Study on depth of measurement and volume variation of nuclides used in nuclear medicine for "in situ" ionization chamber characterization – An experimental and Monte Carlo comparison

Bueno, L.K.; Villani D.; Rodrigues Jr., O.; Potiens, M.P.A.

[1]Instituto de Pesquisas Energéticas e Nucleares, Universidade de São Paulo, São Paulo, Brazil; Lebueno222@gmail.com

Introduction: Nowadays, the field of radionuclide metrology plays an important role in nuclear medicine service (NMS). Usually before any procedure in nuclear medicine it's important to check if the amount of radioactive material administered to the patient is adequate and effective. However, it's necessary to establish correction factors for each sample, geometry and volume considering the associated uncertainties.

The aim of this study is to characterize two radionuclides: ^{67}Ga and ^{201}Tl, to implement a new in situ calibration methodology. According to CNEN-NN-3.05, a nuclear medicine service must have at least one activimeter, which is daily used. Thus, without compromising the routine procedures of an NMS and avoiding damage to heavy and delicate equipment to be moved, we can justify favoritism by implementing an "in situ" calibration technique.

Methodology: In order to ensure that the routine of procedures in a NMS isn't interrupted and to avoid probable damage on equipment to be moved, it's easy to justify favoritism through the implementation "*in situ*" calibration technique. In this work, two radionuclides were characterized: ^{67}Ga and ^{99m}Tc, using the penEasy program, as general use of the PENELOPE Monte Carlo system, to study the response in the CRC-25R ionization chamber varying parameters that influence its response characteristics; and the results of the MC simulations were compared with experimental measurements obtained at the Radiopharmacy Center at IPEN. It was varied the depth of the vials in the chamber and the volume of the radioactive substance inside the vial. The simulation results were obtained in order to evaluate the ideal position (height) for activity measurements for each radioactive source with different volumes of radioactive solution inside the vial. Volumes were varied from 0.5 ml to 3.0 ml and 4×108 simulated particles were kept throughout the study. In this paper, the region with the highest sensitivity of the ionization chamber was considered. In other words, the height in the detector that presented the highest value of energy deposited by the simulation. The results were presented through the response of the deposited energy (eV/Story). The simulations were accomplished varying the height of the vial position from 0 to 20 cm along the well.

Results:. In the first analysis, it's possible to observe that the well-type ionization chamber has similar response characteristics for all radionuclides in this study. These results are observed both in experimental measurements and in MMC simulations. Therefore, the height with greater efficiency depends on the radionuclide and the volume inside the vial. The comparative results of the activimeter's behavior by varying the volume and distance of the 10R-Shott vial containing the ^{67}Ga radionuclide, verifying the agreement of the simulated and experimental data were throughout the study. For this radionuclide, the results were normalized at point of position of 6 cm, where was observed a better efficiency at this point of the chamber in the experimental results. The comparative results of the behavior of the activimeter by varying the volume and distance of the 10R-Shott vial containing the ^{201}Tl radionuclide. Through a comparative analysis it can be observed the agreement of the simulated and experimental data were throughout the study. For this radionuclide, the first 3 volumes were normalized at point 6 cm and the other volumes at point 7.

Conclusions: It's possible to observe a relationship between the vial and the distance from the bottom of the detector, which assumes an increasing behavior. The greatest deposition of energy can be measured between 5cm and 7cm in relation to the bottom of the well. From these heights, photons start to escape from the detector through the opening of the equipment, reducing the efficiency of the sensitive volume in absorbing the photons by approximately ±20%. Also can be observed that the uncertainty component that most contributes to these values is the calibration factor. This value is determined by the equipment manufacturer, provided in the user's manual, determined for each radionuclide to be measured.

References:
[1] CNEN - COMISSÃO NACIONAL DE ENERGIA NUCLEAR. **Radioprotection and Safety Requirements for Nuclear Medicine Services** – CNEN-NE- 3.05. 12p, Rio de Janeiro, 2013.
[2] SALVAT, F. PENELOPE-2018: **A Code System for Monte Carlo Simulation of Electron and Photon Transport**. OECD Nuclear Energy Agency. Available at http://www.oecd-nea.org.
[3] SEMPAU J., BADAL A., BRUALLA L. **A PENELOPE-based system for the automated Monte Carlo simulation of clinacs and voxelized geometries application to far-from-axis fields**, Med. Phys 38 5887-5895, 2011.
[4] KAKOI, A.A.Y. **Analysis of the calibration methodology of the NaI(Tl) detectors at the IPEN In vivo Monitoring Laboratory using the Monte de Carlo method**. 2013. Dissertation (Masters in Nuclear Technology - Applications) – Instituto de Pesquisas Energéticas e Nucleares, University of São Paulo, São Paulo, 2013. doi:10.11606/D.85.2013.tde-10022014-105712. Accessed on: 2022-06-22.
[5] CRC®-25R. **Radioisotope Dose Calibrator.** Manual Stock No. 9250-0122 May 9, 2017.