Relative importance of transverse detector pixel size, DOI and TOF in future whole-body PET/MR systems

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1. Introduction

Compared to current PET-CT systems, the PET ring in a whole-body PET-MR system needs to have a more compact geometry. Furthermore the readout by silicon photomultipliers can enable the identification of detector pixels with smaller transverse pixel size than 4 mm and should result in further improvements in Time-Of-Flight (TOF) resolution. Improvements in PET detector design are however a compromise between Depth-Of-Interaction (DOI) correction, TOF and spatial resolution and should be driven by the improvement in image quality. Therefore we investigated the influence of the pixel size, DOI correction and TOF resolution on the image quality of whole-body scanners. The study is based on the statistical analysis of image reconstructions obtained by Monte Carlo simulations and iterative reconstruction. The non-prewhitening (NPW) observer was used for a comparison of the different scanner configurations.

2. Methods

Simulations with realistic count levels were performed using GATE. The PET scanner was modeled as a cylindrical system with 32.5 cm radius, compact enough for integration in MRI, and axial length of 19.2 cm. A cylindrical phantom of 17.5 cm radius and axial length of 12 cm was simulated. A total of 30 hot spherical lesions with diameter of 5 mm and activity uptake ratio of 8:1 were placed at 5, 10 and 15 cm radial distance, with 10 spheres per distance. The variable design parameters were pixel size (2, 2.6 or 4 mm), TOF resolution (600, 400 or 200 ps) and DOI correction (no or 2 layer DOI). Twelve simulated data sets were reconstructed using MLEM. As a figure of merit (FOM) we used the NPW signal-to-noise ratio (NPW-SNR) derived from the 120 spheres. The SNR of the scanner configurations was compared for iterations at 1% of convergence.

3. Results

The NPW-SNR of the spheres at 10 cm of the design with TOF resolution of 600 ps, pixel size of 4 mm and no DOI correction is taken as reference. Decreasing the pixel size from 4 to 2.6 resp. 2 mm gives an increase in SNR of 40.3% resp. 38.3%. Decreasing the TOF resolution from 600 to 400 resp. 200 ps gives an improvement of 15.9% resp. 46.3%. When comparing no DOI with 2 layer DOI no improvement was obtained for the spheres at 5 cm radial distance. For the design with 2.6 mm pixel size and TOF resolution of 600 ps we obtained an increase of 14.5% resp. 23.13% for the radial distances of 10 resp. 15 cm, when comparing 2 layer with no DOI.

4. Conclusion

When comparing the influences of transverse pixel size, TOF and DOI, reducing the TOF resolution from 600 to 200 ps gives the largest improvement in NPW-SNR. A decrease of the transverse pixel size from 4 to 2 mm gives an improvement which is smaller, but of comparable magnitude. With 2 layer DOI only a significant increase in SNR is obtained for the spheres at radial distances of 10 and 15 cm. This effect is much smaller than the improvements obtained by smaller TOF resolution and transverse pixel size.