Simultaneous MRS and PET of the Human Brain in Healthy and Brain Tumor Subjects

O. C. Andronesi[1], C. Catana[1], H. Kim[1], D. Jennings[1], N. Salibi[2], M. Hamm[2], J. Pfeuffer[2], E. Gerstner[3], T. Batchelor[3], and A. G. Sorensen[1]

[1]Martinos Center for Biomedical Imaging, Radiology, Massachusetts General Hospital, Harvard Medical School, Charlestown, Massachusetts, United States, [2]MGH-Martinos Center, Siemens Medical Solutions USA INC., Charlestown, Massachusetts, United States, [3]Neuro-Oncology, Massachusetts General Hospital, Harvard Medical School, Boston, Massachusetts, United States

Introduction:

MRS and PET provide valuable information about tissue metabolic state in studies of the normal brain and pathological conditions. Potentially, the two techniques complement each other for increasing the specificity and diagnosis accuracy in a complex disease such as brain cancer. Recent progress has enabled the simultaneous acquisition of MR and PET data from the human brain using a combined scanner [1]. Here we report first MRS and PET data obtained on human brain tumors with a similar MR-PET prototype scanner. The head-only MR-PET scanner consists of the whole-body 3T Tim Trio MR scanner combined with the BrainPET prototype head insert (Siemens, Erlangen). An eight-channel array receive coil designed for the PET insert was used to acquire the MR data.

First aim of this work was to study the influence of the PET insert on the quality of the MRS data. The studies were first performed in phantoms and healthy volunteers and then in subjects with brain tumors. The second aim was to make direct comparison between the metabolic information obtained by MRS and PET in glioblastoma (GBM) patients.

Material and Methods:

MRS in phantoms and healthy volunteers: Single voxel spectroscopy (SVS) and chemical shift imaging (CSI) protocols have been investigated with and without the BrainPET prototype head insert present in the bore. Typical acquisition parameters were used: SVS – PRESS excitation, 20x20x20 mm^3 voxel, TR = 2s, TE = 30 ms, NA = 92; CSI – PRESS excitation, outer volume suppression (OVS) with 4 bands, 80x80x10 mm^3 VOI, 16x16 acquisition matrix, TR = 1.7s, TE = 30ms, NA = 3.
MRS-PET in GBM patients: CSI protocol with PRESS fully excited VOI of 70x90x10 mm^3, OVS with 6 bands, 20x20 acquisition matrix interpolated at 32x32, TR = 1.5s, TE = 30 ms, NA = 2. For the PET study, approximately 5 mCi of ^{18}F-FDG were injected 2.5 hours prior to the study. The PET data were acquired simultaneously with the MRS data acquisition and the images were reconstructed using the OSEM 3D algorithm.

Results:

MRS in phantoms and healthy volunteers in the presence of the BrainPET prototype insert

MRS depends critically on the homogeneity of the main magnetic field. Additional inserts in the magnet bore may severely distort the field. Our tests on phantoms have revealed that water linewidth as low as 2 Hz ($T2^* > 200$ ms) can be easily obtained. Shimming a VOI of 10x10x1 cm^3 on volunteers can produce water lines of 11 Hz ($T2^* \sim 32$ ms) which is typical for MRSI applications.

Figure 1 presents SVS and CSI data measured on a volunteer with the PET insert inside the magnet bore. Adequate resolution is obtained that allows identification of the major brain metabolites such as NAA, Cr, Cho, Ins. No visible artifacts can be identified.

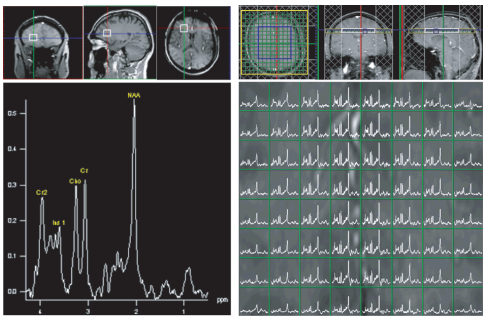

Figure 1. SVS and CSI of volunteer.

Combined MRS-PET in GBM patients MRSI and PET were co-registered with the post Gd-contrast MEMPRAGE image.

In Figure 2 reconstructed spectra are shown in the lower right image and the choline map with a zoom on the highlighted tumor region is shown in the top right image.

Figure 3 shows the corresponding PET slice, demonstrating a region with increased glucose metabolism (arrow) in the Gd-contrast enhancing area.

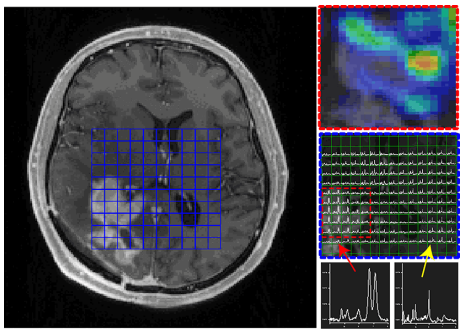

Figure 2. MRSI of GBM patient.

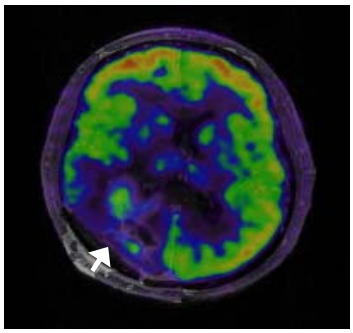

Figure 3. PET image of GBM patient.

Discussions:

Systematic testing on phantoms and volunteers indicate no degradation in the MRS data quality in the presence of the PET insert. The MRS performance of the combined MR-PET system is comparable with the 3T MR scanners from the Tim Trio class.

Analysis of GBM data from a patient under treatment reveals the presence of large lipid peaks in the tumor region (Figure 2, highlighted red region). Lipids have been suggested as a biomarker for tumor apoptosis and necrosis [2]. The lipid distribution correlates well with tumor areas with increased FDG uptake on the PET and with the enhancement on the Gd images. However, the Cho map which is related to malignity shows a different pattern inside the tumor region. While the high lipid content and reduced metabolites levels (NAA, Cho, Cr) in parts of the tumor seems to be in line with histopathological examination that suggests treatment effect and tumor necrosis, the increased FDG uptake in the same region is still able to detect viable tissue. Although the interpretation of these findings is not straightforward, they are related to the tumor microenvironment and its changes, especially relevant between pre and post treatment states.

The results clearly indicate the need for complementary information which can be obtained simultaneously with such a combined investigational device and can have immediate impact on treatment management and prognosis. Further development of the CSI aims at enhancing SNR and reducing chemical shift displacement error to allow a more precise comparison with PET images.

References: [1] Schlemmer HP et al, Radiology, 2008; 248(3):1028-35; **[2]** Hakumaki JM et al, Nat. Medicine, 1999, 5:1323-1327.