Reduction of Eddy-current-induced Distortion in Diffusion-weighted EPI using Spin-tagging

Kun Zhou[1], and Wei Liu[1]
[1]Siemens (Shenzhen) Magnetic Resonance Ltd., Shenzhen, Guangdong, China, People's Republic of

INTRODUCTION: In diffusion weighted echo-planar imaging (DW-EPI), individual DW images used to produce isotropic DW image and ADC map may contain inconstant distortions due to eddy currents, which are introduced by the rapid switching of the large diffusion gradients [1]. The misregistration between individual DW images will lead to blurring isotropic DW image and erroneous ADC map. Different methods have been developed to overcome this problem by improving pulse sequence [2] or post-processing [3, 4]. In this abstract a spin-tagging based method is proposed to correct distortions within individual DW images. After distortion correction, all individual DW images could be aligned with the corresponding non-DW image (b = 0), and the artifacts in the isotropic DW image and ADC map are reduced.

METHODS: In this abstract we use the notation that the image is in the XY plane and the phase-encoding direction lies along Y. In DW-EPI image, eddy currents induced distortion in each column can be considered to be only scaling and shifting [3]. It can be corrected column by column that to magnify the column by a scaling factor $S(x)$ and then translate it by a translating factor $T(x)$. This method uses stripes placed by RF tagging pulses to characterize the distortion and calculate the two factors describing the distortion. The proposed method consists of two steps: image acquisition and post-processing. In the first step, tagged and normal images are measured using EPI sequences with and without spin-tagging preparation, respectively. The strip image is generated by subtracting tagged image from normal one. Note that strip images for both distorted and reference images are required to calculate scaling factor $S(x)$ and translating factor $T(x)$ in the following post-processing step. The stripes present themselves with a certain space frequency which depends on the spin-tagging preparation. For each column the frequency will change if scaling distortion appears, as demonstrated in Fig.1. After the frequencies of distorted column $f_{distorted}(x)$ and reference column $f_{ref}(x)$ are located by peak fitting in frequency domain, the scaling factor for this column is given by: $S(x) = f_{distorted}(x) / f_{ref}(x)$. The shifting factor $T(x)$ is estimated using the correlation function of reference column and distorted column (scaled by the factor of $S(x)$). The position of maximum in this function indicates the shifting factor [3]. Ideally, $S(x)$ should be the same for each column and $T(x)$ changes linearly with x. Therefore linear fits for $S(x)$ and $T(x)$ are performed to remove the random variations. The fitted $S_{fit}(x)$ and $T_{fit}(x)$ are used to calculate the pixel shifting map (PSM) for each pixel: $PSM(x,y) = y \bullet S_{fit}(x) + T_{fit}(x)$, which can be used to correct the distortions. The procedure described before is applied to all the individual DW images with different b value and diffusion directions.

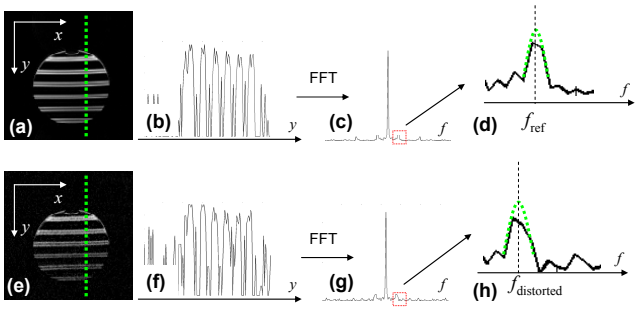

Fig.1. Scaling factor calculation. (a): reference strip image; (e): distorted strip image; (b,f): certain columns from (a,e); (c,g): frequency representation of (b,f); (d,h): determine frequencies of the columns using peak fitting.

The sequence was implemented on Siemens scanners and post-processing was implemented using Matlab. To validate this algorithm, phantom data were measured on 1.5T scanner with the following parameter: TE/TR = 127/500 msec; Bandwidth = 1000 Hz; FoV = 20 x 20 cm; Matrix = 128 x 128; Average = 4; b = 0, 500, 1000 s/mm^2; Diffusion Mode = Orthogonal; Diffusion Scheme = Monopolar. To measure tagged images, a spin-tagging prepared DW-EPI sequence with the same parameters but average time of 1 was played out before this acquisition. Post-processing procedure described before was performed to correct distortions for each b value and diffusion direction.

RESULTS: Image with b = 0 is shown in Fig.2a. DW images with b = 1000 and three different directions (phase-encoding, readout and slice-selection) are shown in (b-d), respectively. Distortion corrected images are shown in the second row. It shows that distortions can be reduced by the proposed method. Fig.3 (a, b) shows the isotropic DW images with b = 1000 calculated using original individual DW images (a) and distortion corrected individual images (b). It is obvious that the proposed algorithm can reduce blurring of isotropic DW images due to individual DW image distortion. Fig.3 (c, d) shows the ADC images calculated using original isotropic DW images (c) and distortion corrected images (d). The ADC map becomes more precise compared with the uncorrected one.

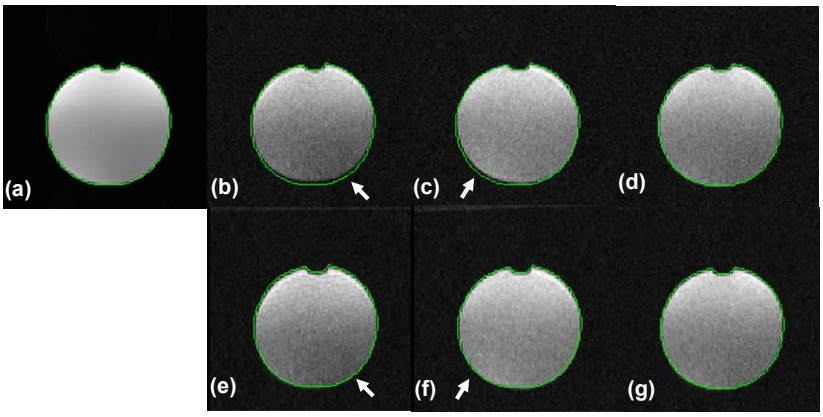

Fig.2. (a) Image with b = 0; (b-d): distorted images with b = 1000, in phase encoding, readout and slice selection direction, respectively; (e-f): distortion corrected images of (b-d).

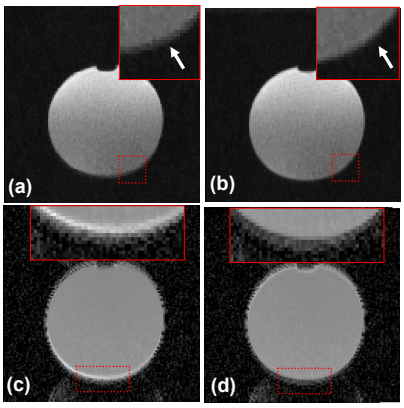

Fig.3. Isotropic DW images (b = 1000) and ADC maps calculated using distorted individual DW images:(a,c), and distortion corrected individual DW images(b,d).

DISCUSSION AND CONCLUSIONS: The proposed method uses strips generated by tagging pulses to characterize distortions in DW-EPI images and directly calculates scaling and shifting factors, which is efficient and time-saving. Because our method does not require the similar contrast between distorted and reference image, it can be applied in images acquired with high b values. The phantom study has demonstrated that the presented method can reduce eddy currents induced distortions in individual DW images and hence improve image quality of isotropic DW image and ADC map.

REFERENCE: [1] Bernstein M et al. Handbook of MRI pulse sequences. San Diego: Elsevier Academic Press; 2004. [2] Reese TG et al. MRM 2003; 49(1):177-182. [3] Haselgrove JC et al. MRM 1996; 36(6):960-964. [4] Bodammer N et al. MRM 2004; 51(1):188-193.