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Editorial

Quantitative PET/MRI Evaluation and Application in Dementia

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Abstract

A recently introduced integrated scanner combining simultaneous positron emission tomography (PET) and magnetic resonance imaging (MRI) (PET/MRI) acquisition presents a unique set of opportunities for neuroimaging research and dementia in particular [1]. Among these, the intrinsic co-registration of the images has the potential to reduce errors in multi-modality image registration, which could lead to better quantification of longitudinal volumetric changes in neuroanatomical features that are important for assessing disease progression. PET tracers could provide functional information of brain biochemical processes by radio-labeling specific molecular with high sensitivity and specificity, while MRI could provide superior structural information. Applying MRI anatomical priors to reduce the PET partial volume effect is straightforward, and could further be used to improve spatial resolution of PET images [2]. The hardware challenge in integrating PET and MRI system is the interaction of the PET electronics and MRI system [3]. The special deign of the PET/MRI-PET detector (so called "MR transparent") architecture includes integrated cooling features to assure optimal PET performance, as well as specialized shielding to virtually eliminate magnetic field interference in the PET data processing chain [4]. On the MRI side, larger bore size with cylindrically optimized homogeneity volume has been used for better image quality [4]. Another challenge of the PET/MRI scanner is the derivation of attenuation correction (AC) from MRI for PET images reconstruction [2]. Three commonly-used MR-based AC (MRAC) methods had been proposed: template-based MRAC, Dixon's method [5] for fat/water separation which assigns AC values based on the segmentation of fat, water and relative bone tissues, as well as dual-echo or multi-echo ultra-short TE (UTE) MRI sequence [6] for delineation of bone, air and software tissue.

Numerous separate PET-MRI imaging studies in Alzheimer's disease (AD) have been performed to study characteristic brain alterations including brain atrophy with earlier involvement of medial temporal lobe, brain hypo-perfusion in the posterior cingulate and parietal regions, reduced functional and structural connectivity, and hypo-metabolism [7,8]. In this study we demonstrate the improvements in neuroanatomical and vascular-metabolic quantifications derived from simultaneous nature of multi-modality image acquisitions. All scans started after injection of 10 mCi of FDG tracer followed by a PET/CT scan (45 minutes post-injection). After completion of the routine PET/CT scan, simultaneous PET/MRI acquisition was performed in a 3T PET/MRI whole body system, with dynamic PET-FDG and advanced MRI sequences including arterial spin labeling (ASL) and resting state functional MRI for quantifying cerebral blood flow (CBF) and functional connectivity [1]. Voxel-wise whole brain analysis showed highly consistent FDG uptake patterns of PET/MRI ($P<0.01$) using two MRI-based AC methods (i.e. Dixon and UTE). The majority of brain voxels (>99%) showed significant correlations (r>0.6, P<0.05) between PET/MRI (Dixon AC) and PET/CT ratio of standard uptake (SUVR) values with cerebellum as reference region (Figure 1A). Additionally, regional SUVR values from PET/MRI and PET/CT were tightly coupled, e.g., in middle temporal gyrus (MTG) (r=0.97, slope =1.02, P<0.001) (Figure 1B). There was mild coupling between blood flow and metabolism in patients in several brain gray matter regions (r>0.71, P<0.05), including one cluster in temporal cortex (r=0.82, P=0.013) (Figure 2).

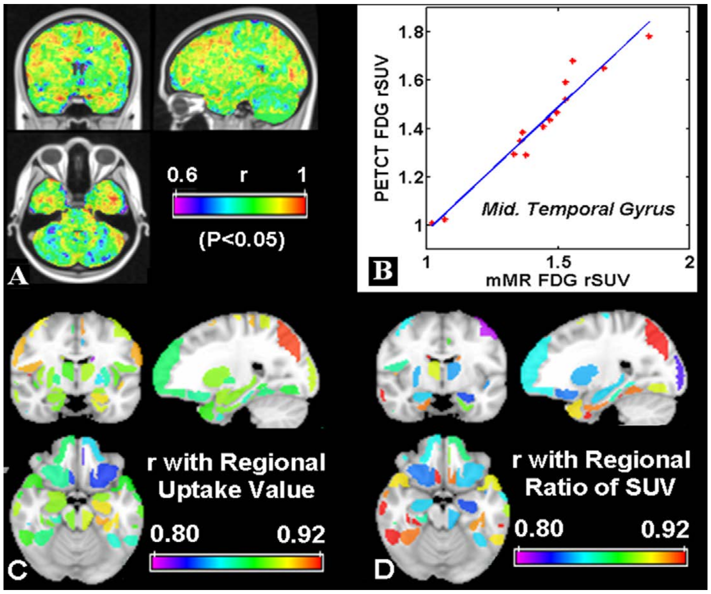

Figure 1. A: Voxel-wise correlation of PET images from PET/MRI with Dixon MRAC and PET/CT showed highly consistent pattern between two PET images (r>0.6, P<0.05). An example of the SUVR values in the middle temporal gyrus (MTG) from PET/MRI and PET/CT is shown in B, with a tight coupling between two PET images across subjects, derived from PET/MRI and PET/CT scanner respectively (r=0.97, slope =1.02, P<0.001). Regional evaluation between Dixon-based PET/MRI and PET/CT based on 112-ROI parcellation in FSL template using original uptake value (C) and ratio or SUV (SUVR) (D) choosing cerebellum as reference region. Color indicates the correlation in each region with 50% probability map (r>0.8, P=0.01).

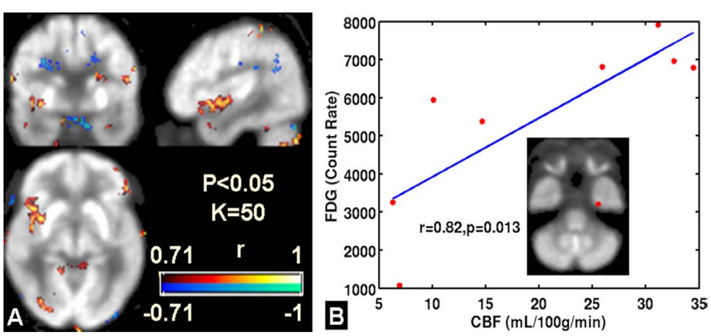

Figure 2. A: Whole brain voxel-wise correlation between PET FDG uptake and fMRI-cerebral blood flow (CBF) (P<0.05, cluster size K>50) measured across subjects, superimposed on the averaged FDG uptake background with the PET/MRI scanner. B: Significant correlation between blood flow measured with MRI and FDG-metabolism via PET in one cluster at the temporal cortex (r=0.82, P=0.013).

In conclusion, integrated PET/MRI images showed comparable image quality to stand-alone imaging modality (both MRI and PET) with the gains of simultaneous multi-parametric acquisitions, reduced scan time and potential patient discomfort.

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