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Abstract

First 3D printed radioactive ^{89}Zr phantoms for Positron Emission Tomography

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In Positron Emission Tomography (PET), phantoms are filled with liquid radioactive solutions for quality assurance (QA), and scanner characterization. The radioisotope ^{89}Zr (half-life $T_{1/2}$=78.4 hours) is used for immunoPET; due to its metallic nature it tends to deposit on the phantom walls [1], resulting in non-uniform distributions that are not suitable for QA. This fact also complicates cleaning and decontamination. Radioactive 3D printed phantoms have been proposed before, such as liquid resin mixed with ^{18}F-fluorodeoxyglucose, the most widely used PET tracer ($T_{1/2}$ =109.8 min) [2,3,4] or ^{68}Ge ($T_{1/2}$ =270 days) [5]. In this work, we 3D printed two radioactive phantoms containing ^{89}Zr following the process described in [4], and studied their suitability for QA in PET, i.e., accumulation of ^{89}Zr on the walls, or deviations from the desired homogeneity. The phantoms were a radioactive point source on a non-radioactive (cold) background, and a spherical source (1 cm^3) within a cylindrical radioactive background (14 cm^3) keeping an 8:1 sphere-to-background ratio. Both were scanned in the Inveon dedicated small animal PET (Siemens Healthineers) for 0.5 h and 4 h, respectively. The sphere was inspired by the QA phantom of the NEMA NU 2–2018 standards [6]. Additionally, a 15-mL syringe filled with the remaining radioactive resin was scanned for 5 min. The PET images of the point source revealed activity in the cold background which indicates that ^{89}Zr deposited on the phantom walls during the print. In the sphere phantom, the radioisotope was not homogeneously distributed; however, the 8:1 ratio was observed in terms of the mean counts of each region. The analysis of the reconstructed images of the syringe showed that the ^{89}Zr accumulated at its bottom and it was precipitating from the resin. This was confirmed by a second scan after a 90° rotation of the syringe. The sphere phantom was rescanned three weeks later, and no significant changes in the activity distribution were observed. This points out to the effectiveness of 3D printing in maintaining the spatial activity distribution within the phantom, preventing the adherence of ^{89}Zr to the phantom walls. We believe that the formation of hot spots within the prints can be solved by continuously mixing the resin while printing. Therefore, future studies should include improving the mixing process.

Author's statement

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