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Article

Assessing the need for a routine monitoring program in three Nuclear Medicine centers in Chile

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Abstract – The workers performing different activities with radionuclides in nuclear medicine centers are at potential risk of external exposure and internal contamination. The IAEA Safety Guide N° RS-G-1.2 proposed criteria for determining the need for a routine monitoring program to assess internal contamination. For this purpose, an Excel template containing the IAEA criteria was applied in three nuclear medicine centers in Chile. The results show that it is necessary to carry out a routine monitoring program for five workers who handle ^{131}I and three for ^{99m}Tc. We propose to implement this template at a national level in order to improve the conditions of radiation protection in the participating centers.

Keywords: nuclear medicine / occupationally exposed worker / internal contamination / routine monitoring program

1 Introduction

Occupationally exposed workers of nuclear medicine centers routinely use different unsealed radionuclide sources for diagnostic and therapeutic procedures. There is an external and internal exposure risk due to the chemical and physical properties, and handling and protection conditions of the radionuclide. A study developed for nuclear medicine centers in Switzerland concluded that external exposure is the greatest contributing factor to the total effective dose of workers, while internal exposure contributes ~1% to the collective dose (Frei *et al.*, 2007). The following expression is used to evaluate the total effective dose, E (ICRP, 2007):

$$E = H_p(10) + E(50), \tag{1}$$

where $H_p(10)$ is the equivalent dose due to external exposure and $E(50)$ is the committed effective dose due to intake of radionuclides, which is evaluated by (IAEA, 1999a):

$$E(50) = \sum_j e_{j,\,inh}(50) \times I_{j,\,inh} + \sum_j e_{j,\,ing}(50) \times I_{j,\,ing}, \tag{2}$$

where $e_{j,inh}(50)$ is the committed effective dose coefficient per incorporated activity for inhalation of a radionuclide j, $I_{j,inh}$ is the incorporated activity of the radionuclide for inhalation, $e_{j,ing}(50)$ is the committed effective dose coefficient of incorporated activity for ingestion of radionuclide j, and $I_{j,ing}$ is the incorporated activity of radionuclide j for ingestion.

According to the Basic Safety Standards (IAEA, 2014), a routine monitoring program should be performed on workers in controlled areas where there are risks associated with incorporation of radionuclides. The International Atomic Energy Agency (IAEA) suggests, in its publication RS-G-1.2, quantitative criteria to enroll a worker in a monitoring program (IAEA, 1999b). The criteria are based on the evaluation of several factors to estimate the dose due to intake of radionuclides in the workplace. The decision to implement an internal monitoring program is carried out when the evaluation results in an annual committed effective dose equal to or higher than 1 mSv.

This study shows the application of IAEA criteria in three Nuclear Medicine centers of Chile to determine the need for a routine monitoring program.

2 Materials and methods

The need to implement an internal monitoring program is evaluated by the decision factor d; when d is equal to or higher than 1 mSv, individual monitoring should be carried out on the worker. The decision factor d is described by the IAEA (1999b):

$$d_j = \frac{A_j e(g)_j f_{fs} f_{hs} f_{ps}}{0.001}, \tag{3}$$

where A_j is the average annual activity of the radionuclide j handled by a worker; $e(g)_j$ is the dose coefficient for inhalation of 5 μm aerosols of radionuclide j by a worker (Sv Bq^{-1}); f_{fs} is a safety factor as the physical form of the radionuclide manipulated based on its physical and chemical properties; the value used was 0.01, which is reported for nonvolatile powder and liquid material (Hickey *et al.*, 1993); f_{hs} is a handling safety weighing factor based on experience from operations

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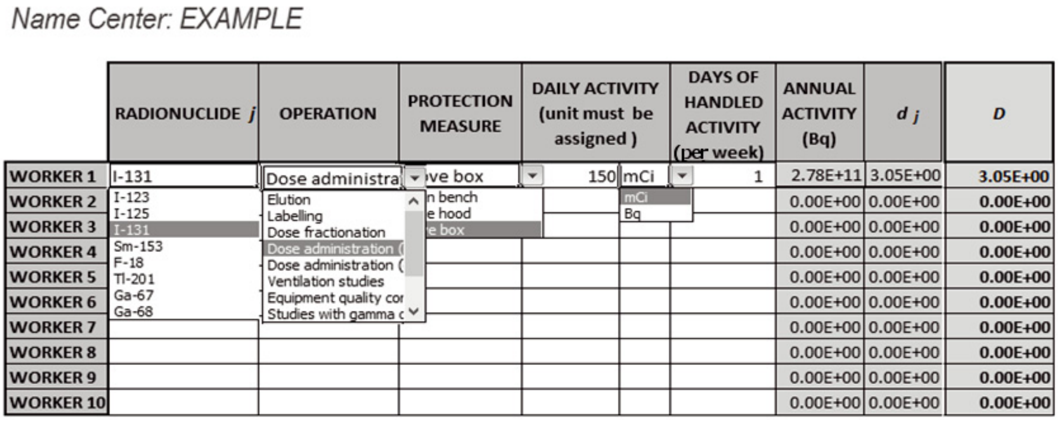

Figure 1. The Excel template calculates the decision factor d for every radionuclide handled by a worker based on the IAEA Safety Guide RS-G 1.2 (IAEA, 1999b). The user can to select drop-down lists representing different workplaces and handling conditions. The daily activity and days per week of the radionuclide handled are entered. The annual activity is automatically calculated considering 50 weeks worked per year. The d factor is displayed for each radionuclide. Finally, D is calculated and displayed.

and the presentation of radionuclide j; f_{ps} is a protection safety weighing factor, based on permanent use of protection instruments in the workplace (*i.e.* gloves, fume hood) and 0.001 is a conversion factor from Sv to mSv. The factor f_{hs} used in our case was reported by Bento *et al.* (2012) because they consider greater diversity of the operations.

The decision factor for all radionuclides handled by workers in the workplace is the sum of all d factors. Thus, the total decision factor D is evaluated by the following expression (IAEA, 1999b):

$$D = \sum_{j} d_j. \tag{4}$$

The calculation of the total decision factor D is used to determine the need for individual monitoring of workers. If $D \geqslant 1$, individual monitoring is necessary (IAEA, 1999b).

If more than one radionuclide is handled in the workplace, decisions to conduct individual monitoring for the separate radionuclides may be based on the following criteria (IAEA, 1999b):

1) all radionuclides for which $d_j \geqslant 1$ shall be monitored;
2) when $D \geqslant 1$, radionuclides for which $d_j \geqslant 0.3$ should be monitored;
3) monitoring of radionuclides for which d_j is much less than 0.1 is unnecessary.

According to IAEA criteria, workers with $d_j \geqslant 1$ shall be monitored, mainly in the case of ^{131}I due to its higher toxicity.

For the application of the proposed IAEA criteria and determination of the decision factor, an easy tool based on an Excel template was designed, which is shown in Figure 1. This template includes $e(g)_j$ coefficients (ICRP, 2012), f_{ps} factors proposed by the IAEA (1999b) and f_{hs} factors reported by Bento *et al.* (2012). The factors used in the template are shown in Tables 1–3.

The template was applied to staff that directly perform diagnostic and therapeutic procedures with radionuclides in three Nuclear Medicine centers located in Chile. Two of the Nuclear Medicine centers are in Temuco and one is in Santiago. The type and frequency of operations performed by each worker were obtained from the daily reports of each center and personnel interviews. Later, these data, with the respective activity and numbers of days per week that a particular operation is performed, are entered into the template. The annual activity A_j is automatically calculated, considering that the occupationally exposed worker is working 50 weeks per year. Finally, the Excel template displays the decision factor d_j and the factor D, which are calculated by equations (3) and (4), respectively.

Table 1. Dose coefficients for inhalation of 5 μm$^{(*)}$ aerosols according to the radionuclide handled (ICRP, 2012). $^{(*)}$ AMAD = 5 μm (ISO, 2006).

Radionuclide	$e(g)_{\text{inh}}$ (Sv Bq^{-1})
^{99m}Tc	2.0×10^{-11}
^{131}I	1.1×10^{-8}
^{67}Ga	2.8×10^{-10}
^{111}In	3.1×10^{-10}
^{123}I	1.1×10^{-10}
^{125}I	7.3×10^{-9}
^{153}Sm	6.8×10^{-10}
^{18}F	8.9×10^{-11}
^{201}Tl	7.6×10^{-11}
^{68}Ga	8.1×10^{-11}
^{89}Sr	1.4×10^{-9}
^{90}Y	1.6×10^{-9}

Table 2. Protection safety factors (f_{ps}).

Protection measure	Protection safety factor f_{ps}
Open bench	1
Fume hood	0.1
Glove box	0.01

3 Results and discussion

Table 4 presents the results of d and D for all workers from the three Nuclear Medicine centers participating in this study,

Table 3. Handling safety factors (f_{hs}) (Bento *et al.*, 2012).

Operation	Handling Safety factor f_{hs}
Elution	1
Labeling	1
Dose fractionation	1
Dose administration (injection)	1
Dose administration (capsules)	0.01
Ventilation studies	1
Equipment quality control	0.01
Studies with gamma camera and PET scanner	0.01
RIA techniques	10
Radioactive waste management	0.01

Table 4. *d* and *D* factors for all workers from the three nuclear medicine centers participating in this study.

		Radionuclide	Operation	d_j	D
CENTER 1	worker 1	^{99m}Tc	Elution	4.97	1.12×10^2
			Injection	3.70	
			Fractionation	6.22×10^1	
			Labeling	4.07×10^1	
		^{131}I	Capsule administration	3.66×10^{-1}	
		^{67}Ga	Injection	2.59×10^{-1}	
	worker 2	^{99m}Tc	Radioactive waste management	1.85×10^{-4}	1.85×10^{-4}
	worker 3	^{131}I	Capsule administration	1.37	1.37
CENTER 2	worker 1	^{99m}Tc	Elution	4.75	8.21×10^1
			Injection	1.83	
			Fractionation	4.75×10^1	
			Labeling	2.78×10^1	
			Radioactive waste management	1.85×10^{-4}	
		^{131}I	Radioactive waste management	1.83×10^{-1}	
	worker 2	^{131}I	Capsule administration	2.65	2.65
CENTER 3	worker 1	^{99m}Tc	Labeling	4.63×10^1	5.2×10^1
			Injection	4.63	
		$^{1.31}$I	Gamma camera studies	1.12	
	worker 2	^{131}I	Capsule administration	2.04	2.04
	worker 3	^{99m}Tc	Gamma camera studies	4.63×10^{-2}	1.17
		^{131}I	Gamma camera studies	1.12	

where mainly ^{99m}Tc and ^{131}I are handled. ^{67}Ga is also used in center 1, for which $d_j < 1$ was obtained. Factor $D > 1$ for all workers, except for worker 2 in center 1, because most workers perform many operations (elution, fractionation, labeling and injection). Therefore, a routine monitoring program should be implemented for most of the workers handling ^{99m}Tc and ^{131}I with $d \geqslant 1$ mSv, and especially for staff handling ^{131}I due to the higher radiotoxicity levels and semi desintegration period. The quantification of intake for both radionuclides can be obtained by means of *in vitro* measurements, using urine samples, or *in vivo* assessment from thyroid gland measurements for ^{131}I, and whole-body counting for ^{99m}Tc.

The elution, fractionation and labeling are performed manually in the studied centers. Automated systems could decrease the values of the *d* factor, improving the conditions for radiological protection in the workplace.

The Supreme Decree No. 3 of Radiation Protection for Chilean radioactive facilities provides, in Article Nº 16, performance of quarterly measurements in urine samples for the case of ^{131}I (Ministerio de Salud, 1985). However, this study shows that *in vitro* or *in vivo* measurements should be carried out routinely in order to enhance the radiological protection in Nuclear Medicine centers that use ^{131}I.

The implementation of a routine monitoring program on workers evaluated under IAEA criteria will make it possible to estimate the committed effective dose (IAEA, 1999b). Thus, the dose due to intake of radionuclides will be added to the external dose in order to obtain the total dose of the exposed worker.

4 Conclusion

The template used for *d* and *D* factor evaluation, based on IAEA Safety Guide RS-G-1.2 (1999b) criteria, is an easy tool that was applied in the centers participating in this study. This template can be extended to other centers of Nuclear Medicine in Chile to determine whether it is necessary or not to implement a program of routine monitoring. Moreover, the template could be useful for the intake estimation of other radionuclides used for diagnostic and therapeutic procedures.

Considering that the decision factor assessment overestimates the committed effective dose, the results show that it is necessary to carry out a routine monitoring program for five workers who handle ^{131}I and three for ^{99m}Tc. Workers that handle ^{99m}Tc should be redistributed in their practices and/or their radiological protection conditions should be improved, in order to decrease d and D values. The use of automated systems could obtain d and D values below 1 mSv. The quantification of intake of ^{99m}Tc could be obtained by means of *in vitro* measurements (*i.e.* using urine samples) or whole-body counting. For workers handling ^{131}I, a routine monitoring program must be carried out using urine samples or thyroid gland measurements.

In order to optimize the radiation protection in each center, we recommended performing the following redistribution of tasks: in center 1, worker 2 should take on some of worker 1's tasks; in center 3, worker 3 should undertake some of worker 1's tasks. Nonetheless, after assessing the redistribution of tasks in each center, the results show that there is no significant decrease in the potential contamination rate for each worker; *e.g.* in center 1, worker 2 should perform injection and labeling; adding these two operations to worker 2, the D factor for worker 1 equals 6.78×10^1 and 4.4×10^1 for worker 2. It was observed that despite applying the above proposed actions, D values are still higher than 1. Therefore, we recommend that each center hires additional personnel in order to maintain $D < 1$. Although this situation would imply further investment from the centers in the short term, it will certainly ensure better radiological protection, which will benefit the staff in the long term.

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References

Bento J. *et al.* (2012) Study of Nuclear Medicine practices in Portugal from an internal dosimetry perspective, *Radiat. Prot. Dosim.* **149**, 438-443.

Frei D. *et al*. (2007) Integration of external and internal dosimetry in Switzerland*, Radiat. Prot. Dosim.* **125**, 47-51.

Hickey E.E., Stoetzel G.A., McGuire S.A., Strom D.J., Cicotte G.R., Wiblin C.M. (1993) Air Sampling in the Workplace, NUREG-1400.

IAEA (1999a) Occupational Radiation Protection, Safety Guide N° RS-G-1.1.

IAEA (1999b) Assessment of occupational exposure due to intake of radionuclides Safety Guide No. RS-G-1.2.

IAEA (2014) Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards, General Safety Requirements Part 3 No. GSR Part 3.

ICRP Publication 66 (1994) Human Respiratory tract model for radiological protection *Ann. ICRP* **24** (1-3).

ICRP Publication 103 (2007) The 2007 Recommendations of the International Commission on Radiological Protection *Ann. ICRP* **37** (2-4).

ICRP Publication 119 (2012) Compendium of Dose Coefficients based on ICRP Publication 60, *Ann. ICRP* **41** *(Suppl.).*

ISO 20553 (2006) Radiation protection monitoring of workers occupationally exposed to a risk of internal contamination with radioactive material.

Ministerio de Salud, Dpto. Asesoría Jurídica (1985) Reglamento de Protección Radiológica de Instalaciones Radiactivas, Decreto Supremo N° 3.

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