fMRI investigations on an MR-PET system during simultaneous PET scanning: technical considerations

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Abstract

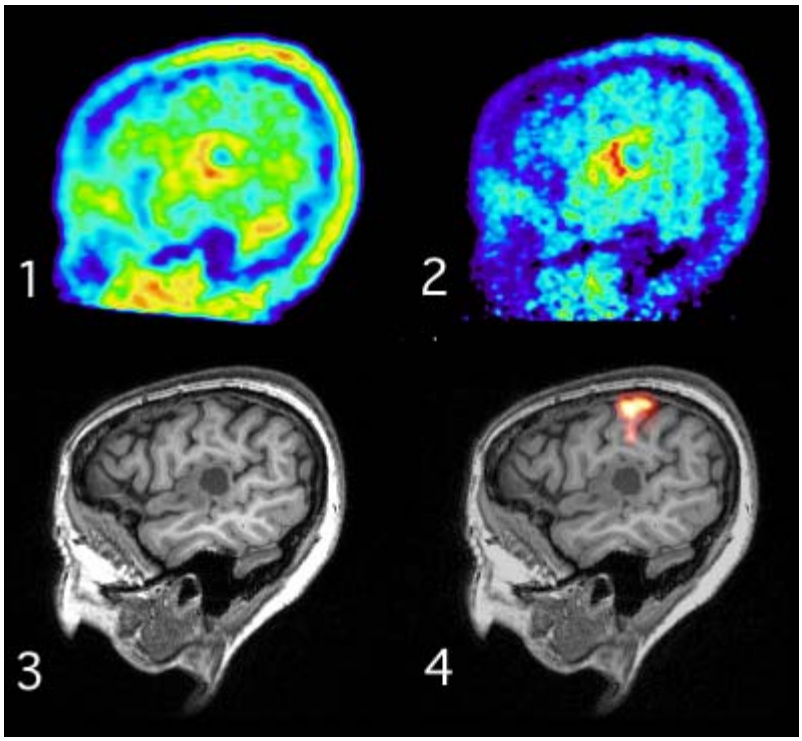
The new technology of hybrid MR-PET scanners offers great opportunities for the investigation of scientific questions and clinical diagnosis that are related to metabolism as well as function and structure of the brain. Despite the fact that the implementation of a PET ring inside the bore of a modern whole body MR scanner is demanding the benefits in terms of scan time reduction as well as spatial and temporal co-registration speak for the combination of these complementary technologies. In this feasibility study we demonstrate the simultaneous acquisition of FET-PET and fMRI data in human subjects with brain tumours.

Introduction

In today's market, PET imaging technologies for clinical purposes are available almost exclusively in the form of combined PET-CT scanners. Both PET and CT are well established and the combination in a single machine is logical and straightforward when designed in form of two coaxial and parallel rings. Because of the richer variety of contrast mechanisms available, MRI could offer more diagnostic opportunities. However, the implementation of a PET system inside the magnetic field of an MR scanner is far more demanding. Conventional photo-multipliers do not work in a magnetic field. Therefore, silicon-based photosensors, so-called avalanche photodiodes (APDs), have been applied as readout electronics. Using this technology, the PET ring can be placed within the bore of the MR scanner such that the field of views (FOVs) of PET and MR system coincide [1,2]. Thus, imaging data using both modalities can be acquired which are intrinsically co-registered in time and space. This construct should offer a wide range of future applications. Given that the current standard in functional imaging is BOLD fMRI, and noting that morphological imaging of brain tumour extent with MR is inferior to that of PET using the amino acid FET. A combination of fMRI and FET-PET should provide simultaneous information on tumour extent and the position of important functional cortical areas and this is a critical experiment to demonstrate the advantages of a combined MR-PET scanner.

Methods

Positron emission tomography (PET) was performed using the amino acid O-(2-[^{18}F]Fluorethyl)-L-Tyrosin (FET)[1] radiotracer [3,4]. After injection of 200MBq of FET, the patient was imaged sequentially on two scanners. First, FET-PET data were acquired on a standalone Siemens HR+ PET system. The scan time in the HR+ PET was 50 min. Afterwards, a combined MR-PET scan was performed on a Siemens 3 Tesla MAGNETOM Tim-Trio system equipped with a BrainPET insert which uses 2.5x2.5x20 mm^3 sized LSO crystals and APD electronics for radiation detection. The BrainPET insert has an outer radius of 60 cm fitting into the bore of the magnet and an inner radius of 32 cm for the MR radio frequency head coil. The axial length of the PET FOV ring is 20 cm. The MR coils used were an eight-channel phased array receive and a birdcage transmit coil. The BrainPET scan time was 40 min and MRI was performed ***simultaneously***. Anatomical images were acquired with a T_1 weighted MP-RAGE sequence. The matrix size was 256x256x192 to achieve a 1mm isotropic resolution within a scan time of 9 min. BOLD fMRI data were acquired with an EPI sequence using an echo time, TE, of 30 ms and a repetition time, TR, of 2 sec for acquisition of a single image. A finger tapping experiment was performed to activate the motor cortex. The block design was: left tapping – pause – right tapping – pause – both hands tapping – pause. To improve the statistics the tasks were repeated four times. Fifteen images were acquired per block of 30 sec leading to a total scan time of 12 min. The fMRI data were processed using SPM5. Fused images were produced with MPI-TOOL. Data from a representative subject, a 53 year old female patient with a left frontal astrozytoma WHO °II-III, are shown below. The patient had treatment with brachy therapy using ^{125}I seeds. This patient was included in a study accepted by the responsible ethic commission and gave written, informed consent.



Results

PET results are shown in the top row of the mosaic figure for the HR+ **(1)** and the BrainPET system **(2)**. The BrainPET insert offers a significantly higher spatial resolution. However, there are faint vertical stripe artefacts that are related to the BrainPET design and may be improved by enhanced correction methods. During MR measurements the BrainPET count rate is reduced by 1-2% depending on the sequence type. EPI shows the strongest effect and the count rate reduction was constant during scan time. Therefore, it can be most likely assumed that the effect is caused by gradient-induced eddy currents. Both PET images show significant FET activity in the area of residual tumour tissue . MP-RAGE and BOLD fMRI results are presented in the bottom row. The MP-RAGE image **(3)** also indicates tissue degeneration around the therapeutically treated area. BOLD fMRI activity **(4)** is shown for the two-handed finger-tapping task. The fMRI results are overlaid on the MP-RAGE image. It is apparent that the activity in motor cortex is in large distance to the residual tumour tissue. The patient did not show motor deficits.

Conclusions

This pilot study demonstrates the feasibility of combined PET and MRI scans on a MR-PET hybrid scanner. The results are promising for future developments and clinical applications. Here, the benefits are the reduction in measurement time, the spatial co-registration of PET and MR data, and the improved PET resolution. MR-PET hybrid scanners offer new perspectives especially for tumour diagnostics and may open up new avenues for scientific questions going beyond mono-modal investigations.

References

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