Distortion Correction of Single-Shot Spin-Echo EPI of the Liver at 3T

K. M. Koch[1], D. Holland[2], D. Xu[1], A. Shankaranarayanan[3], and A. Dale[2]
[1]Global Applied Science Laboratory, GE Healthcare, Waukesha, WI, United States, [2]Department of Neurosciences, University of California, San Diego, United States, [3]Global Applied Science Laboratory, GE Healthcare, Menlo Park, CA, United States

Introduction: Single-shot spin-echo EPI techniques have established utility in clinical diffusion imaging. Though these methods are appealing for their rapid volumetric coverage, they suffer from a correlated sensitivity to B_0 inhomogeneity. The imaging bandwidth of the phase-encoded dimension in single-shot EPI images commonly leads to substantial pixel displacements in imaging applications throughout the body.

Numerous approaches have been proposed to correct EPI image distortion via post-processing. Of these methods, a select few have been demonstrated capable of performing such a correction with the inclusion of intensity compensation for compression and expansion artifacts (e.g. multiple pixels being displaced to a single location). The methods of Holland et al [1], Andersson et al [2], and Gallichan et al [3] collect EPI images of opposite phase-encoding polarity, which are together used to construct a displacement map via optimization of a generalized image-space cost-function. Along with a pixel replacement procedure, these methods also use local gradient information to execute a Jacobian correction of image intensities that compensates for compression and expansion artifacts.

These methods have commonly been applied to single-shot spin-echo EPI images of the brain. Here, we extend this work to examine correction of single-shot spin-echo EPI images of the liver.

Methods: The reversed gradient correction algorithm of Holland et al [1] is applied in this work. This method seeks to optimize the cost function

$$F(\Delta_i) = \sum_{j=1}^{N}\left[J_{Fj} I_F(\vec{r}_j - \Delta_j \hat{y}) - J_{Rj} I_R(\vec{r}_j + \Delta_j \hat{y})\right]^2 + \lambda_1 \sum_{j=1}^{N} \Delta_j^2 + \lambda_2 \sum_{j=1}^{N} \left|\vec{\nabla}\Delta_j\right|^2 ,$$

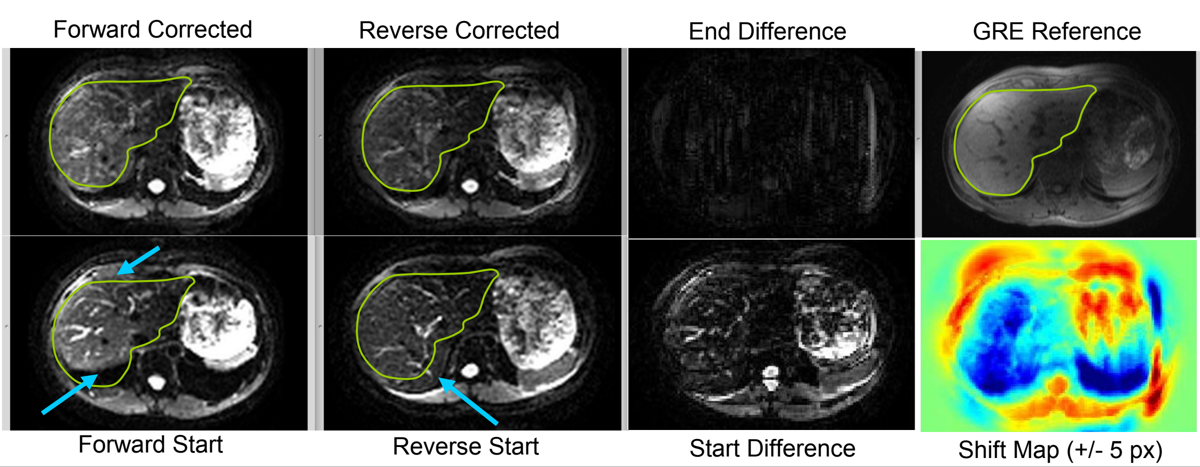
through modulation of the shift map $\Delta(x,y,z)$. In this cost function, I_F and I_R refer to the forward and reverse blip-polarity images; J_F and J_R refer to the forward and reverse Jacobian correction terms,

$J_{Fj/Rj} = 1 \pm \dfrac{\partial \Delta_j}{\partial y}$; and λ_1 and λ_2 are regularization parameters that control the magnitude and variation of the optimized shift maps.

Holland et al [1] have shown that this cost function can be optimized by iteratively solving for perturbations to $\Delta(x,y,z)$ while successively blurring the source images (I_F,I_R) with decreasing Gaussian kernel widths.

While this method has shown great promise in imaging of the brain, here we explore its capability to correct for distortions in the liver. Axial T2-weighted, single-shot spin echo EPI images were acquired with an echo time of 60ms and a repetition time of 3s, using an 8 channel phased array coil and 2X SENSE parallel imaging and 2 signal averages. Data were acquired using a 128x128 grid over 38 cm with 3 mm slices. Both the forward and reverse blip polarity images were acquired in a single breath hold. In a separate breath hold, 3D spoiled gradient-echo images were acquired as an anatomic reference.

Results: Correction of Single-Shot Spin Echo EPI images of the liver at 3T: Bottom row shows initial axial EPI images for both blip polarities and the difference between the two images. The top row shows the same images after distortion correction. The liver is outlined using the GRE reference image as guidance. Arrows in the initial images show areas where the liver was significantly misplaced and misshapen due to initial distortions. Ideally, the two blip polarity images will have minimal difference, which is clearly indicated in the difference image after correction (top row). The displacement map calculated through the described cost-function minimization algorithm [1] is presented in the lower right hand corner.



Discussion: As displayed in the above images, post-processing correction of distortion in single-shot EPI images of the liver is feasible using the blip reversed displacement map optimization presented by Holland et al [1]. In the presented case, the bulk shape and structure of the liver and abdominal region is significantly marred by susceptibility-induced B_0 inhomogeneity. The presented methods are able to significantly repair this large-scale distortion. This correction capability is consistent across the liver volume. Future work will investigate the application of this method in correcting clinical diffusion images of the liver.

[1] Holland et al, Neuroimage 50, 2010 [2] Andersson et al, Neuroimage, 20, 2003, [3] Gallichan et al , MRM, 64, 2010