Application of a Fast High Resolution Whole Brain MRI for Segmentation

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Introduction: MRI segmentation and visualization are noninvasive methods for evaluation of brain changes in neurological disorders. These methods have become increasingly important in clinical neuroscience and drug discovery investigations. Hippocampal volume, for example, has been proposed as a surrogate marker in evaluation of early Alzheimer's disease (1). Brain volume rendering has become routine in clinical fMRI for presurgical planning. The conventional MR sequence FSPGR (or MP-RAGE) has been widely utilized in MR segmentation and clinical fMRI due to suitable contrast for segmentation and for producing thin slice (1-1.5mm slice thickness) whole brain coverage. However, in neurological conditions, such as Alzheimer's disease or brain tumors, patients often cannot tolerate prolonged scan times (e.g. typically approximately 9 minutes) of current protocols. Sequences providing higher spatial resolution with reduced partial volume artifacts will benefit the segmentation of functionally eloquent, but anatomically small regions, such as basal ganglia. In this investigation, we evaluated a novel optimized MR sequence, EasyStep (EZ) that can be used to acquired thin slices covering the entire brain with substantially reduced scan time. Segmentation results obtained with this sequence are also presented.

Method and materials:The EZ pulse sequence uses an 800 microsecond non-selective minimum phase SLR pulse with time-bandwidth of 1.2 on a GE 3T MR system (WI, USA). 8 volunteers were scanned both with ES and conventional FSPGR with same high resolution. ES: TR/TE was 7.1/ 3 msec, 12 degree flip angle. FSPGR: TR/TE/TI: 7.9-8.1/3.2/450 msec. Field of view 22 cm x 17 cm, acquired slice thickness of 0.8 mm contigous slices covering entire brain with scan time of 4 minutes 42 seconds. Automated segmentation algorithms FSL (2) and FreeSurfer (3) were adapted and parameters were calibrated for the segmentation of brain tissue and anatomical structures. Volume renderings were derived.

Results:

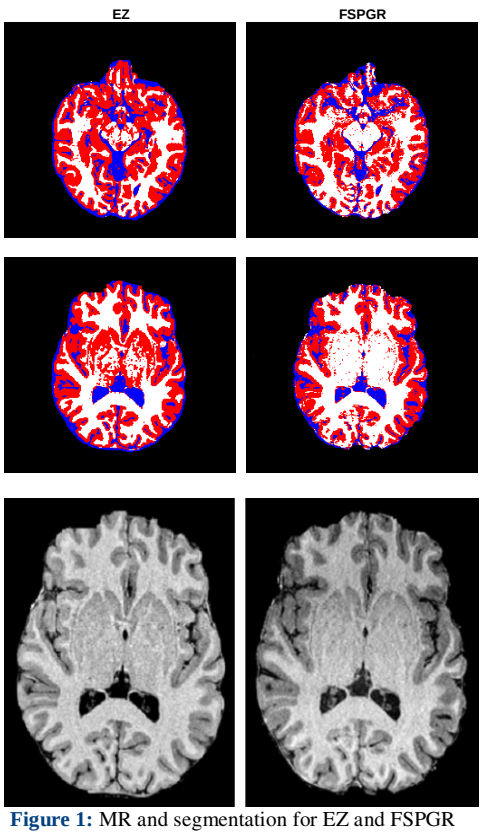

Figure 1: MR and segmentation for EZ and FSPGR

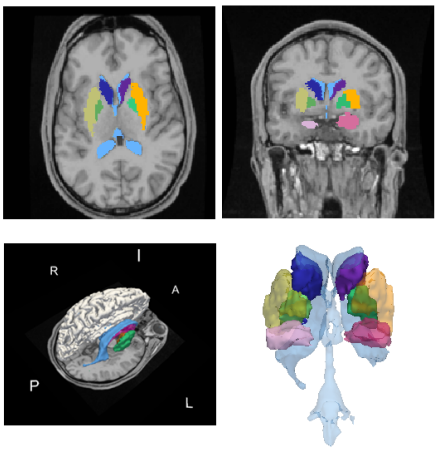

Figure 2: Segmentation of basal ganglia and verntricular system of the new EZ are displaying on the gray scale images (axial and coronal) and 3D

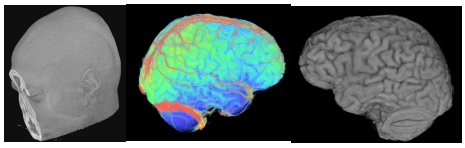

Figure 3: Volume rendering of EZ: face, contrast enhancement of veins and brain surface

We illustrate findings segmentation results based on EZ Step images. Figure 1 shows transverse sections of segmentation of EZ. The red nuclei and the substantia nigra are accurately depicted, while these regions are not segmented in FSPGR images. In the segmentation of EZ, the medullary laminae separating internal and external segments of the globus pallidus are distinguishable, as is the claustrum. These findings contrast with those obtained with FSPGR, in which basal ganglia were not successfully segmented. Visual inspection of the gray scale images indicated good gray-to-white matter contrast for both EZ and FSPGR for cortical gray matter; some details of gray matter were more readily visible in basal ganglia for EZ. ROIs from caudate nuclei, internal capsule and background were sampled to investigate the contrast to noise ratio (CNR) and gray matter to white matter contrast ratio (GM/WM) for EZ and FSPGR. CNR is significantly higher in this localized area in EZ (EZ vs. FSPGR Mean±SD: 10.880 ± 1.279 vs, 6.931 ± 0.778, $p<0.0001$). GM/WM contrast is similar for EZ and FSPGR (Mean±SD: 0.810 ±0.001 vs, 0.802±0.001, p=0.19). Figure 2 shows the EZ segmentation of basal ganglia anatomical structures using the Freesurfer algorithm. Satisfactory segmentation was obtained for brain structures. Figure3 shows the 2D and 3D representation of segmentation results for putamen, globus palladus, caudate nuclei and amygdale—this was accomplished without hand editing.

As part of clinical functional MRI procedures, brain surface volume rendering is routinely used for superimposing on brain activation maps. The volume rendering of brain provides precise anatomical reference. Quality volume rendering was also obtained with the EZ Step data (Figure 3). Gyri and sulcus (plural?)are shown with superior clarity. The 3D volume rendering of post contrast EZ shows enhanced veins and superior sagittal sinus with exquisite quality and without interpolation distortion.

Discussion and Conclusion: The new sub-milliliter isotropic EZ images have similar GM/WM contrast behavior as FSPGR. Automated segmentation utilities FSL and Freesurfer can be adapted for EZ. Moreover, in basal ganglia, EZ has much higher CNR than the FSPGR, which may explain the enhanced segmentation obtained in EZ. EZ also can be used to derive superior quality brain volume rendering for fMRI. This sequence can reduce the data acquisition scan time for structural MRI by approximately 40%.

References:

(1) Ramani A et al. Radiology 2006; 41: 26. (2) Zhang Y. et al. IEEE Trans. On Medcal Imaging, 2001; 20: 45.(3) Han X et al. . IEEE Trans. On Medcal Imaging 2007; 26: 479.