Reduction of Magnetic Field Inhomogeneity Artifacts in EPI with SENSE-GESEPI

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Introduction The signal-loss, image-blurring and geometric distortion artifacts in EPI are caused by the distortion of T2* relaxation modulating EPI k-space trajectory due to magnetic field inhomogeneity. The GESEPI (Gradient-Echo Slice Excitation Profile Imaging) method is shown to be effective in restoring tissue T2* relaxation characteristics (1-2). The utility of this technique for rapid EPI imaging for artifact reduction is limited by the increased data acquisition time. This limitation can be overcome with the SENSE method (3). The SENSE method has been demonstrated to be effective in mitigating the geometric distortion artifacts associated with in-plane local gradient (4). Thus, incorporation of SENSE with GESEPI will provide an effective method to mitigate all three types of artifacts while reducing acquisition time.

Theory The through-plane local gradient plays a dominant role in distortion of tissue T2* relaxation characteristics. Assume that magnetic field inhomogeneity in the slice direction, z, can be approximated with a linear gradient, G_l, the voxel signal intensity for 2D EPI:

$$S = M_0 \exp(-t/T_2^*) \text{sinc}[\gamma G_1 z_0 t/2] \quad [1]$$

where γ is the gyromagnetic ratio, M_0 magnetization and z_0 slice thickness (1). An incremental compensation gradient G_c is applied in *N* steps in the GESEPI technique. In this case the pixel signal intensity for a given G_c step is expressed in k-space as

$$S = M_0 \exp(-t/T_2^*) \text{sinc}[\pi(k_c - k_1(t))z] \quad [2],$$

where $k_c = \gamma G_c \tau/2\pi$, $k_l = \gamma G_l t/2\pi$, and τ being duration of Gc. Applying Fourier transform to Eq. [2] with respect to k_c yields:

$$I = M_0 \exp(-t/T_2^*) \exp[i\gamma G_1 z_0 t] \text{rect} \quad [3],$$

where rectangular function, rect, represents the slice excitation profile. Thus, the GESEPI technique recovers lost signal and reduces image blurring by removal of the sinc-function modulation by G_l. The in-plane local gradient results in voxel distortions and shifts predominantly in the phase-encoding direction in EPI. These artifacts are reduced with SENSE because of the decrease in EPI trajectory length and the increase in phase-encoding gradient strength by a SENSE factor of **r**. SENSE-GESEPI is a complementary method for EPI, allowing for reduction of artifacts caused by both in- and through-plane gradients.

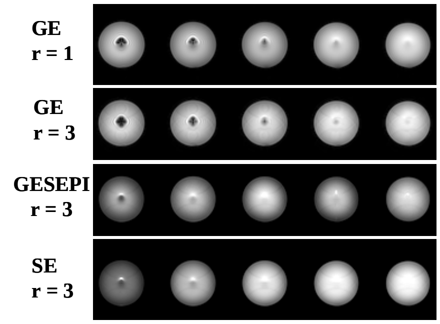

Fig. 1. The T2* EPI phantom images acquired with various methods. The phantom consists of a 16 cm water sphere with a 3 cm air ball in the center. Five axial slices for each method are shown.

Methods The evaluation of SENSE-GESEPI method for EPI image artifacts reduction was performed on both phantom and human subjects on a 3.0 T Integra (Philips Medical Systems, Netherland). The SENSE-GESEPI-EPI were acquired with the TR/TE/FA = 237/30 ms/40°, FOV = 210 x 210 mm², matrix = 80 x 80 (zero-fill to 128 x 128), 7 axial slabs with thickness = 10 mm, compensation steps = 8, r = 1-3, NEX = 1, and acquisition time / volume = 3.6 sec. The SENSE-EPI images of the same ROI were acquired from 28 axial slices with thickness = 2.5 mm, TR/TE/FA = 3.6s/30 ms/90°, r = 1-3, and NEX = 1. The spin-echo EPI, conventional spin-echo (SE) and gradient-echo (GE) images were obtained from the same volume using identical geometric parameters for comparisons.

Results and **Discussion** Figure 1 shows five slices of EPI images of the same volume with the first slice (left column) cutting though an air sphere in the phantom with various acquisition methods. The signal-loss artifact with the GE method exacerbates as the SENSE factor increase to 3. This artifact was significantly reduced with GESEPI, yielding similar image intensity distributions as that with the SE-EPI method. Figure 2 shows three sets of human brain EPI images using GE, GESEPI and SE methods with r = 3. The interference of signal loss artifact (arrows) due to the through-plan gradient is extensive in T2* brain imaging with SNESE at 3.0 T. These artifacts are reduced significantly with the SENSE-GESEPI technique.

The signal-loss, geometric distortion and image-blurring artifacts in T_2*-weighted EPI have a common origin and occur concomitantly. The method removing the signal-loss artifact with current methods do not necessarily remove the image-blurring artifact (5-7). The phantom and human brain data presented demonstrated that the SENSE and GESEPI methods are mutually complementary and facilitating in artifact reduction, and therefore a method of choice of high field T2* EPI applications. The regions influenced by the susceptibility artifacts are associated with many important brain functions (olfaction, memory, etc.). Thus, this technique is highly useful for fMRI.

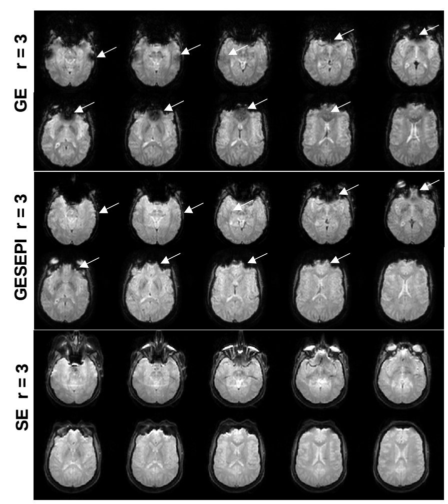

Fig. 2. The T2* human brain EPI images with different acquisition methods. The arrows indicate extensive signal-loss artifacts with GE and their corrections with SENSE-GESEPI.

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