COMPARATIVE EVALUATION OF WHOLE BODY COUNTERS FOR USE IN THE IMPLEMENTATION OF AN ICRP 30 INTERNAL DOSIMETRY PROGRAM

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Introduction

In order to implement an ICRP 30 based internal dosimetry program, a rapid and reliable bioassay evaluation method is needed. Direct bioassay (whole body counting) is the most desirable form of exposure assessment since it eliminates many underlying assumptions. Two commercially available whole body counting systems were evaluated for use in the assessment of intake (i.e., percentage of an annual limit of intake) and subsequent calculation of a fifty year dose commitment. A closed geometry three detector chair and a standup whole body counter were the two systems considered.

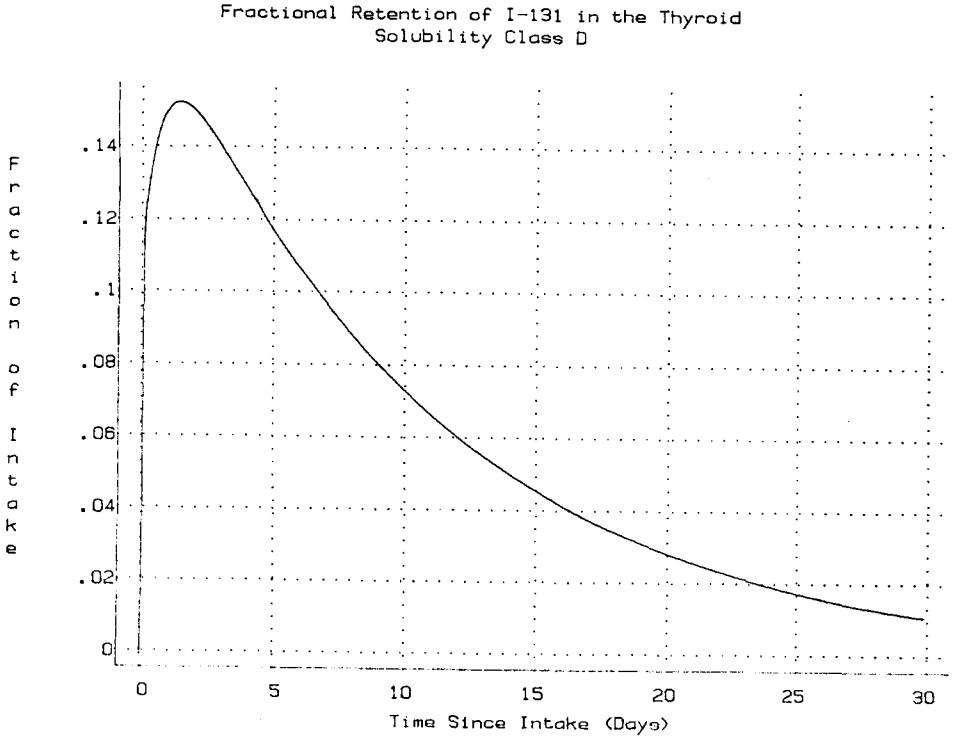
The three detector chair simultaneously measures the lung, the lower torso and the thyroid gland and is considered to be a diagnostic device to be used in the assessment of intake and internal dose assignment. The standup counter is composed of two 4"x4"x16" NaI(Tl) detectors mounted linearly in front of the subject. This detector arrangement provides for relatively high geometrical detection efficiency, but does not possess the organ specificity of the chair counter. Because of this, the standup counter is considered to be useful for screening purposes. Using the metabolic information contained in ICRP 30; however, both of these units can be used to calculate intakes.

Using newly developed computer software based on ICRP 30 methodology, organ specific retention patterns were generated for a variety of commonly encountered fission and activation products. The retention patterns were varied as a function of time. Calibration phantom data was then used to determine the response of each whole body counter to a particular nuclide distribution.

Calculation of Retention Fractions

The software package used to generate the retention curves calculates an intake by analytically solving a first order non-recycling compartmental model. The biological distribution of radioactivity in the body is described as a 20 compartment model with the initial compartment contents set to a predetermined value depending on the mode of intake. In addition, each compartment has an associated first-order transfer rate constant. Given the initial amounts of radioactive material in each compartment and the transfer rate constants between each compartment, the amount of material remaining at any time post-exposure can be calculated. A

representative retention curve generated by the program is given below in Figure 1.



The initial amounts of radioactive material deposited in each compartment is set by the program and depends on several factors. For an ingestion intake, the amount of material in the gastrointestinal tract is set to unity. For an inhalation intake, the lung compartment contents are set to the deposition fractions contained in the report of the ICRP Task Group on Lung Dynamics. The default deposition fractions for the initial lung contents are those for an assumed activity median aerodynamic diameter of 1.0 micron. For purposes of this investigation, all exposures were considered to be to inhalation of 1.0 micron particulate.

Once the initial contents of each compartment were set, the fractional amount remaining in each compartment was calculated. The time periods post-exposure selected for evaluation were zero, 1 hour, 10 hours, 1 day and 30 days. The compartments in the field of view of each detector measurement geometry were then summed. For the closed geometry chair the lung measurement was assumed to view all of the lung compartments with the exception of the naso-pharyngeal region while the lower torso measurement was assumed to view the entire gastro-intestinal tract including the stomach and the upper and lower intestines. The thyroid measurement was assumed

to view only the thyroid gland. For the whole body standup counter, all of the body compartments were assumed to be in the field of view. The minimum detectable intake observed by each detector geometry was then simply calculated using the following expression:

$$\text{Minimum Detectable Intake} = \frac{\text{Minimum Detectable Activity}}{F}$$

where: F = the total fraction of the initial intake viewed by the detector geometry.

Calculation of Detector Responses

The efficiency response of each measurement geometry from the chair and standup counter was obtained using bottle sources which were placed inside of a standard polyethylene based phantom which contains cavities for the simulation of lung, lower torso and thyroid organ distributions. The phantom was designed to conform to MIRD pamphlet No. 5 specifications. Efficiency response values were obtained for a series of isotopes covering an energy range from 165 keV to 1836 keV.

After the efficiency response for each measurement geometry was generated, background counts for each detector were obtained by measuring an uncontaminated subject whose height and weight approximated that of standard man. In this way, the minimum detectable activity for the closed geometry chair and the stand up counter could be calculated. The minimum detectable activity calculation was performed at the 95 per cent confidence interval. The minimum detectable intake was then calculated by dividing the minimum detectable activity by the fraction of the initial intake present at each measurement geometry.

Results

Tables 1 and 2 give the results of the minimum detectable intake calculations for both the chair lung measurement geometry and the standup counter geometry at various times post-exposure.

Table 1

Minimum Measurable Intakes at Various Times Post-Exposure Standup Counter

	Minimum Measurable Intake (Bq)					
Nucl.	Init	1 Hr.	10 Hr.	1 Day	10 Day	30 Day
Cr-51	1406	1406	1443	1591	6660	11803
Mn-54	152	152	152	163	481	629
Co-58	152	152	152	167	666	851
Fe-59	274	274	278	296	814	1184

Table 1 (continued)

Nucl.	Init	1 Hr.	10 Hr.	1 Day	10 Day	30 Day
Co-60	163	163	163	178	629	666
Zn-65	307	307	307	326	518	629
Ru-106	1406	1406	1443	1554	5476	6031
I-131	163	244	355	444	1408	9361
I-133	181	281	518	1036	----	----
Cs-134	144	144	144	148	170	200
Cs-137	148	148	152	155	178	200

Table 2

Minimum Measurable Intakes at Various Times Post-Exposure Closed Geometry Chair (Lung Measurement)

	Minimum Measurable Intake (Bq)					
Nucl.	Init	1 Hr.	10 Hr.	1 Day	10 Day	30 Day
Cr-51	2257	2331	2923	3552	6401	11063
Mn-54	207	237	274	322	518	703
Co-58	207	215	266	322	518	629
Fe-59	363	407	481	555	1036	1887
Co-60	203	211	263	315	444	481
Zn-65	407	407	518	629	925	999
Ru-106	2516	2627	3256	3885	5698	6068
I-131	259	351	555	1184	2.3E8	2.4E21
I-133	259	359	777	2368	----	----
Cs-134	252	337	518	1036	9.2E7	1.6E20
Cs-137	274	366	555	1110	9.9E7	1.7E20

The results demonstrate that the both systems are capable of measuring small intakes at short times post-exposure for both the insoluble (i.e., Co-60) and the soluble (i.e. Cs-137) nuclides examined. At longer times post-exposure; however, the lung measurement in the chair does not provide adequate sensitivity for soluble nuclides. This is due to the relatively rapid clearance of these nuclides out of the lung and subsequent deposition into other organs. For example, at 10 days post-exposure, intakes for both Cs-137 and Cs-134 can not be adequately evaluated in the chair while the standup counter is still quite sensitive even out to 30 days post-exposure.

Conversely, for some insoluble nuclides deposited in the lung such as Co-60 and Co-58, the chair measurement geometry provides somewhat better minimum measurable uptake capabilities at measurement times greater than 10 days post-exposure. In addition to this, the organ specific measurement capabilities of the closed geometry chair can be used to establish a subjects's own clearance patterns which can be used to calculate a more exact dose commitment. This precludes the use of using the default metabolic parameters contained in ICRP 30.