Influence of linear steady background gradients on the accuracy of molecular diffusion anisotropy evaluation using MRI

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Introduction: Molecular diffusion contrast is widely used in MRI in the attempt to characterize tissue micro-architecture[1-2]. Especially diffusion anisotropy has been reported as successful in monitoring the white matter fibers integrity in several neurological disorders[3]. The presence of local magnetic field inhomogeneities can affect the evaluation of the apparent diffusion coefficient[4-5]. However up to know no studies have been reported concerning the possibility of misleading evaluations of the diffusion anisotropy due to the presence of magnetic field background gradients.

Purpose: The aim of this study was to clarify whether the presence of steady background gradients leads to inaccuracies in diffusion anisotropy measurements by means of diffusion tensor imaging (DTI) and to estimate the order of the error.

Material and Methods: Analytical expressions were derived, which account for the effect of steady linear background gradients on the accuracy of molecular diffusion parameters such as fractional anisotropy (FA) by using the diffusion tensor formalism. DTI was performed at 1.5T on water phantom in the presence of linear steady background gradients of increasing strength. Calculations were compared to experimental measurements. The strength of background gradients at the interface between tissues with different magnetic field susceptibility was estimated on phantoms and *in vivo* with gradient-echo phase images.

Results: As predicted by the calculations, the bias in the FA evaluation increased with the background gradient strength (Fig. 1). Low FA (0.0173±0.0089) was measured in the isotropic phantom after iterative shimming. Increased FA was found in the presence of background gradients of 401.5±3.4µT/m (0.0548±0.0087) and 758±12µT/m (0.0912±0.0071) (Fig. 1). Relatively high magnetic field gradient strengths were measured at the interface water-bone (313±13µT/m) and water-titanium (1305±22µT/m). A local magnetic field gradient strength of 401±10µT/m was measured in one healthy volunteer at the level of the temporal lobe at 3.0T.

Conclusion: The presence of magnetic field inhomogeneities affects the estimation of the diffusion anisotropy by using the diffusion tensor formalism. Misleading evaluation of the FA may be expected at the interface between tissues with different magnetic susceptibility (e.g. abdominal diffusion imaging), or in the proximity of impaired tissue (e.g. tumors, hemorrhages). Particular attention is desirable in studies performed at high magnetic field strength as field inhomogeneities rise with the static magnetic field strength.

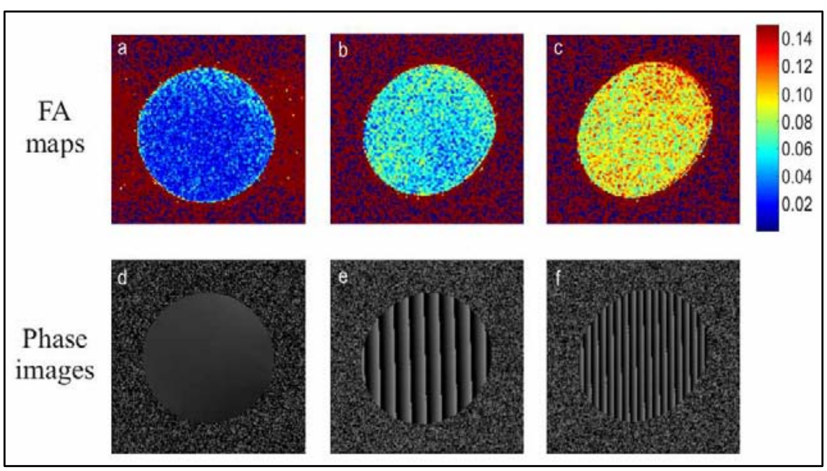

Fig. 1 The FA maps calculated after iterative shimming (a) and with background gradients of intensity 401.5±3.4µT/m (b) and 758±12µT/m (c) are displayed. The corresponding phase images are also shown. The measured FA values increased with the background gradient strength. A five-fold overestimation of the diffusion anisotropy was found in the presence of a background gradient of 758±12µT/m of intensity (f). The characteristic image sharing due to the presence of a gradient orthogonal to the readout direction is recognizable in both the phase images and the FA maps.

Reference: [1]Le Bihan D, et al., JMRI 2001; 13: 534-546. [2]Yamada I., et al., Radiology 1999; 210: 617-623. [3]Rovaris M., et al., Neurology 2005; 65: 1526-1532. [4]Stejskal E., Tanner J., J Chem Physics 1965; 42: 288-292. [5]Zhong J., et al., J Magn Reson 1991; 95: 267-280.