Analysis of Streak Artifacts in Gradient-Echo EPI Sequence Using 1.5T MRI System

J-Y. Chung[1], Y. Han[1], and H. Park[1]
[1]Dept. of EE, KAIST, Daejeon, Korea, Republic of

Introduction

Even though echo-planar-imaging (EPI) sequence is the fastest imaging method, EPI sequences (gradient-echo (GRE) or spin-echo (SE)) have limitations in application areas due to two major artifacts, Nyquist ghost artifact and geometric distortion. In order to reduce the ghost and geometric artifacts, nonlinear phase correction methods were developed [1]. However, the nonlinear phase correction methods sometimes generates streak artifact when GRE-EPI reference data is used. Although the nature of streak artifacts have been described in several literatures [2,3], an acute sources of streak artifacts has yet to be studied. In this study, we analyze the streak artifacts in a GRE-EPI sequence when a nonlinear phase correction method is used, and present the acute source of streak artifacts.

Methods

We performed several experiments using 1.5 Tesla (Avanto, Siemens Medical Solutions, Erlangen, Germany) MRI system with a quadrature head coil. To analyze sources of the streak artifacts, we performed several experiments with GRE-EPI imaging scans using a non-phase-encoded reference scan. In order to analyze the effect of noise on the streak artifacts as mentioned by the previous study, we acquired GRE-EPI reference data using various SNR conditions, i.e., two different numbers of averages (NEX = 1 and 32) and two different flip angles (FA = 9° and 90°). We then investigated the GRE-EPI reference data in terms of the dephase scheme. To analyze the effect of field inhomogeneity, we also acquired GRE-EPI reference data using various shimming values. In the experiments, we acquired the reference data (single-shot GRE-EPI) using the parameters as follows; TE=40ms for GRE-EPI imaging and reference scans, TR = 3000ms, matrix size = 64×64, number of slices = 36, slice thickness = 5mm, FOV = 25.6×25.6 cm^2, NEX = 1. The field homogeneity for these experiments was shimmed by an inbuilt 3D shimming procedure.

Results

In the experiments, the same GRE-EPI image was corrected by various reference data having different SNR. The experimental results are shown in Fig. 1. Figures 1a and 1b show the phase-corrected images from a nonlinear phase correction with NEX of 1 and 32, respectively, both having a FA of 90°. Figure 1c shows a phase-corrected image from a nonlinear phase correction with a FA of 9° and NEX of 1. From these results, we can conclude that SNR improvements of the reference data by signal averaging or large flip angle cannot correct the streak artifact if the noise is not completely removed.

The reference data after a 1D FT along the readout (RO) direction correspond to the projection data along the phase-encoding (PE) direction. Figures 2a and 2b show the magnitudes of the GRE-EPI reference data in the same slice after a 1D FT along the RO direction, which correspond to projection data acquired at multiple echo times. The data are obtained using different magnetic field shimming values, and hence the position of zero magnitude in the projection data can be changed, as marked with arrows in the figures. As a result, the streak artifacts are shown at different positions, as shown in Figs. 2c and 2d. Thus, it can be concluded that the streak artifacts appear at positions where the magnitude of the projection data becomes almost zero, i.e., where the spins are dephased out. Due to the main field inhomogeneity, the spins of the GRE-EPI reference data are dephased in multiple echo signals. The signal dephase can affect the magnitude of the projection data such that it approaches zero. Phase estimation from almost zero magnitude can result in the streak artifacts.

Conclusions

We knew that the streak artifacts were generated in some slices among when the nonlinear phase correction is used, and were very sensitive to the main field inhomogeneity. According to our analysis from experiments, the streak artifacts were generated by the phase error that was misestimated due to field inhomogeneity in the GRE-EPI reference scan.

References

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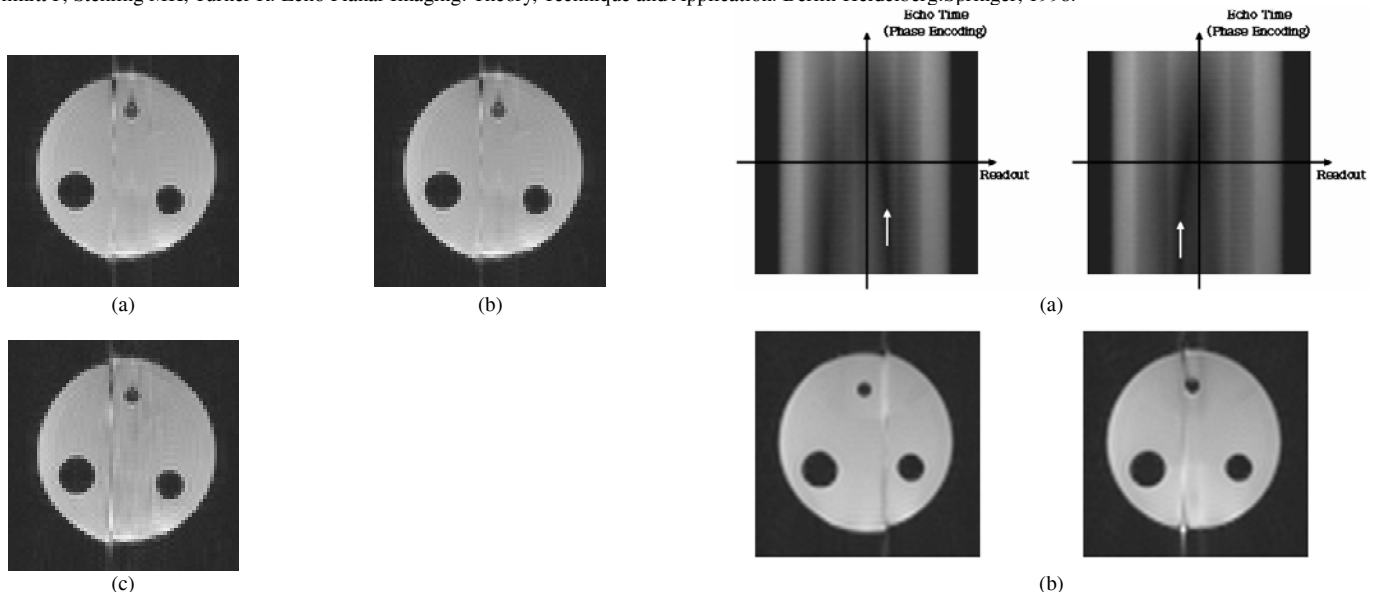
(a)

(b)

(c)

Figure 1. Experimental results having streak artifacts from a GRE-EPI imaging scan. (a) The corrected EPI image from the reference data having NEX = 1 and FA = 90°, (b) the corrected EPI image from the reference data having NEX = 32 and FA = 90°, and (c) the corrected EPI image from the reference data having NEX = 1 and FA = 9°.

(a)

(b)

Figure 2. (a) (b) The magnitudes of the GRE-EPI reference data after 1D FT acquired using different shimming values, (c) (d) the corrected images of (a) and (b), respectively, using nonlinear phase correction.