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Development of an “in situ” calibration methodology to activity meters

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Abstract. The performance of a safety and efficient practice of a nuclear medicine service depends, among other factors, on a complete quality control program, especially in the case of the radionuclide activity measuring instrument, the activimeter. Several factors may influence the accuracy of the measurements performed with an activimeter, and the largest sources of errors are related to the types of containers that contain radiopharmaceuticals (eg, thickness, size and volume). A complete quality control program should include the calibration of all measurement instruments used in the procedure. However, in Brazil, the actual standard that establishes the requirements of radiological protection for nuclear medicine services (NMS), does not include the calibration of the activimeter. Considering that these instruments, for various reasons, are difficult to remove for sending to a Calibration Service, the purpose of this work is to develop a methodology for activimeter calibration that can be applied "in situ" to the most used radiopharmaceutical, ^{99m}Tc.

Keywords. activimeter; radionuclide; calibration; 99mTc.

1. Introduction

Radionuclides used for therapy and diagnostics in nuclear medicine associated to a chemical, biological and physical function [1] act as a radioactive tracer allowing their evolution until the interest region. The ^{99m}Tc is used for about 90% of clinical routine [2], which are produced by generators, being continuously produced by the decay of ^{99}Mo. Its periodic extraction enables a constant supply in the form of generator in the nuclear medicine centers. The Instituto de Pesquisas Energéticas e Nucleares (IPEN) currently produces 38 different radiopharmaceuticals, besides being the only producer of Technetium Generators (^{99m}Tc) in the country [3].Radiopharmaceuticals (gamma and beta-emitting radioisotopes) before application to patients should be subjected to equipment measurements at the nuclear medicine service (NMS) to ensure an appropriate applied dose [4].One of the services provided by the Instrument Calibration Laboratory (LCI), of the IPEN, and used by several hospitals, industries and clinics located throughout Brazil is the calibration of radiation measuring instruments. This is carried out using secondary standard systems and following international and national recommendations. [4,5,6,7,8]. The Comissão Nacional de Energia Nuclear carried out in 2013 the latest revision of the NN-305 where it establishes quality assurance programs for activimeters and requires each NMS to have at least one activimeter in addition to the radiation

protection instruments [9], however, in Brazil, there is no obligation to apply a calibration program in this type of instrument. Commonly the activimeters in NMS are in difficulty places to reach such as hot cells or inside heavy shields making impossible to send them to the calibration laboratory. Considering those facts, a calibration methodology has been developed that can be applied at the place where the equipment is located, without the need for locomotion. The uncertainties of the correction factors were calculated from the uncertainty propagation in correlated variables according to the equation below:

$$\frac{\sigma_{FC}}{FC} = \sqrt{\left(\frac{\sigma_{\overline{AF}}}{AS}\right)^2 + \left(\frac{\sigma_{\overline{AF}}}{A_p}\right)^2 - 2\frac{cov(\overline{A_S},\ \overline{A_{fp}})}{(\overline{A_S} * \overline{A_f})}}$$

2. Materials and Methods

The calibration methodology applied in the Primary Standardization Laboratory National Physical Laboratory (NPL), England [10], served as a basis for the development of this work. Considering that the ^{99m}Tc is the most used radioisotope in clinical routines in Brazil and is produced by the radiopharmaceutical production sector of IPEN. Three calibration methodologies have been established that can be applied "in situ" making measurements on the activimeters by NMSs. The first part of each methodology is described in the items 2.1, 2.2 and 2.3. The second part, which includes the vial residue measurement, the correction factor for the geometry calculation and the calibration coefficient determination for the IPEN vial and the 10R Schott vial were equal to the three methodologies. A quality control program was applied to LCI before applying the methodologies.

2.1. First Methodology: Reference Sample (^{99m}Tc) sent by LCI to NMS

1. The LCI request to the radiopharmaceutical production sector of IPEN a sample of ^{99m}Tc, with approximately 100mCi, in a volume of 6 ml in the same type of vial sent to the NMS (vial IPEN).
2. The LCI makes a measurement in the vial IPEN and send to sample to the SNM;
3. The NMS takes a measurement on its activimeter and sends it back to the LCI, describing the types of vials used by the NMS;
4. A calibration coefficient is generated for the vial IPEN;
5. The source is transferred to the reference vial 10R Schott [3].

2.2. Second Methodology: Sample sent by NMS no LCI-IPEN in the vial IPEN

1. The NMS will be provide the reference source to the LCI;
2. The hospital performs a measurement of the source of ^{99m}Tc in the vial IPEN on its activimeter and describes the types of containers used in the service;
3. The source is sent to the LCI and a measurement is taken on the standard activimeter
4. A calibration coefficient is generated;
5. The source is transferred to the reference vial 10R schott [3].

2.3. Third Methodology: Sample sent by the production sector to the LCI to calibrate your activimeters

This methodology is very similar to the second methodology because the source will be provided by the user to the LCI. The difference is that the user is the radiopharmaceutical producer sector of IPEN. In this case the source is taken by the LCI in the production sector, after authorization from the radioprotection supervisors of both sectors for the transfer of radioactive material.

3. Results and Discussion

First methodology: Table 1 shows the calibration coefficients (N_A) using two activimeters located in controlled access rooms, NMS-A e NMS-B. To observe variations due to different geometries, two vials were used, the vial IPEN (belonging to IPEN) and vial 10R Schott (provided by the NPL). The coefficients generated using the reference vial (10R Schott) were generated in LCI, compared to the measurement made with the vial IPEN at the clinic.

Table 1: Calibration Coefficients (N_A) obtained by applying the First Methodology for activimeters NMS-A and NMS-B [3]

Activimeters	N_A - NMS (vial IPEN)	N_A - LCI	
		Vial 10R Schott no corrections	Vial 10R Schott with corrections
NMS-A	0.990 ± 0.026	0.964 ± 0.027	0.990 ± 0.027
NMS-B	1.050 ± 0.028	1.042 ± 0.029	1.051 ± 0.028

Second methodology: The methodology was applied using a sample of ^{99m}Tc in the vial IPEN (volume of 6,0ml). The calibration coefficients using the reference vial (10R Schott) were generated in LCI, compared to the measurement made with the vial IPEN at the clinic. In a clinical routine the calibration coefficients should be used with the correction as shown in Table 2, and are valid only in the presented geometry.

Table 2: Calibration Coefficients (N_A) obtained by applying the Second Methodology for activimeter NMS-C [3]

Activimeter	N_A - NMS-C (vial IPEN)	N_A - LCI	
		Vial 10R Schott no corrections	Vial 10R Schott with corrections
NMS -C	0.981 ± 0.026	0.943 ± 0.26	0.982 ± 0.027

Third methodology: two activimeters were tested with the same technical characteristics belonging to the production sector of the IPEN. The sample ^{99m}Tc was provided with a volume of 6,0 ml to LCI,

in the vial IPEN. The calibration coefficients were determined and the corrected values presented in Table 3 and are only valid in the geometry used.

Table 3: Calibration coefficients obtained by applying the Third Methodology to the Activimeters belonging to the Production Sector, volume 6,0 ml [3]

Ativimeter	N_A – Production Setor (vial IPEN)	N_A - LCI	
		Vial 10R Schott no corrections	Vial 10R Schott with corrections
CR-0055	0.992 ± 0.023	0.959 ± 0.023	0.999 ± 0.023
CR-2096	0.978 ± 0.023	0.945 ± 0.023	0.981 ± 0.023

4. Conclusion

Three different calibration methodologies were proposed, considering the available logistics and also the source of the reference source. In all cases there is no need to send the instrument to the LCI. The first methodology should be applied in cases where the LCI sends a reference source to the NMS. In the second methodology the NMS sends a previously measured source to the LCI that will determine your actual activity. The third methodology should be applied for the calibration of activimeters belonging to the radiopharmaceutical production sector of the IPEN. In this case the reference source will be sent to the LCI by the production sector. In all cases, calibration coefficients found differing from one. The maximum variation was 5%, indicating that the doses to be administrated to the patient s are 5% lower than the measured. The volume transference to difference vials may introduce errors up to 3% due to the residue.

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