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Determination of uncertainties associated to the *in vivo* measurement of iodine-131 in the thyroid

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HIGHLIGHTS

- Uncertainties associated to the *in vivo* measurement of ^{131}I were evaluated.
- Both systems presented reliable techniques for occupational monitoring purposes.
- Activity distribution and overlaying structures are the most critical parameters.
- The uses of a mechanical coordinate system is recommended to guarantee reproducibility.
- Geometric deviation values are comparable to international standards.

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ABSTRACT

Intakes of radionuclides can be estimated through in vivo measurements, and the uncertainties associated to the measured activities should be clearly stated in monitoring program reports. This study aims to evaluate the uncertainties of in vivo monitoring of iodine 131 in the thyroid. The reference values for high-energy photons are based on the IDEAS Guide. Measurements were performed at the *In Vivo* Monitoring Laboratory of the Institute of Radiation Protection and Dosimetry (IRD) and at the Internal Dosimetry Laboratory of the Regional Center of Nuclear Sciences (CRCN-NE). In both institutions, the experiment was performed using a NaI(Tl) 3″3″ scintillation detector and a neck-thyroid phantom. Scattering factors were calculated and compared in different counting geometries. The results show that the technique produces reproducibility equivalent to the values suggested in the IDEAS Guide and measurement uncertainties is comparable to international quality standards for this type of *in vivo* monitoring.

1. Introduction

The internal dose resulting from the intake of radionuclides can ´t be measured directly. In practice, it must be assessed from individual monitoring, either *in vivo* or *in vitro*, through the analysis of biological indicators. The use of *in vivo* methods for internal dosimetry consists in the qualitative and quantitative determination of radionuclides present in the human body and in specific organs or tissues ((International Atomic Energy Commission) (IAEA), 1999). According to the Brazilian Association of Technical Regulations ((Associação Brasileira de Normas Técnicas) (ABNT), 1998), when reporting the result of the measurement of a physical quantity, it is required to report an indication of the quality of the result, so that those who use it can evaluate its reliability. Without this indication, measurement results can't be compared, either among themselves or with reference values provided in a specification or a norm. Therefore it is necessary to have a procedure readily implemented, easily understood and generally accepted to characterize the quality of a result of a measurement, that is, to evaluate and express its uncertainty (ISO Guide to the Expression of Uncertainty in Measurement).

Measurement uncertainties are usually difficult to estimate. When activity levels are low and close to the detection limit, uncertainties due to counting statistics may dominate the overall uncertainty. For radionuclides that are easily detected and present

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Table 1
Typical scattering factors for *in vivo* measurement of radionuclides emitting photons with energies > 100 keV (Castellani et al., 2013).

Source of uncertainty (Type)	SF
Counting statistics (A)	1.07
Variation of detector positioning (B)	< 1.05
Variation of background signal (B)	< 1.05
Variation of overlaying structures (B)	1.12
Variation of activity distribution (B)	< 1.05
Variation in body dimensions (B)	1.07
Calibration (B)	1.05

in sufficient quantities, uncertainties due to counting statistics will be small compared to the other sources of uncertainty. Consideration must also be given to systematic uncertainties in other parameters of the measurement procedure, calibration, or correction for body size of *in vivo* measurements (Kramer and Meyerhof, 1994). These uncertainties apply to the measurement of activity in the sample or person. The main sources of uncertainty associated to the *in vivo* monitoring process are presented in Table 1, with their respective scattering factors of radionuclides emitting low, medium and high photon energy radiation. In addition to the parameters suggested by the IDEAS Guide (Castellani et al., 2013), counting fluctuations may occur due to the positioning of the phantom, i.e. the reproducibility of the counting geometry. Thus, the aim of this study is to assess the sources of uncertainty associated with *in vivo* monitoring of ^{131}I in the thyroid carried out in two different *in vivo* counting systems.

2. Materials and methods

2.1. Calculations of total scattering

The uncertainties evaluated in this work are expressed in terms of scattering factors. Such approach assumes that the distribution of the counts can be described by a log-normal function. Thus, the scattering factor is calculated as the geometric standard deviation of the distribution, as suggested in the IDEAS Guide (Castellani et al., 2013). The scattering factor associated to each individual component and the total scattering factor of the method can be calculated according to (Eqs. (1) and 2) respectively.

$$SFi = \exp\left[\sqrt{\sum_i \ln^2\left(\frac{x_i}{\bar{x}}\right)}\right] \quad (1)$$

$$SF = \exp\left[\sqrt{\sum_i \ln^2(SFi)}\right] \quad (2)$$

Where *SF* is the total scattering factor and *SFi* is the scattering factor due to component I; x_i is counting value of component I and x(bar) is the corresponding mean count of the experiment.

The scattering factors presented in the IDEAS Guide should be understood as reference values, and used only for comparison purposes. They should not be considered as real values applicable to all detection systems and geometries. It should also be highlighted that the Guide does not detail the experimental procedure adopted to obtain the scattering factors presented in the document, but only energy ranges as a reference for comparison.

The experiments were carried out at In Vivo Monitoring Laboratories located in IRD (System A) and CRCN (System B), where the standard thyroid monitoring geometries consist, respectively, in positioning a NaI(Tl) 3 × 3″ scintillation detector at 15 and 21 cm from subject's neck (Fig. 1). The 21 cm distance is the collimator length at the system B.

In the present work, the uncertainty associated to the following parameters were evaluated using a thyroid phantom containing a standard source of ^{133}Ba, a simulator for ^{131}I, frequently used for this application because of its longer half-life compared to ^{131}I and the equivalence of their photon emissions (Dantas et al., 2011).

2.2. Counting statistics

A series of ten 15-minutes counts were carried out in thyroid geometry in order to quantify the effect of counting statistics on the measurement uncertainty.

2.3. Detector positioning

This experiment aims to simulate the movement of the subject during the counting; therefore, a series of fifteen 5-minutes counts were performed in different positions in relation to the standard geometry (15 cm or 21 cm distance between the thyroid phantom and the detector, at counter systems A or B, respectively), as shown in Figs. 2 and 3. In the case of System B, it is not possible to move the detector forward because, at the standard geometry, the collimator is already in contact to the neck surface.

2.4. Background signal

This experiment was performed in the standard thyroid geometry. The procedure consisted in counting a group of 10 unexposed subjects in series of 15-minutes counts each.

2.5. Overlaying structures

Acrylic plates were used to simulate different thicknesses of the tissue over the region of the thyroid. The acrylic was chosen due to its attenuation characteristics of photons that are similar to human tissue (International Commission on Radiation Units (ICRU), 1989). Five plates were produced with thicknesses ranging from 0.5 to

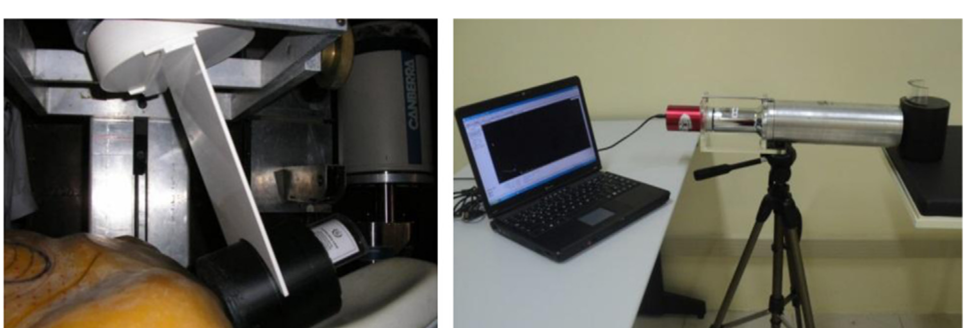

Fig. 1. Standard geometry used for thyroid monitoring at Systems A and B.