MR-based Field-of-View Extension: Compensation of Field Imperfections

J. O. Blumhagen[1,2], R. Ladebeck[1], M. Fenchel[1], J. Kampmeier[1], and K. Scheffler[2]
[1]Magnetic Resonance, Siemens Healthcare, Erlangen, Bavaria, Germany, [2]Division of Radiological Physics, University of Basel Hospital, Basel, Switzerland

Introduction. Recently, the potential impact of a limited MR-based field-of-view (FoV) in whole-body MR/PET attenuation correction has been shown [1]. In MR/PET the tissue attenuation map can be calculated from the MR images. However, the FoV restriction may cause a truncation of the MR data for bigger patients and therefore can bias the PET data reconstruction. Furthermore, an extended FoV can be useful in image-guided radio-surgery and biopsy. FoV limitation due to B0 inhomogeneity and nonlinearities in the gradient field is well-known and several distortion correction methods have been studied [2-4]. In this work, we will show exemplarily for 2DFT spin-echo (SE) sequences a method that offers an extended FoV in the transversal plane of up to 600mm using a gradient field that compensates B0 inhomogeneities.

Materials and Method. In 2DFT SE imaging, distortion along the frequency-encoding direction can be described by the sum of the relative error in the gradient field c(x,y,z) = δBgx(x,y,z)/Gx and the deviation from the static magnetic field δB0(x,y,z)/Gx [3]. Therefore an optimal gradient strength was calculated to compensate the B0 inhomogeneity by the gradient nonlinearities at a specific position:

$$x' - x = c(x,y,z) + \delta \mathrm{B0}(\mathrm{x,y,z})/\mathrm{Gx}_{\mathrm{opt}}(x,y,z) \overset{!}{=} 0$$

$$\Rightarrow \mathrm{Gx}_{\mathrm{opt}}(\mathrm{x,y,z}) = -\,\delta \mathrm{B0}(\mathrm{x,y,z})/\mathrm{c}(\mathrm{x,y,z}),$$

where x is the real position and x' is the distorted position.
Field plots of the main magnetic field and the gradient field were acquired using a half moon probe array containing 24 probes and rotating around the magnetic field axis with 24 angular positions per turn. In-plane distortions were simulated pixel-wise for readout (RO) gradients of -2.48mT/m and +2.48mT/m.
The 2D SE sequence was modified to calculate and adjust the optimal RO gradient strength automatically.
A phantom experiment was performed on a 3T whole-body system. The sphere structure phantom was placed at the edge of the magnetic bore (x=-300mm) to validate the simulation data. In-plane distortions for 11 readout gradient strengths in the range of ± 10mT/m were evaluated. Finally, in a volunteer experiment the volunteer's arms were placed as much outside as possible (x= ±300mm) and a transversal plane at z=0 was acquired. The field-of-view was set to 600mm with 1.88*1.88mm in-plane resolution and 5mm slice thickness. Readout gradient strengths of -2.3mT/m and 3.1mT/m were used to reduce the distortions of the right arm and the left arm, respectively.

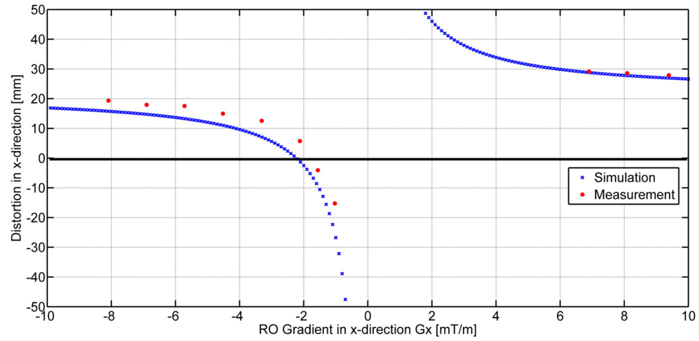

FIG 1: Simulation (blue circles) and measurement (red circles) of distortion in readout direction at x=-300mm.

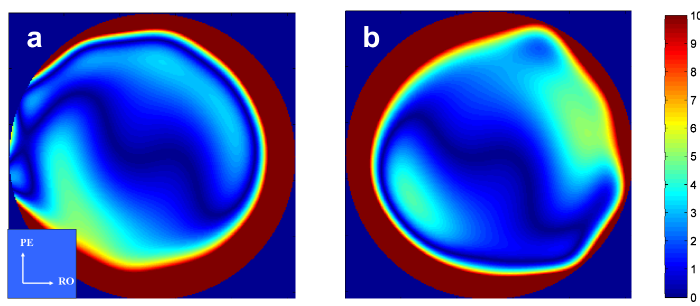

FIG 2: Pixel-wise simulation of distortions [mm] in readout direction. Readout gradient optimized for right arm (a) and left arm (b).

Results. The observed distortions with respect to the readout gradient strength are displayed in Figure 1. At -2.1mT/m distortions in readout direction are totally removed in the phantom experiment. Figure 2 shows the pixel-wise simulation of distortion for readout gradients of -2.48mT/m (2a) and +2.48mT/m (2b). The positions of zero-distortion are found at both the left and the right edge of an extended FoV at x=±300 mm. The typical distortions of the volunteer's arms (FIG 3, I) were significantly reduced by using an optimal readout gradient strength (FIG 3, II). The volunteer's arms lying nearly at the magnetic bore (x up to ±300 mm) were achieved distortion-free without any post-processing distortion correction.

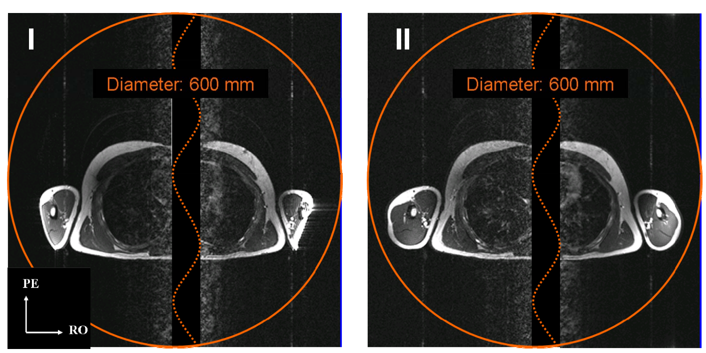

FIG 3: Transversal slice, field of view: 600mm. The typical distortions of the volunteer's arms (I) were compensated using an optimal readout gradient strength for the left and right arm (II).

Discussion. Magnetic field inhomogeneities can be compensated by nonlinearities of the gradient field. As a result, using an optimal readout gradient strength, a strong reduction of distortion at a region of interest in an extended FoV up to 600mm was observed in both, simulation and measurement. Although not yet analyzed in any detail, a limitation of this method in z-direction is expected due to non perfect fit of gradient pattern to B0 pattern. Combining the presented method with a post-processed B0 correction to extend the FoV in z-direction is subject for further research.

Conclusion. Our method offers a distortion-free transversal MR scan of patient's arms lying outside the normal specified field-of-view and therefore promises a potential to improve MR-based PET attenuation correction.

References. (1) Delso G et al. Med Phys 37 (2010). (2) Baldwin L N et al. Med Phys 34 (2007). (3) Bakker C et al. Magn Reson Imaging 10 (1992). (4) Schmitt F. CAR Berlin (1985).