Evaluation of a clinical PET/MR system

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Introduction:

Hybrid imaging devices combining Positron-Emission-Tomography (PET) with Magnetic-Resonance-Imaging (MRI) have been shown to possess a great potential for small animal studies. Recently PET/MR systems have also been built for human applications. Here we present an evaluation of the first hybrid PET/MR device, which has the capabilities to perform simultaneous PET/MR acquisitions of the human brain. The influence of the PET insert on the MR imaging performance was evaluated. Furthermore fundamental PET parameters were accessed with and without MR sequences running. *In vivo* PET/MR studies of patients have been performed, where the attenuation correction for the PET was based on MR data.

Material and Methods:

The experimental, human PET/MR system consists of 32 detector cassettes. Six LSO/APD block detectors are housed in each cassette (matrix of 144 crystals, with individual crystal size of 2.5x2.5x20 mm^3). The total PET/MR FOV is 250 mm in transversal direction and 192 mm in axial direction. The PET insert is installed inside a standard 3 T clinical MR system. Simultaneous PET/MR images can be acquired using a quadrature transmit/receive (TRX) head coil that is installed inside the PET insert. Moreover a 8 channel receive coil fits inside the quadrature coil to allow for parallel acquisition techniques such as SENSE and GRAPPA.

For the evaluation of the MR performance a multipurpose phantom, filled with an aqueous solution of 1.25 g $NiSO_4$ x 6 H_2O per 1000g water was placed inside the quadrature coil of the PET/MR system. MR image quality was accessed with the PET insert installed inside the MR system or with the PET insert removed from the MR. For the configuration without the PET insert, a wooden construction covered with a thin copper foil was installed inside the MR scanner to mimic the radio frequency shielding of the PET. This is needed to achieve the same coil tuning environment as with the PET installed. A series of four MR sequences was acquired, respectively without and with the PET insert installed. The sequences were: a turbo spin echo (TSE) sequence, a FLASH sequence, a spinecho (SE) and an echo planar imaging (EPI) sequence. Signal to noise ratio as well as image homogeneity were evaluated for every sequence. A mapping of the main magnetic field (B_0) homogeneity was performed using a gradient echo sequence with two different echo times (GRE, TR=300 ms, TE_1=10 ms, TE_2=20 ms, α=25°, matrix=128x128, voxel size=2.3x2.3x5.0mm^3, BW=260 Hz/pixel). The phase images obtained by this sequence were unwrapped and finally used to calculate a B_0-Map for the system without and with the PET insert installed. The RF field (B_1) inside the TRX coil was evaluated applying a se sequence with stimulated echo. By accessing the amplitudes of the spin-echo and the stimulated echo (SE, TR=300 ms, TE=14 ms, α=90°, matrix=128x128, voxel size=2.3x2.3x10 mm^3, BW=260 Hz/Pixel) a B_1 map was acquired. EPI imaging stability was accessed without and with the PET insert installed in the MR system. In addition fundamental PET imaging parameters (e.g. sensitivity) were accessed for the PET insert. A patient study was performed using [^{68}Ga]DOTATOC (a marker for neuroendocrine tumors) as tracer. PET data reconstruction was performed using fully MR based attenuation correction.

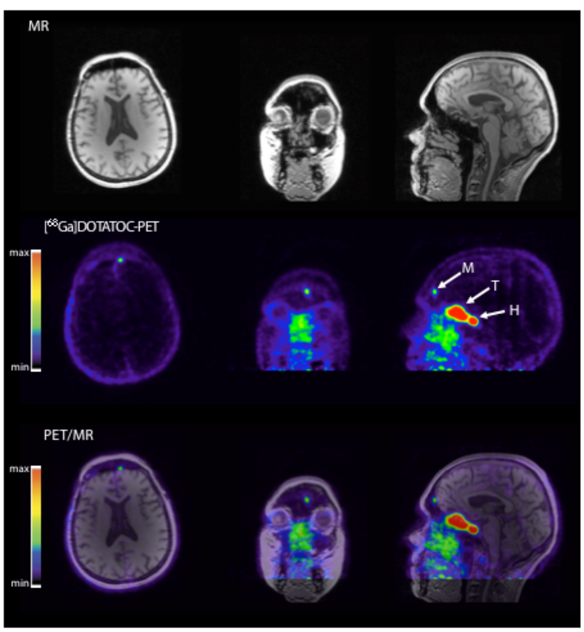

Figure 1: Simultaneous acquired MR and PET images of a patient with meningnoma. The tumor (T) near to the hypophysis (H) is clearly depicted in the MR and PET images. A small metastasis (M) was easily identified using the PET images.

Results:

The SNR values (SNR±SD) were respectively for the configuration without the PET insert installed for the TSE (39.3±9.0), FLASH (36.6±8.5), SE (37.5±10.2) and EPI (22.0±6.7) and with the PET insert for the TSE (39.4±9.3), FLASH (37.3±8.4), SE (38.2±10.8) and EPI (16.6±4.2). The image homogeneity values (homogeneity±SD) were respectively for the TSE (74.7±5.2)%, FLASH (72.2±7.6)%, SE (69.8±6.8)% and EPI (57.0±19.8)% and with the PET insert for the TSE (73.2±5.1)%, FLASH (71.0±8.4)%, SE (67.4±7.0)% and EPI (56.6±20.4)%. The B_O homogeneity showed only deviations smaller than 6 µT (2 ppm at 3 T). The B_1 homogeneity of the RF-coil was not influenced by the presence of the PET insert. The temporal EPI signal intensity was slightly noisier with the PET insert installed, but remained stable over time. The spatial resolution of the PET was between 2.1 mm and 2.8 mm at the center of the FOV. The relative PET sensitivity was reduced by about 15% when a MR sequence was running. The patient images show adequate PET and MR image quality (Figure 1).

Discussion and Conclusions:

The MRI shows only slight degradation of image quality when the PET insert was present. These deviations are however unlikely to fundamentally impact clinical imaging. The B_0 and B_1 homogeneity of the system is appropriate to perform advanced MRI studies. A slight influence on the PET insert was seen, when MR sequences were running, further evaluations are performed to track down this issue. Patient studies show the potential of simultaneous PET/MR in the field of oncology and treatment planning. With such a device it seems feasible, that many of the already established preclinical PET/MR protocols can be transferred into clinical research and practice.