EPI Distortion Correction Using Magnitude Difference Map

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Introduction

Due to low bandwidth in phase encoding direction, EPI is vulnerable to off-resonance effects such as B0 filed inhomogeneity & magnetic susceptibility variation. Compared with the original images, EPI images will be compressed, dilated or sheared according to different distribution of B0 inhomogeneity. Meanwhile, image intensity will be varied from its original value. These artifacts, called geometry distortion & intensity distortion, will deteriorate image quality and hence will reduce the diagnosis value of EPI images.

Theoretically, EPI distortion can be reduced by decreasing echo spacing or echo length, but these approaches will be either limited by hardware capability, or compromised with spatial resolution. Thus, various approaches have been proposed to correct EPI distortion. These include methods that use two distorted images acquired with inverse gradients [1], and methods that use phase difference map [2].

Here, a kind of signal acquisition & post-processing method using signal magnitude difference map (MD Map) is introduced to correct EPI distortion, including geometry & intensity distortion. In this method, specific RF pulse, such as SpSp pulse in Fig 1, is designed to excite spins with different resonance frequencies (caused by B0 inhomogeneity) using different flip angles. In this way, a distorted image will be generated but weighted with B0 map. Then, with such two acquisitions but using different weighting strategies, an MD map can be obtained from the two B0-weighted images. Accordingly, B0 map can be derived from MD map and distortion can be corrected using the B0 map.

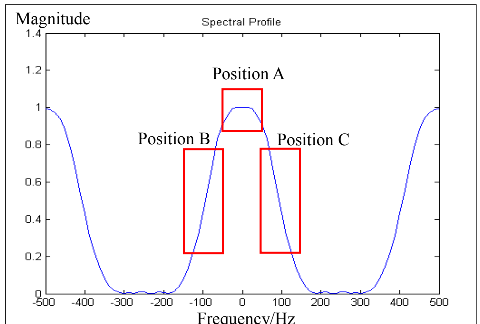

Fig 1. Excitation RF Spectral Profile in the proposed method. In normal EPI, Position A is centered in water CF to realize water excitation; Instead, in the proposed method, position B & C are respectively centered in water CF to obtain two B0-map weighted images.

Methods

The method to correct EPI distortion with MD map can be described in the following 6 steps:

1. Design specific excitation pulse with the requirement that spins with different resonance frequencies should have different flip angles. In our experiments, SpSp pulse shown in Fig.1 is utilized since it's commonly used as EPI excitation pulse to excite water while suppressing fat.
2. EPI excitation with the designed pulse. As shown in Fig. 1, instead of normal EPI excitation with Position A centered in water central frequency (CF), Position B & C are centered in water CF successively in two acquisitions in the proposed method. The center of Position B & C are varied from that of Position A with –100Hz & 100Hz respectively. Thus, two B0-map weighted images are obtained from the two acquisitions. Here, since SpSp pulse can't be used to suppress fat any more, fat saturation pulse is needed before EPI acquisition.
3. Calculate MD map with the two B0-map weighted images. Different kinds of signal magnitude differences function can be defined. For instance, direct division of the two B0-map weighted images can give a practical MD map.
4. Derive the relationship between MD map & B0 map based on the RF profile.
5. Generate B0 map according to the relationship between MD map & B0 map. In order to prevent noises coming into distortion correction, necessary filtering, interpolation & smoothing are performed on the original B0 map.
6. Distortion correction using B0 map, and add the two distortion-free images to get a uniform combined image.

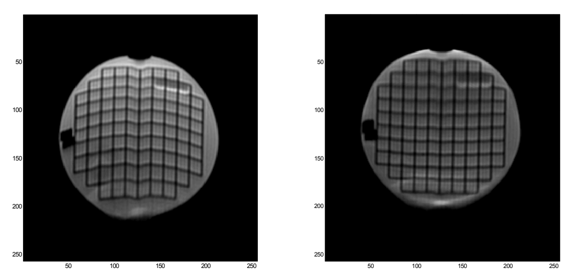

Fig 2. Phantom Experiment. Left image: Uncorrected EPI image shows significant distortion along phase encoding direction; Right image: Corrected image with MD map method.

Results

Phantom & volunteer experiments are performed using MD map method on GE 1.5T scanner and shown in Fig. 2 & 3. In normal EPI scan, phantom image with regular lattice will show great distortion along phase encoding direction. After acquired & processed with MD map method, almost all the distorted lines along phase encoding direction are successfully corrected. Same improvement can be observed in human brain images in Fig.3.

Discussion

The results from our study show that EPI distortion can be well corrected with the MD map method. Benefiting from the use of signal magnitude, the proposed method has many advantages compared with the existing approaches. Firstly, unlike the method using inverse gradient [1], distortions of the two acquired images are exactly the same, so pixel corresponding issue inhibit in that method will not appear here. Secondly, this method is immune from N/2 ghost. As is shown from Fig.2, distortion correction works well with ghost existing. Also, minimal modifications on sequence are needed. All the sequence timing & gradients keep exactly the same while only the spectral excitation frequency is varied.

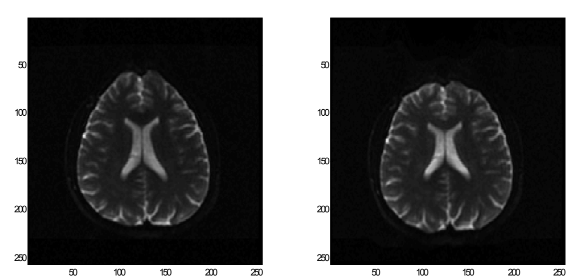

Fig 3. Human Brain Experiment. Left image: Uncorrected EPI image shows significant distortion along phase encoding direction. Right image: Corrected image with MD map method

References

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[2] QS Xiang and FQ. Ye. Correction for geometric distortion and N/2 ghosting in EPI by phase labeling for additional coordinate encoding (PLACE). MRM. 57:731–741 2007