A novel calibration approach to clinical PET/CT imaging.

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Introduction

Quantitative ^{18}F-FDG Positron Emission Tomography (PET) has become a routine imaging modality for diagnosis and for therapy response assessment in clinical oncology. Through the use of standardized uptake values (SUV) metabolic or functional information on PET images can be evaluated semi-quantitatively. SUV's, or changes thereof have been shown to yield diagnostic and prognostic information.

However, it is well-known that SUV's are affected by the limited spatial resolution of PET systems. SUV calculations of small lesions depend particularly on a proper calibration of the PET using a suitable phantom imaged under a reproducible study protocol.

Standard PET calibration may include a phantom containing a set of hollow spheres that have to be filled with ^{18}F solution of known radioactive activity. Such calibration is a rather lengthy procedure and requires a knowledgeable user on-site. Furthermore this process is costly and the user is exposed to radioactivity during this work. Here, we propose a novel calibration phantom for reproducible system calibration for a single or multiple sites.

Material and Methods

Our proposed PET calibration phantom consists of a 20 cm cylindrical plastic phantom with two concentric circular arrangements of 6 spherical reference sources each. All spheres are filled with a homogeneous activity of about 0.1MBq/ml of ^{68}Ge-resin ($T_{1/2}$~270d). The spherical moulds were produced from epoxy resin using rapid prototyping techniques. The wall thickness of each sphere is 1 mm.

The 6 sources placed in the outer circle mimic the standard arrangement used in conventional phantoms with source diameters ranging from 10 mm to 31 mm (0.5 ml to 16 ml). An additional set of 6 smaller sources with diameters ranging down to 2.5 mm is employed for the inner circle.

The spheres can be mounted in the empty cylinder, or in the cylinder filled with a uniform background activity to assess lesion recovery in air and soft tissue (water), respectively.

^{68}Ge decays to short-lived ^{68}Ga, which is a positron emitter. The mean free path (FWHM) of positrons emitted from 68Ge in water is 1.6 mm compared to only 1 mm for positrons emitted by ^{18}F.

In order to validate our approach to a long-lived and reproducible calibration phantom based on 68Ge for clinical PET we compare the recovery coefficients of the 68Ge-resin filled phantom with a standard 18F-filled phantom for the same 6 standard spherical lesions. All measurements were repeated for a range of acquisition times and simulating lesions in water (soft tissue) and air (lungs). First recovery measurements of this work-in-progress were performed on a whole-body PET/CT (Biograph HiRez16, Siemens).

Results

Recovery measurement in water showed no significant difference for 18F- and 68Ge-based phantoms.

Recovery measurements in air indicated a slightly degraded image quality for the 68Ge-based phantom caused by positrons from the very surface of the spheres escaping to air and the subsequent extended annihilation distribution pattern. However, this effect had no influence on the recovery measurements.

Supplemental measurements on the smaller spheres of the solid-state phantom in air and water proved the effects of positron range on recovery factors to be limited to spheres well below 10 mm diameter.

Conclusion

We present a novel approach to PET calibration using an efficient and user-friendly phantom filled with longer lived radioisotope. Our approach does not require repeated refilling or handling of open radioactivity and thus limits individual set-up errors and costs.

First validation of the new calibration phantom yields reproducible results and indicates adequate recovery estimates for lesions as small as 10 mm. Frequent PET quality control and a base recovery estimation can be facilitated using this solid-state phantom as presented, thus supporting PET quality control measures according to directive L-09-03 from BAG.