CALIBRATION OF THE LNMRI SECONDARY STANDARD IONIZATION CHAMBER FOR ^{131}I CAPSULES USED IN NUCLEAR MEDICINE

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Abstract: The radionuclide ^{131}I has been increasingly used in nuclear medicine therapy procedures. Nowadays, the ^{131}I source administered to the patient is manufactured in two different geometries: solution and capsules. The purpose of this study is the measurement of the activity present in a ^{131}I capsule without destroys it. The methodology to determine the capsules activity and the calibration factor was developed using an IG12 secondary standard activity measurement system based on the well-type ionization chamber set up at Brazilian National Laboratory for Ionizing Radiation Metrology (LNMRI) of Institute of Radiation Protection and Dosimetry (IRD).

Key words: Nuclear Medicine, Activity Standardization, Metrology Quality, ^{131}I.

1. INTRODUCTION

Cancer is one of the most public health troubles, and thyroid cancer represents among 1 and 2% of the cancers. However, is the most common endocrine cancer and its occurrence has been increasing lately. The thyroid is a gland that is located in front of the neck and is responsible for the production of two important hormones, T3 and T4 that control body metabolism speed, body development and nervous system activity [1]. The Radioiodine Therapy is a nuclear medicine procedure that treats thyroid cancer cells after thyroidectomy, the removal of the gland thyroid surgically. In Radioiodine Therapy, ^{131}I capsules or solutions are ingested by patients and the beta radiation emitted by this nuclide is responsible for deliver a high radiation dose to the thyroid cells, capable to kill them. Nowadays most of the clinics and hospitals use ^{131}I in capsules, however, commercial radionuclide calibrators (or dose calibrators) commonly used in nuclear medicine centers don't have calibrator factor to measure ^{131}I activities in capsule geometry. In Brazil, the measurement of the activity that a patient will receive in a nuclear medicine procedure mustn't overcome 10% of accuracy, and the international recommendations point to 5% [2,3].

2. PURPOSE

When radionuclide calibrators are manufactured, they are subjected to different calibrations, for the various radionuclides used in nuclear medicine practices. For each nuclide and specific vial geometry, one calibration factor is determined, and usually applied to a dial that will have to be selected according to the nuclide to be measured. Radionuclide calibrators found in nuclear medicine centers as well as the LNMRI IG12 secondary standard ionization chamber don't have calibration factor to measure ^{131}I in capsule geometry. There is only calibration factor to measure ^{131}I solution contained in glass ampoule. The main aim of this study is to calibrate the LNMRI secondary standard ionization chamber for ^{131}I in capsule geometry. Thus secondary standards can be produced and be used to calibrate the radionuclide calibrators of nuclear medicine centers obtaining more accurate measurements of activity or radiopharmaceuticals. Accurate measurements are required by the need to optimize the radiation dose received by the patient and at the same time, achieve the intended objective (image quality for diagnostic and therapeutic outcome).

3. METHODOLOGY

In order to determine the calibration factor for capsules, two different methodologies were carried out. The first one, consisted in contaminate original inactive capsules, provided by Nuclear and Energetics Research Institute (IPEN), the same institute that provide the ^{131}I contaminated capsules in Brazil for the nuclear medicine centers. The other one, consisted in dissolve contaminated capsules, provided by IPEN, identical to that provided to the nuclear medicine centers. In the first method mentioned, a capsule containing inactive NaI salt is contaminated with a known activity of a solution of ^{131}I using a syringe. The capsule is placed into a 10R Type 1+ Schott vial and the ion current generated by

this capsule in the ionization chamber is measured and related to added activity obtaining thus the intended calibration factor in A/Bq (ampere/becquerel). In the second method, the ion current of ^{131}I capsule is measured in the ionization chamber and after quantitatively dissolved in distillated water heated to 35 ^{0}C. Weighted aliquot of the dissolved solution is transferred to the glass ampoule and the original activity of the capsule is determined in the IG12 ionization chamber using the calibration factor previously determined by the absolute 4πβ-γ coincidence counting method with traceability to the Internacional Reference System of Bureau International des Poids et Mesures (SIR/BIPM). Knowing the activity and the ion current generated in the ionization chamber the calibration factor of ^{131}I for geometry of capsule is again determined. Block diagram of the procedure for determining the calibration factor of the second method is showed in Fig. 1. Finally one capsule of ^{131}I measured with this calibration factor were used to evaluate the performance of the commercial radionuclide calibrators routinely operated in several nuclear medicine centers of Rio de Janeiro city.

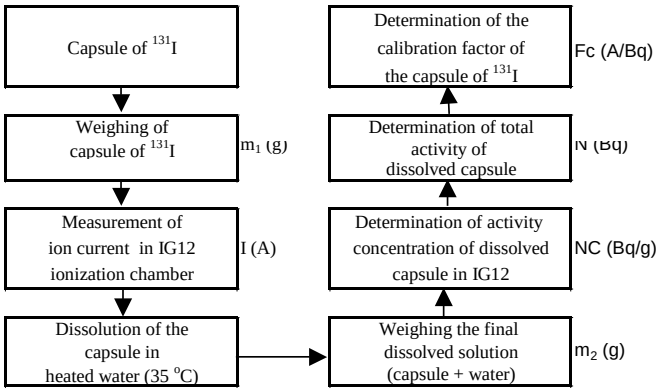

Fig.1 Block diagram of the procedure for determining the calibration factor of capsule of ^{131}I

4. RESULTS

In the first method a solution of ^{131}I with activity concentration of 120.198 ± 0.553 MBq/g in 05/10/2010 12h00 local time was used to contaminate three capsules. The traceability of this activity was established in the international key comparison organized by IAEA in 2006. The mass of the capsules varied from 0.559 to 0.592g, the added ^{131}I solution from 0.0235 to 0.0524 g and the added activity from 2.825 to 6.302 MBq. Each capsule placed inside the 10R vial was measured twice: in the second measurement the capsule was inverted over the first measurement to check possible geometric dependence. Table 1 shows the results of the determination of the calibration factors for capsules of ^{131}I. The application of Grubbs statistic test showed no evidence of the existence of any outlier in the evaluated results [5].

In the second method nine capsules were dissolved with heated water at 35 ^{0}C in order to obtain the calibration factor of IG12 ionization chamber, according the procedure described in Fig. 1. Table 2 shows the results.

Table 1. Measurement of calibration factor for IG12 ionization chamber by first method.

Capsule	Activity added (MBq)	Calibration factor (A/Bq x 10^{-18})	Standard uncertainty (%)
01	4.350	6.51609	0.48
01 inverted	4.350	6.52989	0.47
02	2.825	6.52914	0.47
02 inverted	2.825	6.54194	0.47
03	6.302	6.56760	0.47
03 inverted	6.302	6.58091	0.47
Weight mean		6.54473 ± 0.021022	

Table 2. Measurement of calibration factor for IG12 ionization chamber by second method

Capsule	Total mass of dissolved capsule (g)	Calibration factor (A/Bq x 10^{-18})	Standard uncertainty (%)
01	6.69998	6.38530	0.53
02	6.76462	6.45118	0.71
03	6.644530	6.43784	0.59
04	6.69422	6.41244	0.49
05	6.72551	6.44910	0.63
06	6.60810	6.43439	0.58
06	6.60810	6.44883	0.58
07	10.51968	6.49758	0.57
08	10.54464	6.49373	0.57
09	10.66196	6.47710	0;57
Weighted mean		6.44588 ± 0.01011	

Again no outlier was evident by applying the Grubbs test. The activity of a capsule of ^{131}I was measured with the calibration factor thus obtained and compared with the activity measured by some nuclear medicine centers of Rio de Janeiro city. The results are showed in Fig. 2 where R is the ratio of activity provided by the participant to activity determined at LNMRI and considered as the reference activity. The reference activity was measured in the second standard IG12 ionization chamber of LNMRI that is calibrated with a solution standardized by absolute coincidence method with traceability to SIR/BIPM. The results of LNMRI and other National Metrology Laboratories for ^{131}I activity measurements can be found in the Key Comparison Data Base (KCDB) of BIPM and presented in Fig. 3 [ ].

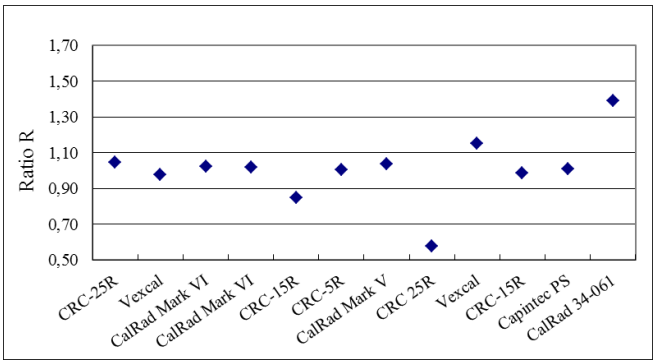

Fig. 2 Performance of the radionuclide calibrators of some nuclear medicine centers of Rio de Janeiro city.

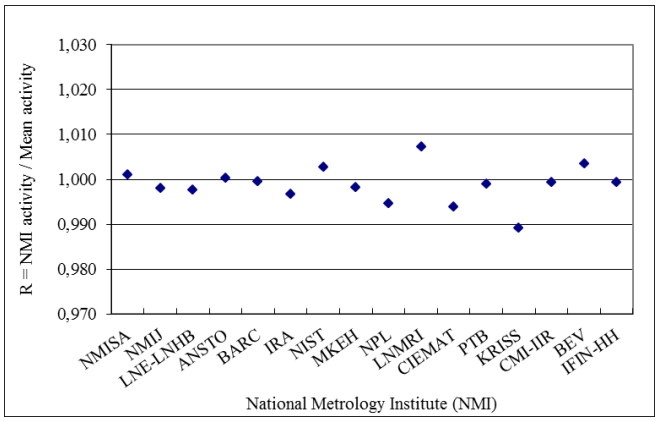

Fig. 3 International key-comparison of activity measurements of ^{131}I.

5. DISCUSSION

The calibration factor evaluated by first method is 1.5% higher than the second method. Applying the test of null hypothesis for the variances it appears that they are equals to a confidence level of 0.95. But when applied to the average values the null hypothesis is not accepted and they cannot be considered equals. A possible cause of this discrepancy could be the activity loss by evaporation, on the cap of the vial used to dissolve the capsule. New evaluation will be done to quantitatively determine this value. In the performance test 7 nuclear medicine centers with 12 radionuclide calibrators took part in the comparison. Four results were outside the limits of accuracy standard recommended by CNEN (±10%). One result underestimates by almost 50% and the other overestimates by more than 30% the activity demonstrating the need to implement a program of quality assurance and good practice for patient safety.

6. CONCLUSION

The results of this work have demonstrated that the IG12 well-type ionization chamber is appropriated to measure the activity of ^{131}I capsules without destroys it with accuracy suitable for nuclear medicine application. The results of performance test indicate that there is a real problem with capsules measurements in nuclear medicine centers due to the high activities involved. Further measurements are required to resolve the discrepancy identified between the two methods described in this work.

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