Comparison of surface contamination monitors for in vivo measurement of ^{131}I in thyroid

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Abstract: The routine handling of radiopharmaceuticals in nuclear medicine represents a significant risk of internal exposure to the staff. The IAEA recommends the implementation of monitoring plans for all workers subject to a risk of exposures above 1 mSv per year. However, in Brazil, such recommendation is practically unfeasible due to the lack of a sufficient number of qualified internal dosimetry services over the country. This work presents an alternative based on a simple and inexpensive methodology aimed to perform in-vivo monitoring of 131I in thyroid using portable surface contamination probes. All models evaluated showed suitable sensitivity for such application.

Keywords: Internal dosimetry, iodine-131, radiation protection, nuclear medicine.

1. INTRODUCTION

The handling of radioisotopes in the nuclear medicine cycle (production and clinical use of radiopharmaceuticals) represents a risk of internal and external exposures to the workers. This requires the implementation of routine occupational monitoring plans. Currently, in Brazil there are approximately 430 Nuclear Medicine Services in operation and authorized by the Nuclear Regulatory Board [1]. In a significant number of such workplaces, workers are routinely exposed to the risk of intakes of ^{131}I, which is the most critical radionuclide in terms of internal exposure in nuclear medicine. However, it happens that, in Brazil, like in many other countries, there is not enough dosimetry laboratories qualified to offer internal monitoring of radionuclides. This work describes the evaluation of fifteen models of surface contamination probes as an alternative to implement an inexpensive methodology to perform in vivo thyroid monitoring of the workers using the equipment available in the nuclear medicine clinics and hospitals.

2. MATERIALS

2.1. Neck-thyroid phantom

A Neck-thyroid phantom containing 15211 Bq of ^{133}Ba in 10/06/2011 was used for the calculation of the calibration factor of each probe. The phantom is made of polyurethane-base tissue equivalent material (Figure 1). A filter paper simulating a human thyroid is spiked with a known amount of the certified ^{133}Ba liquid source.

Figure 1. Neck-thyroid phantom developed at the *In-Vivo* Monitoring Laboratory of IRD [2].

2.2. Portable surface contamination monitors

Table 1 presents a list of fifteen equipment evaluated in this work that have been previously calibrated at the *Laboratório Nacional de Metrologia das Radiações Ionizantes* (LNMRI-IRD) and at the *Laboratório de Ciências Radiológicas* (LCR-UERJ).

Table 1. List of Portable monitors evaluated.

Trade Mark	Model	Quant.	Type
Eberline	E-120	1	Geiger-Muller
Prólogo	PSN-7013	1	Geiger-Muller
Berthold	LB-124 Scint	1	Scintillator
IEN	MIR-7026	2	Geiger-Muller
MRA	GP-500	1	Geiger-Muller
Polimaster	PM 1400	1	Geiger-Muller
Thermo Scient.	RadEye B20	1	Geiger-Muller
Tech. Associates	PUG-7A	1	Geiger-Muller
Dosimeter	3007A	1	Geiger-Muller
Tracerco	T401	1	Geiger-Muller
Ludlum	Model 3	3	Geiger-Muller
Thermo Scient.	Identifinder	1	Scintillator

3. METHODS

3.1. Calibration of the monitors

The calibration procedure was conducted as follows:

Step 1: The ^{131}I equivalent activity of the phantom was calculated as 16684 Bq according to equation (1) and corrected for radioactive decay taking into account the half-life of ^{133}Ba and the time elapsed between the dates of source fabrication and calibration of the probe.

$$\text{At Eq I}^{131}{}_{Bq} = \text{A (Ba}^{133}\text{) x } \frac{\Sigma\ (\gamma\ \text{Ba}^{133})}{\Sigma\ (\gamma\ \text{I}^{131})} \qquad (1)$$

Where At Eq I^{131} = Equivalent activity of ^{131}I;

A (Ba^{133}) = Activity of ^{133}Ba (Bq) present in the phantom; Σ (γ Ba^{133}) = Sum of emission intensities γ of ^{133}Ba; and Σ (γI^{131}) = Sum of emission intensities γ of ^{131}I.

Step 2: The measurement setup was established as shown in Figure 2, and the phantom count rate was recorded over five sequential measurements at the standard geometry of 3 cm between the detector front and the phantom surface.

Step 3: A blank phantom was measured in five sequential counts in the same setup for background account.

Step 4: The calibration factors were calculated for the standard geometry according to equation (2):

$$\text{CF}_{cpm/Bq} = \frac{\text{cpm}}{\text{A}_{\text{calib}}} \qquad (2)$$

Where: cpm = net count rate (total cpm of phantom subtracted by background count rate); and A_{calib} = ^{131}I equivalent activity content of the phantom.

Figure 2. Calibration setup of the portable monitor using a Neck-thyroid phantom.

3.2. Evaluation of sensitivity

The evaluation of the sensitivity of the method for its application in routine internal monitoring is based on the calculation of three parameters: (i) Minimum Detectable Activity (MDA); (ii) Minimum Detectable Intake (MDI) and; (iii) Minimum Detectable Effective Dose (MDED).

The MDA of the method is calculated as follows [3]:

$$\text{MDA}_{Bq} = \frac{4{,}65 \text{ x } \sqrt{\text{N}}}{\text{CF}} \qquad (3)$$

Where: N = Total counts of the background in 1 minute; and CF = Calibration Factor (cpm/Bq).

In order to be considered useful for internal monitoring purposes, the technique should, at least, be able to detect an activity that would result in an effective dose below 1 mSv per year for the most likely internal exposure scenario [4].

The MDI is a function of the MDA and depends on the exposure scenario and time, in days, elapsed between intake and *in-vivo* measurement. In this work MDI and MDED where calculated for retention fractions "m(t)" values of 1 and 7 days.

The Minimum Detectable Intake (MDI) is calculated as follows:

$$\mathrm{MDI}_{Bq} = \mathrm{MDA} / \mathrm{m(t)}_{inh\ or\ ing} \quad (4)$$

Where: MDA = Minimum Detectable Activity (Bq); and m(t) = Retention fraction in the compartment of interest for inhalation or ingestion (Bq/Bq).

The last parameter to be calculated is the Minimum Detectable Effective Dose, based on the MDI, considering the dose coefficients associated to the corresponding intake scenario adopted in the simulation. It is calculated as follows:

$$\mathrm{MDED}_{mSv} = \mathrm{MDI}_{inh\ or\ ing} \times \mathrm{e(g)}_{inh\ or\ ing} \quad (5)$$

Where: MDI = Minimum Detectable Intake (Bq); and $e(g)_{inh\ or\ ing}$ = Dose coeficiente (mSv/Bq).

The values of "m(t)" and "e(g)", presented in table 2, are available in the Publication 78 of the ICRP [5] and may also be generated for specific exposure scenarios and times after intake through the software AIDE [6].

Table 2. Retention fractions and dose coefficients generated with the software AIDE.

m(t) (Bq/Bq)				e(g) (mSv/Bq)	
1 day		7 days		Inh	Ing
Inh	Ing	Inh.	Ing	1.98×10^{-5}	2.17×10^{-5}
0.229	0.252	0.229	0.252		

4. RESULTS

Table 3 presents the results of the counts, calibration factors, minimum detectable activities and minimum detectable intakes for each detector. Detector count rates were recorded in cpm for harmonization purposes since some models present output in cpm and others in cps (values in cps were multiplied by 60). The values of MDI correspond to an intake by inhalation considering the time of 1 day elapsed between intake and measurement.

Table 3. Results of calibration performed at the standard geometry of 3 cm.

Detector	Counts (cpm)	CF (cpm/Bq)	MDA (Bq)	MDI (Bq)
E-120	100	0.0069	6708	29294
GP-500	72.5	0.0153	3782	16515
PSN-7013	47.5	0,0100	3948	17240
MIR-7026 #1	33	0.0069	6094	26612
LB-124 Scint	4020	0.8439	220	962
PM 1400	101.76	0.0078	2823	12330
MIR-7026 #2	125.40	0.0096	5123	22373
RadEye B20	173.64	0.0133	2945	12862
PUG-7A	262	0.0202	4033	17610
3007A	200	0.0154	2554	11154
T401	113.4	0.0087	4429	19341
Model 3 #1	116.4	0.0089	4202	18349
Model 3 #2	160	0.0124	3553	15516
Model 3 #3	146.4	0.0113	3234	14120
Identifinder	25811	2.0127	310	1354

Table 4 presents the values of MDED calculated according to the methodology described previously.

The values correspond to the calibrations performed at 3 cm and considering times of 1 and 7 days elapsed between intake and measurement. It can be observed that there are not much significant difference between values of MDED calculated assuming inhalation or ingestion. This fact is related to the biokinetic and dosimetric models of ^{131}I and reduces the uncertainty on internal dose estimations.

Table 2. Minimum Detectable Effective Doses for 1 and 7 days after intake. Measurements performed at the standard geometry of 3 cm.

Detector	MDED (mSv)			
	1 day		7 days	
	Inh	Ing	Inh	Ing
LB-124 Scint	0.019	0.019	0.031	0.031
Identifinder	0.027	0.027	0.044	0.044
3007A	0.221	0.220	0.364	0.360
PM 1400	0.244	0.243	0.402	0.398
RadEye B20	0.255	0.254	0.420	0.415
Model 3 #3	0.280	0.278	0.461	0.456
Model 3 #2	0.307	0.306	0.506	0.501
GP-500	0.327	0.326	0.539	0.533
PSN-7013	0.341	0.340	0.562	0.556
PUG-7A	0.349	0.347	0.574	0.568
Model 3 #1	0.363	0.362	0.599	0.592
T401	0.383	0.381	0.631	0.624
MIR-7026 #2	0.443	0.441	0.730	0.722
MIR-7026 #1	0.527	0.525	0.868	0.859
E-120	0.580	0.578	0.956	0.945

5. CONCLUSIONS

Among the models evaluated in this work, the ones which presented the highest sensitivity were the Berthold LB-124 SCINT and the Thermo Scientific Identifinder. For such models, the MDED were estimated as 0.019 mSv and 0.027 mSv respectively, assuming an *in-vivo* measurement performed 1 day after an intake by inhalation or ingestion, and a MDED of 0.031 mSv and 0.044 mSv, respectively, for a measurement performed 7 days after the intake. These results rely on the fact that such models are made with scintillation crystals, ZnS(Ag) and NaI(Tl) respectively, resulting in a higher efficiency for photons when compared to Geiger-Muller based detectors. The Eberline E-120, a Geiger-Muller probe, presented the least sensitive output. In this case the estimated MDED were 0.58 mSv and 0.95 mSv respectively for measurements performed 1 and 7 days after an intake by inhalation or ingestion. However, even considering the differences in sensitivity among the various models, it can be concluded that all probes evaluated are suitable for the proposed application since all of them present enough sensitivity to perform measurements 7 days after the intake of an activity of ^{131}I that would result in an effective dose below 1 mSv for the simulated exposure scenario proposed in this work.

6. REFERENCES

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