Evaluation of MR Compatibility of a SiPM-based PET scanner for simultaneous PET/MR studies operating at animal 7-T MR scanner

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Purpose

Simultaneous PET/MRI holds several major methodological and scientific advantages over other multimodal imaging technology because of its highly accurate functional and anatomical information. For the development of MR compatible PET, SiPM, used as a light detector, is more suitable than a conventional PMT (photomultiplier tube) because of its fully MR compatible operation, small size, and similar gain comparable to PMT. The purpose of this study is to assess the relevant influences of novel SiPM-based PET scanner on MR images at ultra-high magnetic field.

Methods

A 7-T MRI system (BioSpec 70/20USR, Bruker, Germany), 35-mm-inner-diameter mouse body transceiver coil and corn-oil filled uniform cylinder phantom (ID = 26.2 mm, T1 = 423 ms, T2 = 130 ms) were used for evaluation. The RF coil was positioned inside PET insert which consists of semiconductor photo-sensor, inorganic scintillator (LYSO), and non-magnetic electronics shielded by carbon fiber case[1] to evaluate the effects on MR environments caused by PET insert. MR performance was tested under three conditions; two by let PET insert unit inserted in magnetic bore to be power-off and power–on, one by removing PET insert unit. Image qualities such as SNR and image intensity homogeneity were measured. The conventional MR sequences and their parameters used for image quality evaluation are listed in Table 1. As a sequence used in most fMRI studies, a gradient-echo EPI was used for EPI quality evaluation and its parameters were as follows; TR/TE/FA = 2000 ms/9 ms/30˚, FOV = 60 × 60 mm^2, matrix = 64 × 80, slice thickness = 1.5 mm, 5 slices, pixel bandwidth = 67.9 Hz/pixel. A total of 180 volume scans were acquired during 6 min. to evaluate the image quality of EPI images and temporal drift of mean signal intensity.

Table 1 Sequences and their parameters used for SNR and image homogeneity measurement

Sequence	TR (ms)	TE (ms)	Voxel Size (mm^3)	Matrix Size	FA (˚)	BW (kHz)
2D FSE	2500	35	0.14×0.14×1	256×256	90	100
2D SE	500	10.5	0.14×0.14×1	256×256	90	100
2D GRE	18	4.3	0.14×0.14×1	256×256	20	250
3D SPGR	9.5	3	0.14×0.14×1	256×256	15	100

Table 2 Results of the Homogeneity and SNR measurement (X: w/o PET, Off: PET power-off, On: PET power-on)

Sequence	Homogeneity			SNR		
	X	Off	On	X	Off	On
2D FSE	93.6	92.7	92.4	96.6	88.9	80.5
2D SE	93.7	93.5	92.8	92.9	86.0	77.9
2D GRE	86.8	83.6	84.2	30.9	27.6	25.5
3D SPGR	71.0	70.0	67.7	29.4	26.0	23.9

Results

There was almost no change in the signal intensity homogeneity of MR images of uniform corn-oil phantom for various standard MR imaging sequences. However, the PET insert unit caused the SNR degradation (about 16%) in MR images mainly due to the increased variation in background intensity (Table 2). Figure 1 shows that there was no time varying difference of EPI signal intensity between image volumes. The RMS stability of EPI image intensity during multiple scans was 0.15%, 0.16%, and 0.14% in cases of the absence of PET insert unit, power-off and power-on states in the presence of PET insert unit in magnet bore, respectively.

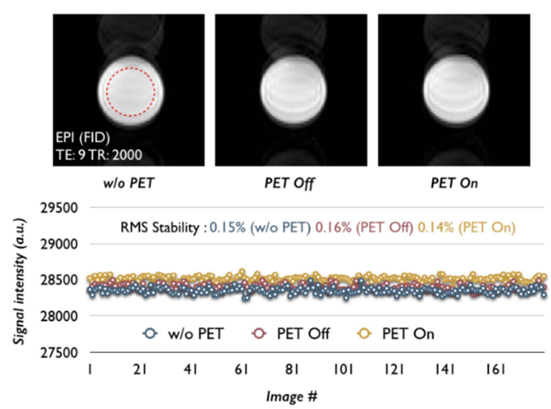

Figure 1 GRE-EPI Images (top) and temporal signal intensity variation between image volumes (bottom)

Discussion

The experimental results show that the PET insert unit affects minor effect on MR images that can be ensured for preclinical evaluation. The magnetic susceptibility caused by PET insert unit did not make noticeable field distortion. However, the electrical noise of PET insert unit induced some noise signal in RF coil that lead background intensity variation. Therefore, the optimization of RF shielding of PET insert unit will be helpful for reducing this unwanted noise. Encouraging result of simultaneous PET/MR imaging (figure 2) and very small temporal variation under 0.16% in EPI signal intensity shows that it is possible to perform multi -functional study of PET and functional MRI using our PET insert unit.

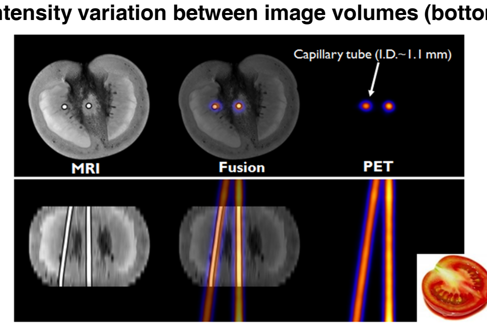

Figure 2 Simultaneous PET/MR images of cherry tomato with ^{18}F-FDG filled capillary tube

Conclusion

In summary, the evaluation of the MR compatibility of our preclinical SiPM-based PET insert unit has shown that there is only minor degradation on the MR imaging performance for the practical MR image acquisition and functional MRI operation. This combination of PET and MRI systems will have a great potential for multi-parametric PET/MR imaging.

References

1. G. B. Ko et al. *New high performance SiPM PET insert to 9.4-T MR scanner for simultaneous PET/MRI studies.* J Nucl Med. 2013; 54 (Supplement 2):46.