Internal Exposure in Research and Clinical Medicine

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Introduction

When using unsealed radioactive sources for research or in a clinical environment there is always the risk of contamination and/or incorporation (see e.g [1,2,3,4,5]). Therefore, the people who are working with these radionuclides have to be monitored regularly if there is a chance exceed legal limits for intake and/or contamination are exceeded. The objective of this study is to define under which circumstances regular monitoring of the people working with unsealed sources has to be performed. In addition risk assessments of internal exposure in research labs or in a clinical setting are given.

Material and Methods

In table 1 a summary of the most important radioactive isotopes used in research and clinical medicine is given in the first columnm. The typical amount of activity handled per year in research laboratories and in a clinical setting is given in column 2. As a comparison values for the German Annual Limit of Intake (ALI) as defined by the German Radiation Protection Ordinance (‚Strahlenschutzverordnung') [6], the US ALI as defined by CRC10 [7], the recommended screening methods and intervals according to the German Guideline (‚RiPhyKo') [8] is given.

Radio-Nuclide	Typical Annual Activity handled	Annual Limit of Intake Germany [6]	Annual Limit of Intake USA [7]	Screening Method [8]	Recommened Screening Interval [8]	Application
^{3}H (HTO)	1 GBq	3 GBq	3 GBq	Urine	30 d	Research
^{14}C (org.)	500 MBq	90 MBq	74 MBq	Urine	30 d	Research
^{32}P	4 GBq	6 MBq	15 MBq	Urine	30 d	Research
^{99m}Tc	2.000 GBq	5 GBq	NN	WBC	1 d	In-Vivo-Diagnostics
^{111}In	10 GBq	200 MBq	222 MBq	WBC	14 d	In-Vivo-Diagnostics
^{123}I	10 GBq	100 MBq	222 MBq	Thyroid Probe	1 d	In-Vivo-Diagnostics
^{125}I	400 MBq	2 MBq	2 MBq	Thyroid Probe	90 d	In-Vitro-Diagnostics
^{131}I	2.000 GBq	1 MBq	2 MBq	Urine, Thyroid Probe	14 d	Therapy
^{201}Tl	10 GBq	800 MBq	740 MBq	WBC	14 d	In-Vivo-Diagnostics

Table 1: Radionuclides, annual activity handled, annual limit of intake (Germany, USA), screening method, rcommended screening interval and typical applications (WBC: whole body counting).

As can be seen from table 1 the incorporation risk is high whenever the annual activity handled exceeds the ALI by several orders of magnitude.
Two cases are considered to be exceptions:

1. ^{99m}Tc and ^{123}I due to their short half-lives of 6 and 12 hours, respectively. Incorporation monitoring on a regular basis is generally not necessary unless there is the suspicion of incorporation.
2. ^{125}I is mainly used for radioimmunoassays and is manufactured as a ready-to-use kit without any need of manipulating the radioactive tracer.

Criteria for Regular Monitoring of Internal Exposure

A criterium for the need of a regular screening of the internal exposure is given by the maximum activity a person might unknowingly incorporate. According to the German rules the following equation has to be applied [8]:

$$\mathbf{A(U) = a * N * A > 0{,}1 * ALI \quad \{eq.1\}.}$$

A: Annual mean activity handled (cumulated activity divided by the number of working days);
N: number of days of possible exposure;
a: fraction of the activity handled which might be incorporated unknowingly
A(U): Maximum level of activity which can be incorporated during one year
ALI: Annual limit of intake (see e.g. table 1)

An example for the application of eq. 1 for people working in nuclear medicine is given in table 2. In table 2 the radionuclide and the activity handled in Würzburg in 1994 is given (column 3). For **a** a value of 5 10^{-5} is recommended with the exception of the synthesis of new tracers labelled with radioactive iodine isotopes (**a =** 1 10^{-3}). In column 6 the criterium for a regular incorporation monitoring is calculated for Würzburg. The ratio of the maximal activity which might be incorporated unknowingly to the ALI is given. Three cases have to be considered:

- For in-vivo-diagnostics with ^{99m}Tc a theoretical value of 2% of the ALI can be incorporated unknowingly. This value is rather low but, nevertheless, contamination monitoring or monitoring with a simple device might replace regular screening procedures in a whole body counter.
- Working with iodine isotopes for producing new radiotracers seems to make regular screening necessary due to the easy contamination of the air and the corresponding low values for the ALI.
- For people working at a therapy ward for radioiodine therapies regular monitoring is strongly recommended as the patients exhale levels of ^{131}I up to 0.5% of the administered activity [9] as can be seen from incorporation measurements of personnel and relatives of radioiodine patients ([2],[3]).

Radionuclide	ALI[6]	Handled in Würzburg 1994	A	a	A(U)/ALI
^{99m}Tc	5 GBq	2100 GBq	10 GBq	$5\ 10^{-5}$	$2\ 10^{-2}$
^{131}I Diagnostics	1 MBq	285 MBq	1,5 MBq	$5\ 10^{-5}$	$1,5\ 10^{3}$
^{125}I	2 MBq	360 MBq	1,8 MBq	$5\ 10^{-5}$	$9\ 10^{2}$
^{131}I Radiochemistry	1 MBq	-	10 MBq	$1\ 10^{-3}$	5
^{131}I Therapy	1 MBq	900 GBq	4,5 GBq	$5\ 10^{-5}$	50

Table 2: Examples for criteria for the requirement of regular screening

Screening Methods

The following screening methods can be applied in internal exposition monitoring depending on the specific situation:

- Activity concentration in the air
- Measuring the activity retained in the body
- Measuring the activity level int the excretions

Usually one of these methods is chosen according to the radionuclide and the corresponding chemical compound used. The three major methods used for clinical environments and/or research is

- Measuring the activity in a whole-body counter
- Measuring the activity in the thyroid
- Measuring the activity concentration in the urine.

Measuring the body burden with a whole body counter or a probe is carried out whenever photons are emitted by the radionuclide in measurable quantities and the distribution of the radionuclide in the body is known to such an extent that a reliable interpretation of the results is possible. This is particularly the case for probe measurements of the iodine contents of the thyroid.

Measurements of the activity level in the excretions has to be carried out whenever purely beta emitting radionuclides are involved (such as ^{3}H or ^{32}P). For the measurements a 24h collection of the exretions is strongly recommended.

Screening Interval

The screening methods chosen are such that an intake of 3% of the ALI is detected. The choice is determined by the effective half-life of the radionuclide and the lower limit of detection of the measuring device. In Germany the following criteria are to be applied to determine a reference value [8]:

1. An incorporation at the beginning of the measurement interval should not underestimate the actual intake by more than a factor of 3 if one assumes that the intake took place in the middle of the screening period.
2. An intake with a value of 3% of the intake divided by the number of measurments at the beginning of the screening period must be discovered by the screening procedure.

Incorporation Monitoring at a Radioiodine Therapy Ward

In Germany all the patients who will have a radioiodine therapy have to be admitted to a therapy ward. The staff of the ward (nurses and doctors) has to take care of the patients and, therefore, is exposed to ionising radiation. 19 people working at the therapy ward and in the radiochemistry department of the Klinik und Poliklinik für Nuklearmedizin der Universität Würzburg were monitored in a 14 d interval. The monitoring was carried out using a thyroid probe with a collimated HPGe-detector of 35%

efficiency. The measuring time was 100s, the distance neck-collimator 150 mm. The lower limit of detection (LLD) was 13Bq ^{131}I. The probe was calibrated with a neck phantom and a ^{131}I calibration source supplied by the Physikalisch-technische Bundesanstalt (PTB). In fig.1 the required lower limit of detection [8] is plotted vs. the length of time between two screening measurements. If the interval is longer than 17 days between two measurements the calculation of a possible intake might be erroneous by more than a factor of 3.

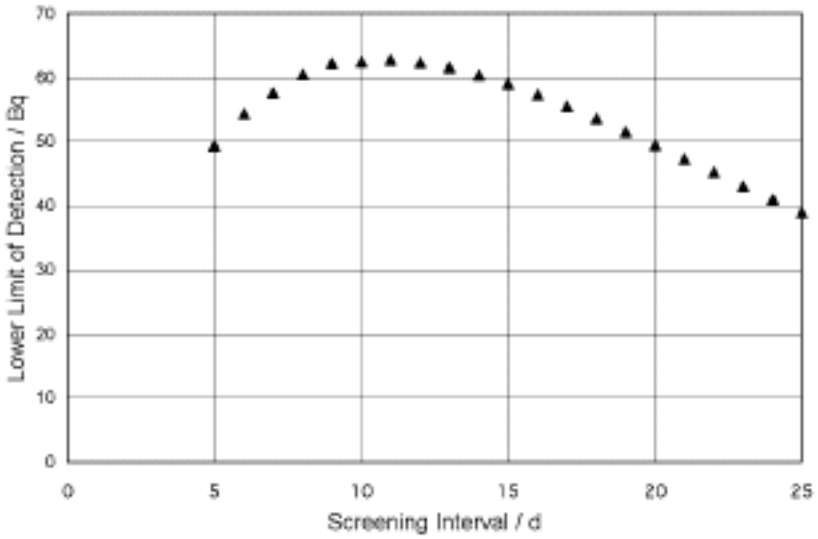

Figure 1: Required LLD for a thyroid probe according to the German regulations for ^{131}I

In table 3 the results of the screening are summarized. Overall there were more than 60 measurements. Due to shifts in the working schedule a regular screening within an interval of 14 days was hard to achieve.

The mean value of the measurements above the LLD is 48 Bq with a maximum of 193 Bq. Assuming a constant level of ^{131}I-activity in the thyroid of 48 Bq, an annual organ dose (thyroid) of 2.4 mSv is reached. The corresponding effective dose is 0.1 mSv.

ID	21.1.99	10.2.99	3.3.99	13.3.99	17.3.99	24.3.99	7.4.99	21.4.99	14.5.99	4.6.99	16.6.99
1		0			31	60	0				
2		25	129	176				101	20	31	
3	25	89			101				95		
4											
5	72	0	83	49	31			0	54		106
6		37		31	31	31	60			31	49
7											
8	60	49	54		54	118	77			118	66
9		0			54			43	25		
10											
11	37	20									
12	60		20								
13											
14	0		106	77*	66						
15	14		0	20**	0						
16	0	0					0		0		0
17	25	43	31		49		20	72		193	72
18				49			0			89	
19		0									

Table 3: Results of incorporation monitoring for ^{131}I at a large therapy ward
(all values are given in Bq, 0: less than 13 Bq, Blank: not monitored, *plus 600 Bq ^{123}I, **plus 300 Bq ^{123}I)

Regular screening for a specified group of people is easily done. The results of our measurements are in good agreement with previous measurements carried out in Essen [1]. In this study higher values were found for the ^{131}I activity level in the thyroid which can be explained easily by the fact that at that time the therapy ward in Essen had no air conditioning system.
The highest dose reached via incorporation is less than the exposure measured by external dosimetry with a film badge. Nevertheless, the internal exposure cannot be neglected.

Conclusions

To conclude one can say that monitoring of personnel in research labs is required only for persons handling high activities (compared to the ALI) of radioactive isotopes (e.g. synthesis of new radiopharmaceuticals). In a clinical environment (e.g. radioiodine therapy) there is an incorporation risk only when using ^{131}I for radioiodine therapies. For the other isotopes the risk can usually be neglected with the exception of accidental incorporation.

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