Volume-Selective Thin Slice Thickness EPI for Whole Brain fMRI: Comparison with Z-Shimming EPI

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INTRODUCTION: The susceptibility-induced local magnetic field gradient (SFG) in regions near air-tissue interfaces causes signal loss in gradient-echo EPI. This signal drop-off leaves the acquisition of fMRI data inaccessible to gradient-echo EPI in the orbitofrontal cortex (OFC) and inferior temporal lobe regions. The z-shimming technique[1] or using thin slice thickness[2] has been used to effectively recover the signal loss. Volume-selective z-shimming[3] method was used to improve the temporal efficiency by compensating only a few slices affected by the SFGs. In this work, volume-selective method was applied to thin slice thickness technique to take advantage of high temporal efficiency in order to cover the whole human brain for fMRI studies. The correction of the SFG induced signal loss by both thin slice thickness and z-shimming techniques were compared.

METHODS: A volume-selective variable slice thickness EPI sequence was implemented on a 3.0 T MR scanner(Philips Healthcare, Cleveland, OH) and tested on a 17 cm spherical agar gel phantom and healthy volunteers. A total of 30 oblique axial slices were acquired to cover the whole brain cortex, the slice thickness at the region affected by SFGs was reduced to half and the slice number was doubled to keep the same coverage. Six pairs of thin slices of 2.0 mm thickness were used in this example; sum of squares was used to combine each pair of thin slices into one slice for image reconstruction. This resulted in 24 final slices of 4.0 mm thickness, as illustrated in Fig 1. Other imaging parameters were: TR/TE = 2000/30 ms, FA = 77 degree, slice gap = 0.5 mm, FOV = 192 mm, matrix size = 64x64 and in-plane resolution = 3.0x3.0 mm^2. 140 set of images were acquired for each fMRI run. The same imaging parameters were applied to a volume-selective z-shimming EPI sequence, except the six pairs of thin slices were replaced by six z-shimmed slices of 4.0 mm thickness.

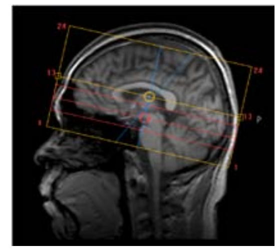

Figure 1. Slice prescription of volume-selective imaging. Red box indicates the coverage of the thin slices or the z-shimmed slices.

RESULTS and DISCUSSION: Six slices covering inferior OFC and inferior temporal lobe are shown in Fig 2. MRI signals in the areas experienced large SFGs was significantly recovered by either volume-selective thin slice thickness or z-shimming technique. Temporal signal to noise ratio(tSNR) in three selected region of interests (ROI) are summarized in Table 1. ROI-3 is set in area where was not affected by SFG. Z-shimming technique has slightly higher tSNR. Thin slice thickness imaging worked better in the lower bottom slices close to the brain stem, which is indicated in the first column in Fig 2; this is due to the major SFGs are in-plane and not through the axial slice thickness direction. Phantom test results confirmed that thin slice thickness imaging has lower tSNR, shown in Fig 3. Volume-selective z-shim technique requires non-compensation slice number to be a multiple of 2 for short TR, e.g. 2 seconds, in order to limit the number of z-shim compensations and special slice acquisition order is required to ensure the steady state of the z-shimmed slices[3]. The effective TR of z-shimmed slice is half of that of the non-compensation slice. Volume-selective thin slice thickness technique can be easily implemented on a research or clinical MRI scanner and is operated without the need for additional procedure. Additional scans are required for z-shimming technique to optimize the compensation gradient for each z-shimmed slice. Thin slice thickness technique can acquire images in sequential slice order to mitigate the head motion artifacts in fMRI images and its characteristic of being more robust than z-shimming technique to complex SFGs will benefit the fMRI studies that are interested in amygdala and hippocampus areas such as in emotional learning and memory tasks[4,5].

Table 1. average tSNR in selective ROIs

	ROI-1	ROI-2	ROI-3
convention	24±13	45±23	137±18
thin slice thickness	43±15	72±16	106±15
z-shimming	42±24	84±29	126±14

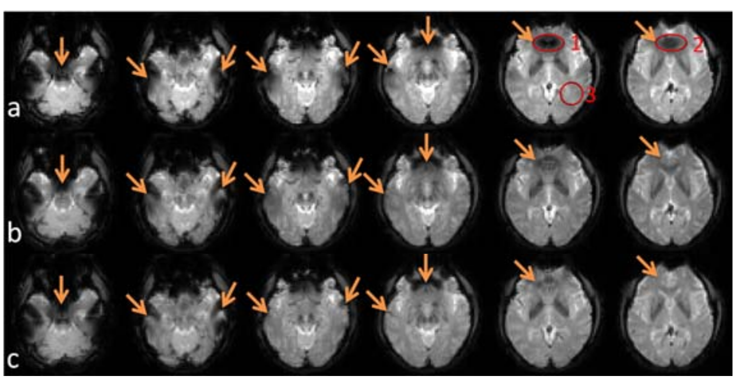

Figure 2. Orange arrows indicate the signal loss locations. Red ellipses and circle are the ROIs used for tSNR measurement. (a)conventional single shot gradient echo EPI;(b) thin slice thickness imaging; (c) z-shimming imaging.

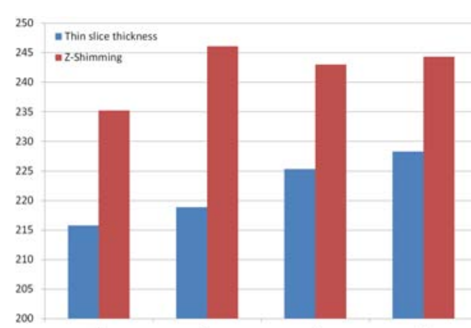

Figure 3. Average of tSNRs in 4 slices of an agar gel phantom.

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