Novel and Compact PET insert for simultaneous PET/MR imaging of small animals

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Introduction:

In the recent years combined, simultaneous PET and MR imaging has become more important, especially in the domain of monitoring metabolic processes. It has been developed as an excellent tool in the area of clinical and preclinical research. The combination and fusion of datasets of different imaging modalities open up a large field of new possibilities in research and diagnostics. This work discusses the development of a highly efficient and compact PET/MR imaging system for small animals, allowing studies of rats and mice. The performances with respect to imaging quality, temporal and spatial resolution of PET- and MR-imaging have been carefully measured on the bench and phantoms. In vivo studies are presented to show the possibilities of PET/MR imaging in small animal research.

Material and Methods:

PET/MR System: Based on a prototype-system [1] the new compact PET insert that was constructed (Fig. 1) consists of 16 detector units arranged in radial direction, each populated with three Lutetium oxyorthosilicate (LSO) crystal blocks (15x15 crystals, 1.5x1.5x10mm³ each crystal) mounted along the z-direction. The design of the front ring and the inner diameter of the PET-Insert of 112mm allow a reproducible fixation of different standard RF coils with respect to the magnet-center and radial orientation. A novel electrical shielding prevents influences of the PET-electronics to the MR-system with respect to noise and electromagnetic radiation. The PET-insert housing also includes a sophisticated temperature regulation based on compressed air and vortex tubes (EPUTEC, Kaufering Germany) that are stabilizing the detector-electronics with high accuracy to a chosen temperature limit without influences from outside environment. For acquisition an INVEON electronics (Siemens Preclinical Imaging, Knoxville USA) was used and interfaced by a carefully designed filter-electronics housed together with the whole electronics in an electronic cabinet (Fig. 2) outside the faraday cage. The maximum PET-FOV is 72mm in transversal as well as 72mm in axial direction. The PET insert was installed in a 7T ClinScan small animal MR scanner (Bruker Biospin MRI, Germany) equipped with a BGA20S.

PET Performance: For evaluation the performance with respect to the spatial resolution of the PET-Insert a Micro Delux Derenzo Phantom (DSC Data Spectrum Corporation, USA) was filled with 18MBq of [^{18}F] Fluorodeoxyglucose (FDG) and a scan of 20 min was performed inside the MR System. For reconstruction an image-reconstruction tool was developed and the images were reconstructed by OSEM algorithm with 16 iterations; 4 subsets were used without additional image corrections. **MR Performance:** The Image quality and MR performance was evaluated with and without installed PET-Insert using different QA-routines at Syngo VB15 (Siemens Erlangen, Germany) with respect to SNR, Cross Term and Eddy Current Compensation, Shim and Spike-Check. In addition long term stability measurements were performed using EPI-sequence (ep2d_fid, TR=2500ms, TE=20ms) in terms of temporal stability. ***In vivo* imaging:** For evaluation of the *in vivo* imaging capabilities rat brain images were acquired with [^{18}F]FDG with a injected dose 39 MBq. The data where acquired statically over 1 hour. The image was reconstructed with FBP algorithm. During the PET-acquisition a 3D TSE sequence was running; TR: 3000ms, TE: 205ms, with a Matrix of 160x256x120 and a voxel size of 0.22x0.22x0.22mm³. Images were fused by using PMOD (Zuerich, Switzerland)

Fig. 1: PET-Insert

Fig. 2: PET-electronic cabinet

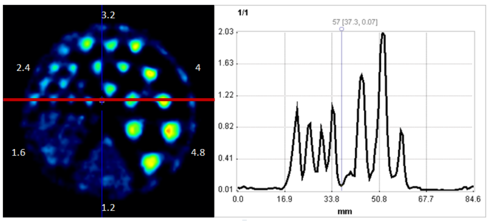

Fig. 3: Measurement of the spatial resolution with Derenzo Phantom

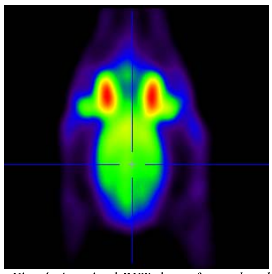

Fig. 4: Acquired PET-data of a rat head

Results:

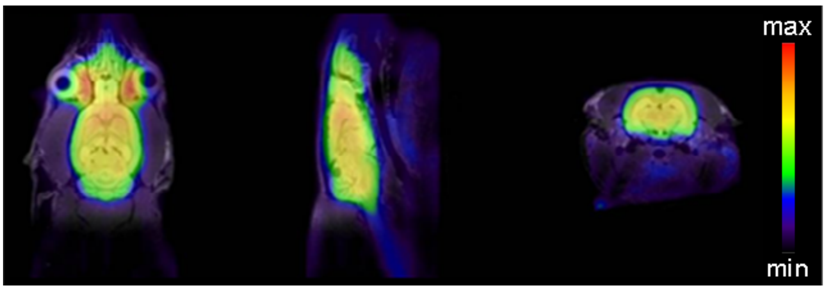

FIG.5. Rat-head imaging using combined, simultaneous PET/MR acquired with the prototype system.

The image of the Derenzo Phantoms (Fig. 3) shows that we can resolve hot spots with a diameter of less than 2.4mm in transaxial direction. The results of the QA-checks show clearly that the MR-system works in specifications as normal as in absence of the PET-insert. In terms of EPI temporal stability no significant chances of the signal drift could be observed. This also includes no significant changes with respect to SNR and image homogeneity. No MR-imaging artifacts, e.g. noise patterns could be observed while simultaneous PET and MR-data were acquired. Simultaneously acquired [^{18}F]FDG PET data (Fig.4/5) reveal the typical pattern of brain glucose metabolism, with additional high [^{18}F]FDG uptake in the haderian glands (area between eyes and olfactory bulb). This metabolic PET data is amended by the matched T2-weighted 3D anatomical data of the rat brain (Fig. 5), allowing to exactly identify structures such as the cerebellum or thalamus.

Conclusion:

We have shown that the PET/MR System is performing as expected. Up-to-dates results have shown that the PET-Insert works stably and in a performance range of other available stand-alone PET scanners. Preliminary tests with our prototype system show that we can improve the spatial resolution by reconstruction methods specifically adapted to the PET-Insert and including image corrections. Further developments for image correction with respect to normalization, attenuation and scatter correction have to be done next. The MR results show that simultaneous PET/MR-data can be acquired with equivalent performance and quality as in absence of the PET-insert. The *in vivo* example indicates the possibilities of PET/MRI regarding to its options in the wide field of metabolic processes. The ease-to-use handling capabilities of the PET-system offer now the possibilities to use this new generation multimodality technology in a routine preclinical environment.

References:

[1] H. F. Wehrl et al., A new PET insert for simultaneous PET/MR small animal imaging, Proc. ISMRM 2012, [2] C.C. Liu et al, PET Performance measurements of a next generation dedicated small animal PET/MR Scanner, Proc. IEEE NSS/MIC/RTSD 2012