Assessment of position dependent eddy current distortions in DW EPI measurements: monopolar versus bipolar diffusion preparation

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Introduction

In diffusion weighted echo-planar images (DW EPI) eddy currents occur due to the strong diffusion gradients and cause spatial distortions. One solution to reduce those distortions is to apply bipolar (bp) [1] instead of monopolar (mp) [2] diffusion preparation schemes. The disadvantage is an increase in echo time leading to a decreased signal-to-noise ratio (SNR) [3], especially in tissues with short T2 (liver, renal medulla, muscle) [4, 5]. Lately the gradient system quality concerning the generation of eddy currents improved, so that adverse effects (especially close to the isocenter) could be reduced. However, not every organ can be positioned at isocenter. The trade-off between loss in SNR at improved spatial registration and higher SNR with the risk of spatial misregistration would depend on the position in the scanner. EPI sequences - with mp and bp diffusion preparation - were applied to a phantom positioned at isocenter and off-center and maximum distortions were measured.

Material and Methods

A cylindrical phantom (outer diameter 12 cm) was filled with 1.25 l of water doped with 0.4 ml Gd-DTPA and a plastic cuboid (4x4x3.5 cm^3) was positioned in the middle of the cylinder (figure 1a). This phantom was examined at a 3 T whole body MRI unit (Siemens Healthcare, Erlangen, Germany) at isocenter, 15 cm x-off-center and 15 cm y-off-center (figure 1b). DW EPI sequences were applied with b-values of 400 s/mm^2 and 1000 s/mm^2 and 6 and 12 diffusion directions. The sequence parameters were: TR = 3500 ms, TE = 61 - 84 ms, FOV = 192x192 cm^2, matrix = 128x128, 16 slices, slice thickness = 1.5 mm and bandwidth = 1500 Hz/pixel. Evaluation was performed with a Matlab® program plotting a profile through the middle of the normalized b0-image and b400- /b1000-images along the phase-encoding direction (figure 1). Normalization was done by accumulating the mean out of four ROIs in the water. For better quantification each profile was interpolated. For the diffusion direction with maximum misregistration the distance between the b0-profile and the corresponding b400- /b1000-profile at the pixel intensity 0.5 was calculated for all interfaces (air-water, water-cuboid, cuboid-water, water-air) and averaged.

Results

The distortions at the different positions and gradient schemas appeared as false scaling and translation in the phase-encoding direction only due to the low bandwidth (in phase-encoding direction). The values of the maximal distortion for the 6 directions (Table 1) and 12 directions showed the same trend. An increase in distortion was seen by comparing the results for the mp and bp sequence at the two b-values in the x- and y-off-center. The bp sequence showed fewer artifacts as the mp sequence. Evaluations of the mp and bp images acquired at y-off-center revealed that the distortions at the interfaces increase with their distance from the isocenter (figure 2). This cloud also be seen by comparing the signal profiles obtained at isocenter with those at y-off-center.

Table 1: Maximal distortions in the mp and bp images at the various positions.

	isocentre	15 cm x-offcentre	15 cm y-offcentre
mp: b=1000 s/mm^2	0.5 mm	2.1 mm	3.0 mm
bp: b=1000 s/mm^2	0.5 mm	0.9 mm	0.6 mm
mp: b=400 s/mm^2	0.3 mm	1.2 mm	2.1 mm
bp: b=400 s/mm^2	0.2 mm	1.0 mm	0.3 mm

Discussion

The experiment showed that at given gradient strength the eddy current induced distortions increase with the displacement from the isocenter. Using a standard scanner at isocenter no measurable differences in the images occurred between the mp and bp DW EPI measurements. A distortion of less than half a pixel (0.75 mm) in mp images seems acceptable. Close to the isocenter mp sequences can be applied with the advantage of higher SNR (due to a TE shorter by 14 ms) and without considerable misregistration artifacts. For off-center-positions bp sequences seem to be the method of choice because the distortion is halved in comparison to mp sequences.

References

1. Reese et al. MRM 2003;49:177-82.
2. Stejskal et al. J Chem Phys 1962;41:288–92.
3. Alexander et al. MRM 1997;38:1016-21.
4. Martirosian et al. In Proc CD, ISMRM 2010.
5. Kyriazi et al. Eur Radiol 2010;20:2422–31.

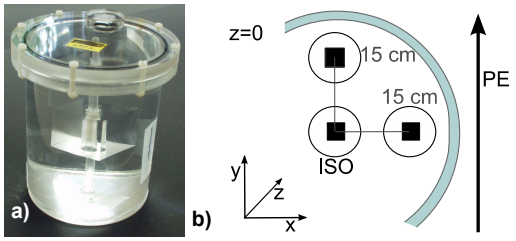

Figure 1: a) picture of the phantom – a cylinder containing water doped with Gd-DTPA and a plastic cuboid. **b)** Positions of the phantom inside the scanner – isocenter, 15 cm y-off-center and 15 cm x-off-center

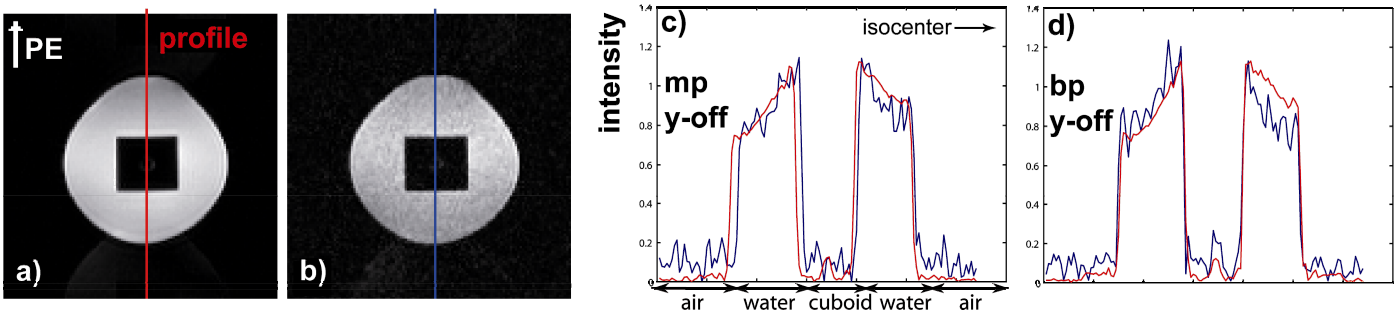

Figure 2: DW EPI images of the phantom at 15 cm in the y-off-center with a b-value of **a)** 0 s/mm^2 and **b)** 1000 s/mm^2. **c)-d)** Profiles along the phase-encoding direction (y-axis) for y-off-center measurements with b0 (red) and b1000 (blue) **c)** mp and **d)** bp diffusion gradients.