Tc-99m		
	SM rad/Ci-h	SC rad/Ci-h	SE rad/Ci-h
Kidney R		7.5	8.4±1.7
Kidney L		1.6	2.1±0.4
Kidneys AV	3.9	4.6	5.3±1.0
Ovary R		0.83	0.72±0.1
Ovary L		0.45	0.35±0.07
Ovaries AV	0.45	0.64	0.54±0.1

TABLE 1 The absorbed dose per unit cumulated activity given by MIRD SM, calculated SC, and experimentally measured SE for kidneys and ovaries with Tc-99m in the liver

Targetorgan	Sourceorgan:Kidneys					
	I-123			I-131		
	S M rad/Ci-h	S C rad/Ci-h	S E rad/Ci-h	S M rad/Ci-h	S C rad/Ci-h	S E rad/Ci-h
Liver	5.1	5.4	6.0±1.2	11.0	13	1.2±2.4
Lungs	1.0		1.0±0.2	2.5		3.1±0.6
Ovaries	1.3	1.9	1.4±0.3	3.4	3.7	4.2±0.8

Table 2 The absorbed dose per unit cumulated activity partly given by MIRD SM partly calculated SC and determined experimentally SE in the present work for liver lungs and ovaries with I-123 and I-131 in the kidneys.

Target organ	Statistical measure	Sourceorgan:Kidneys			
		I-123		I-131	
		C	E	C	E
Liver	$\bar{D}$ |rad|	3.86	4.20±0.8	10.2	9.61±1.9
	R |rad|	17.7	17.9±4.0	41.6	40.0±8.0
	R/$\bar{D}$	4.58	4.26±1	4.37	4.16±2.5
Ovaries	$\bar{D}$ |rad|	2.10	1.51±0.3	3.91	4.50±0.9
	R |rad|	2.00	1.40±0.3	2.33	2.50±0.6
	R/$\bar{D}$	0.95	0.93±0.5	0.60	0.56±0.3

TABLE 3 The average absorbed dose $\bar{D}$ and the range R between the maximum and minimum value of absorbed dose in liver and ovaries with I-123 and I-131 in the kidneys (cumulated activity 1 Ci-h)

REFERENCES

(1) MIRD Pamphlet No 5
(2) MIRD Pamphlet No 2
(3) MIRD Pamphlet No 11