New Method for Correction for Distortion Caused by Static-Field Inhomogeneity in Gradient-Echo EPI

D. A. Yoder[1], J. M. Fitzpatrick[2], C. B. Paschal[3,4], J. C. Gatenby[4], Y. Zhao[4]

[1]State University of West Georgia, Carrollton, GA, United States, [2]EECS, Vanderbilt University, Nashville, United States, [3]Biomedical Engineering, Vanderbilt University, Nashville, TN, United States, [4]Radiology & Radiological Sciences, Vanderbilt University, Nashville, TN, United States

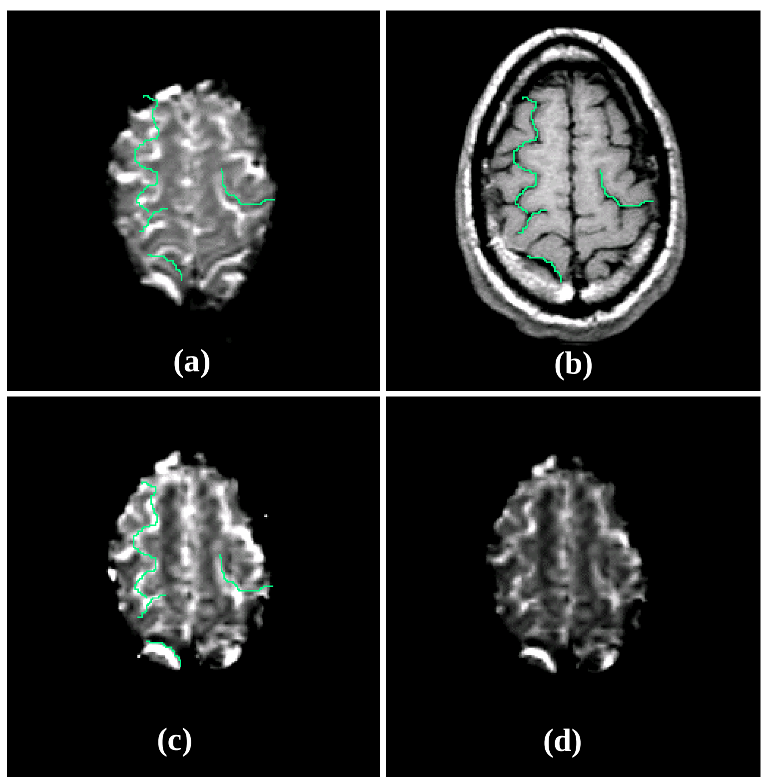
Introduction. Geometric and intensity distortion arising from static-field inhomogeneity can be severe in gradient-echo echo-planar imaging (GE-EPI), especially at field strengths of 3T and higher. Reference-image correction methods are applicable [1] but require many additional scans. We propose a method that requires only two additional scans.

Method. The two additional scans are spin-echo echo-planar images (SE-EPI) that are identical to the GE-EPI except for the addition of a refocusing RF pulse and the reversal of the phase-encoding gradient in the second SE-EPI. The two SE-EPI are used to determine a distortion map by means of the forward-reverse method of Chang and Fitzpatrick [2]. This method was developed for spin-warp imaging, where the in-plane distortion lay in the readout direction (x direction), but it is applicable whenever the conservation principle used by that method holds, *i.e.*, the integral of intensity between any two points along a line in the direction of the reversed gradients is unchanged when the gradients are reversed. The principle applies here to the phase-encoding direction (y direction) for the SE-EPI pair but not to similar pairs of GE-EPI. Thus, we apply the method to the SE-EPI pair to obtain the distortion map. The distortion is a shift in the y direction. This distortion map applies also to the GE-EPI, which suffers geometric distortion identical to that of the first SE-EPI. We can use the map to unwarp the GE-EPI and to correct for the change in intensity that accompanies stretching or squeezing, but, because of the missing refocusing pulse, there is additional intensity distortion caused by intravoxel dephasing. We have derived the following new approximation for the corrected intensity in terms of the measured intensity for GE-EPI:

$$i\left(x, y_1 - s\left(x, y_1\right)\right) = \left(\left(1 - 4\left(r\frac{ds}{dy_1}\right)^2\right) \Big/ \cos\left(\pi r \frac{ds}{dy_1}\right)\right) i_1\left(x, y_1\right) \Big/ \left(1 - \frac{ds}{dy_1}\right) \qquad (1)$$

where i and i_1 are corrected and measured image intensities, respectively, $s(x, y_1) = y_1 - y(x, y_1)$ is the shift, y and y_1 are the correct and distorted positions, respectively, $r = TE/(T - T_x)$, TE is the echo time (from excitation to center of k-space), T is the data collection time (time for complete traversal of k-space), and T_x is the time for collection of one horizontal (x direction) line of k-space. The leading factor on the right compensates for intravoxel dephasing.

Experiment. We acquired two SE-EPI and one GE-EPI, all three of which had the same following acquisition parameters: TE/TR=35/8000ms, 128x128 imaging matrix, readout bandwidth = 62.5 kHz, 24cm FOV, B_o =3T. We used the two SE-EPI in the forward-reverse method to determine $s(x, y_1)$ and we used $s(x, y_1)$ and the GE-EPI, $i_1(x, y_1)$ in Eq. (1) to calculate the corrected GE-EPI. We also used an altered version of Eq. (1) in which the leading factor is omitted. Finally, we acquired one spin-warp SE image (TR/TE = 1000/8 msec, 256x256, 24cm FOV, B_o =3T) to serve as a reference.



Results. The figure shows (a) the uncorrected GE-EPI, (b) the reference image, (c) the corrected GE-EPI, and (d) the corrected GE-EPI without the correction for intravoxel dephasing. We have traced some selected sulci on the high-resolution image and superposed them onto the other images to show both the effect of distortion and the success of our correction method. The tracings are clearly much closer to the correct sulci in (c) than in (a). The intensities in (c) are clearly higher in many areas than those in (d).

Conclusions. Correction of gradient-echo EPI by means of the acquisition of two spin-echo EPI is a feasible technique for correcting distortion arising from static-field inhomogeneity.

References.

[1] Chen, NK, Wyrwicz, AM, *Magn. Res. Med.* **41**:1206-13, 1999.
[2] Chang H, Fitzpatrick JM, *Trans. Med. Im.* **11**:319-29, 1992.

.