Assessment of Adaptive Multi-Pinhole Collimators for Multi-Purpose SPECT

Ilker Ozsahin[1,2,*] and Greta S. P. Mok[3,4]

[1.] Brain Health Imaging Institute, Department of Radiology, Weill Cornell Medicine, New York, New York, USA York, USA
[2.] Operational Research Center in Healthcare, Near East University, Nicosia/TRNC, Turkey
[3.] Biomedical Imaging Laboratory, Department of Electrical and Computer Engineering, Faculty of Science and Technology, University of Macau, Macau SAR, China
[4.] Center for Cognitive and Brain Sciences, Institute of Collaborative Innovation, University of Macau, Taipa, Macau SAR, China
* Corresponding author, ilo4001@med.cornell.edu

Single photon emission computed tomography (SPECT) is, by far, the most important method for diagnosing and monitoring the treatment of cardiovascular conditions. In preclinical settings, SPECT is a useful modality for small animal imaging (SAI). Besides, it is the primary imaging method, in addition to positron emission tomography (PET) and magnetic resonance imaging (MRI), for neurodegenerative diseases such as Alzheimer's disease and Parkinson's disease. A multi-pinhole (MPH) collimator has been developed and applied in research and commercial clinical and preclinical SPECT to improve the performance of conventional collimators. When compared to single pinhole and parallel-hole collimators, multi-pinhole collimators have the potential to further improve the trade-off between sensitivity and resolution. This study extends the investigation of the previously designed adaptive MPH collimators' performance characteristics [1,2].

The geometric calibration of the multi-pinhole collimators is necessary to determine the geometric parameters, e.g., radius-of-rotation, pinhole positions and axis-of-rotation offset for image reconstruction. Accurate geometric parameters improve the image quality and reduce the artifacts for more accurate quantitative analysis of the reconstructed images. Our calibration code was implemented using IDL (L3Harris Geospatial Solutions, Inc.). The calibration process includes the following steps [3]: (1) acquiring tomographic projections of a calibration phantom consisting of point objects and determining the centroid of the projected images of the point objects on the detector at each projection; (2) describing mathematically how a point object projects on the detector at every projection angle by deriving the analytic equations relating the unknown geometric parameters to the projected point locations; (3) calculating the projections of the phantom based on those equations using certain initial estimates of the unknown geometric parameters; and (4) updating these initial estimates by minimizing a pre-defined objective function (e.g., least-squares) that quantifies the difference between calculated results and the physically acquired results in (1).

Three adaptive MPH collimators were evaluated: six-pinhole (6-PH) for SAI, nine-pinhole (9-PH) for brain imaging, and twelve-pinhole (12-PH) for cardiac imaging (Figure 1). The distances between the center of FOV (CFOV) and the center of the pinhole for 6-PH, 9-PH, and 12-PH collimators are: 5.0 cm, 16.7 cm, and 18.6 cm, respectively. The collimator lengths, i.e., collimator-detector distances are 21.2 cm, 12.7 cm, and 15.8 cm, respectively. Collimators were positioned on a diagnostic SPECT scanner in a separate manner, and projection data was obtained with the use of a ^{57}Co point source containing ~100 μCi that was placed across the FOV in x, y, and z directions, where x is parallel to the axis of the collimator passing through the physical center of the collimator plate, y is the vertical axis, and z is the axial axis of the scanner bore (Figure 2). The origin of the coordinate system is the CFOV. The projection data were collected for each position over the course of five minutes, and the results of three separate acquisitions were averaged.

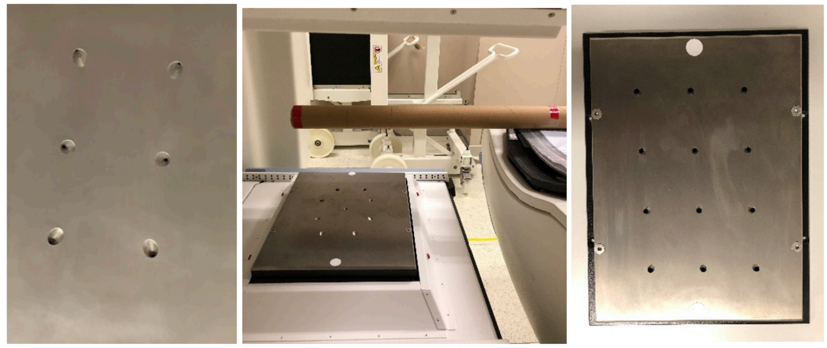

Figure. 1. 6-PH collimator (left), 9-PH collimator (middle) and 12-PH collimator (right) for small animal imaging, brain imaging and cardiac imaging in this study.

The sensitivity was determined by dividing the number of counts detected by the number of counts emitted, and the system resolution was determined by the full-width-at-half-maximum of the point spread function. The sensitivity and spatial resolution were found to be 0.012% and 1.7 mm for 6-PH, 0.037 %and 11.6 mm for 9-PH, and 0.036% and 9.2 mm for 12-PH, respectively. The results also demonstrated the theoretical calculations for sensitivity as well as resolution are well matched by the experimental findings. Adaptive MPH collimators offer superior performance compared to standard parallel hole collimators and can be utilized in preclinical and clinical investigations. This enhances the general-purpose SPECT imaging platform for activities that require a reduced FOV. Research and commercial MPH systems were developed and evaluated but no adaptive system for different applications are developed. This is also based on, and can be tailored made for, existing clinical systems thus is very convenient and economical for the clinical centers.

[1] C Si *et al*., Design and evaluation of an adaptive multipinhole collimator for high-performance clinical and preclinical imaging. Nucl Med Commun 37 (2016) 313-321

[2] I Ozsahin and G S P Mok, Preliminary Performance Evaluation of Adaptive Multi-Pinhole Collimators for SPECT, 2019 IEEE Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC), Manchester, UK, (2019), 1-2

[2] Y Wang and B M W Tsui, Pinhole SPECT With Different Data Acquisition Geometries: Usefulness of Unified Projection Operators in Homogeneous Coordinates, IEEE Trans Med Imaging **26** (2007), 298-308

The authors acknowledge funding from the Science and Technology Fund (FDCT) of Macau (0091/2019/A2).