Evaluation of SPECT/CT performance for optimal small animal imaging

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Background

In resent years, small animal imaging systems have obtained both excellent resolution and high sensitivity with reasonable acquisition time by introducing multi-pinhole collimators (MPCs). And, they successfully visualize *in vivo* distribution of the radionuclides in small animals. They are expected to contribute to investigations about biological function, drug development and so on.
As current small animal imaging scanners can cover wide range of energy between 10 and 300 keV, they can successfully image various kinds of radionuclides. By using these scanners, even iodine-125 (I-125), which emits gamma rays with the energy as low as 28keV, can be imaged because the attenuation of gamma rays inside small animals is less significant compared to human bodies. Since I-125 has a half-life of 60 days long enough for tracer experiments, it is often used in the field of molecular biology. Therefore, it would be attractive if *in vivo* distribution of I-125 labeled compounds was visualized.
In this study, we evaluated the performance for Tc-99m (140 keV) and I-125 (28 keV) of the SPECT/CT scanner called NanoSPECT/CT (Bioscan, Washington, D.C.) to establish the optimal imaging conditions for small animals.

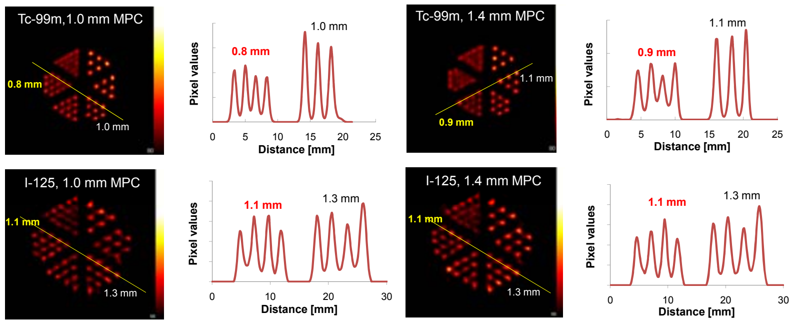
Experimental evaluation using phantoms and point sources

We evaluated the spatial resolution, sensitivity, linearity and uniformity for both Tc-99m and I-125 using MPCs with the pinhole diameter of 1.0 and 1.4 mm.

Spatial Resolution

We investigated the spatial resolution using Jaszczak phantoms with diameter of 0.7-1.2 mm and 1.0-1.5 mm. They were filled with 37 MBq/mL of Tc-99m or 15 MBq/mL of I-125. The number of projection was set to 128 and the total acquisition counts were set to 300 Mcounts. The energy window was set to 140 keV±10% for Tc-99m and 28 keV±30% for I-125, respectively. All acquisition data were reconstructed using the OSEM algorithm (Subset/Iteration: 4/1-6, 2/7-9). The field of view (FOV) was 37.2 mm. The matrix size was 124 x 124. And, voxel size was 0.3mm. Visual assessment and count profile curve analysis were performed to evaluate the obtained images.

Tc-99m showed 0.8 mm of the spatial resolution for 1.0mm MPC and 0.9mm for 1.4 mm MPC. I-125 showed poorer resolution than Tc-99m, due to scatter in phantom and NaI crystal. Its spatial resolution showed 1.1 mm for both MPCs.



Maximum sensitivity

We evaluated the maximum sensitivity for Tc-99m and I-125 using point source with the radioactivity of 3.0 MBq. The point sources were made of epoxy reign and they were set at the center of FOV. The number of projection was set to 128 and acquisition time was set to 30 sec/projection, resulting in the total acquisition time of 16 minutes. We evaluated the count ratio per radioactivity concentration (kcps/MBq).

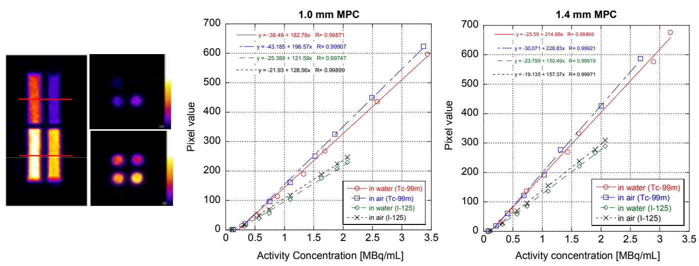
	1.0mm MPC	1.4mm MPC
Tc-99m	0.82 (0.08%)	1.67 (0.17%)
I-125	1.00 (0.10%)	2.06 (0.21%)

The maximum sensitivity of 1.4 mm MPC for Tc-99m was about twice as high as that of 1.0 mm MPC. I-125 showed higher sensitivity compared with Tc-99m. The reasons for this result were that the lower the energy of emitted gamma rays is, the higher the detection efficiency of photpeak is and that I-125 is likely to induce phtoelectric effects in NaI crystal because the K-shell electron binding energy of NaI is near 28 keV.

Linearity

To evaluate linearity of this scanner, we made a phantom that had 0.68 mL of eight column containers in it. These column containers were filled by Tc-99m and I-125 with the radioactivity concentration between 0.13 and 3.37 MBq/mL. The radioactivity was measured by using curie-meter (IGC-7, ALOKA, Tokyo, Japan). The phantom was measured under the following two conditions: 1) the outside of the column containers was filled by water and 2) it was filled by air. The data were acquired from 24 projections with the acquisition time of 300 sec/projection. The acquisition was repeated four times and the total acquisition time was 2 hours. All acquired data were reconstructed using the OSEM algorithm (Subset/Iteration: 4/1-6, 2/7-9), and the correlation between radioactivity concentration and pixel values was investigated.

Linearity phantom

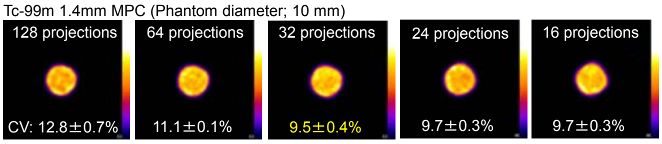


The obtained linearity was good regardless of the types of nuclides and aperture. The attenuation rates of I-125 were 33.1% lower for 1.0 mm MPC and 33.4% for 1.4 mm MPC, compared with Tc-99m. The lowest radioactivity concentration for which the linearity was shown was 0.21 MBq/mL. The specific radioactivity higher than this number is easily available for Tc-99m by using a Mo-99 generator whereas it is not easily available for I-125. As the half-life of this radionuclide is long enough, its image quality can be improved by the elongation of the acquisition time. But, the biodistribution of radiocompounds might be altered during long acquisition time.

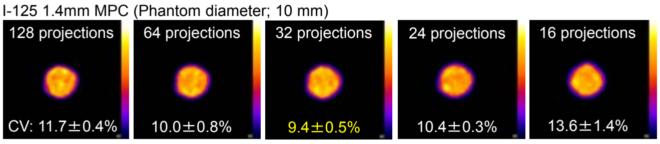
Uniformity

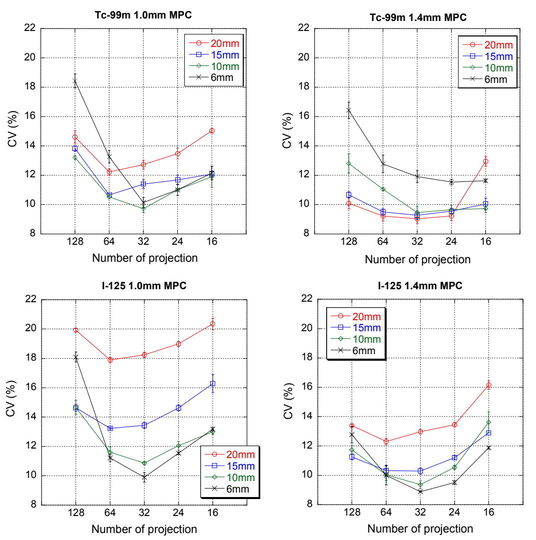
We evaluated the uniformity using column phantoms filled by radionuclides of 3.7 MBq/mL with the inner diameter of 6, 10, 15 and 20 mm. The number of projection was changed to 16, 24, 32, 64 and 128. The acquisition time was set to 300 sec/projection resulting in total acquisition time of 30 minutes. All acquisition data were reconstructed using the OSEM algorithm. The coefficient of variance (CV: %) was calculated by putting the ROI whose size was set to 80% of the diameter of each phantom.

Tc-99m 1.4mm MPC (Phantom diameter; 10 mm)



I-125 1.4mm MPC (Phantom diameter; 10 mm)





For I-125, 1.4 mm MPC showed better uniformity than 1.0 mm MPC. The smaller the diameter of phantom was, the better uniformity was shown for I-125. The uniformity was also dependent on the number of projection, and the best result was shown at 32 projections for the inner phantom diameter of 6 and 10 mm and at 64 projections for that of 15 and 20 mm. For Tc-99m, the phantom size that showed good uniformity was different for the type of MPC. The good uniformity was shown for the phantoms with the diameter over 10 mm for 1.4 mm MPC whereas it was shown for the phantoms with the diameter less than 10 mm for 1.0 mm MPC.

Conclusion

This scanner showed both excellent resolution and high sensitivity with the wide range of radioactivity consentration used in small animal imaging. Our results demonstrated that this scanner can visualize I-125, which emits low energy gamma rays, as well as Tc-99m.
This scanner would be able to image functional heterogeneity inside the tumor with various kinds of radionuclide. But, to obtain good quality of images, it is essential to establish the optimal imaging conditions in consideration with the object size, specific radioactivity of the compounds, accumulation ratio and biodistribution of the compounds. Our experimental results would be expected to be useful fundamental data to optimize the small animal imaging.

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