MRI Signal Response Mapping (SIRMA) to Dephaser to Quantify Susceptibility Gradient

F. franconi[1], J-J. Le Jeune[2], P. Richomme[1], and L. Lemaire[2]
[1]PIAM, Université d'Angers, Angers, France, Metropolitan, [2]UMR-S646, INSERM, Angers, France

INTRODUCTION :

Susceptibility effects are a very efficient source of contrast in Magnetic Resonance Imaging. However, detection is hampered by the fact the induced contrast is negative. In this work, the SIgnal Response MApping to dephaser (SIRMA) method is proposed to map susceptibility gradient to improve visualization.

THEORY :

In gradient echo acquisitions, the echo formation of susceptibility affected spins is shifted in k-space, the shift being proportional to the susceptibility gradient[1]. The SIRMA method measures these shifts from a series of dephased images collected with additional incremental dephasers. These dephasers correspond either to a slice refocusing gradient offset[2] or to a reconstruction window off-centering[3]. The signal intensity profile as a function of the additional dephaser, was determined on a pixel-by-pixel basis from the ensemble of dephased images (fig. 1a). Susceptibility affected voxels presented a signal response profile maximum shifted compared to non-affected voxels ones. Shift magnitude and sign were measured for each pixel to determine susceptibility gradients and produce susceptibility gradient map.

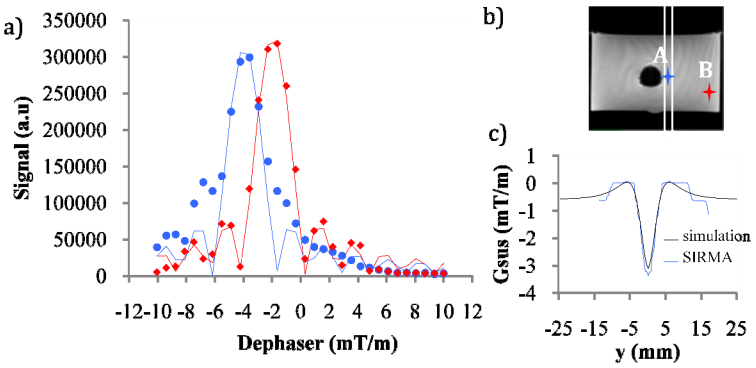

Figure 1 : Quantization of susceptibility gradient in the vicinity of an air tube perpendicular to Bo : (**a**) Signal response curves to dephaser for two voxels differently affected by susceptibility, identified on the 2D gradient-echo image (**b**), (experimental [A (●), B(♦)] and simulated data [A (–), B(–)]). Comparison of susceptibility gradient profiles (**c**) simulated (–) or measured with SIRMA (–) for the slice indicated on (**b**).

MATERIALS AND METHODS :

MRI was performed on a 7T Bruker Avance DRX system (Bruker Biospin SA, Wissembourg, France). ***In vitro*** experiments aim to demonstrate the ability of the method to quantify gradient inhomogeneities. Quantization accuracy was evaluated comparing SIRMA images and simulations performed on the well-characterized air filled cylinder model (Fig. 1b). Performances of the SIRMA method with respect to echo time, slice distance from the center of tube, phase encoding steps and maximum gradient value in the slice direction were also evaluated on cylinders filled with various SPIO concentrations.
Robustness of the method was assessed ***in vivo*** after an infusion of SPIO-loaded nanocapsules into the rat brain using a convection-enhanced drug delivery approach.

RESULTS AND DISCUSSION :

Figure 1c shows the good agreement between simulated and measured susceptibility gradients obtained on the air cylinder model. Performances evaluation showed limited influence of acquisition parameters (standard deviation of the susceptibility gradient value of less than 5% when TE varied from 3.5ms to 7.5ms and phase encoding steps and maximum gradient value varied respectively from 8 to 64 steps and from 43% to 123% of the slice refocusing gradient). ***In vivo,*** the region of massive susceptibility gradient induced by the SPIO loaded nanocapsules was clearly delineated and quantify on SIRMA map (fig. 2).

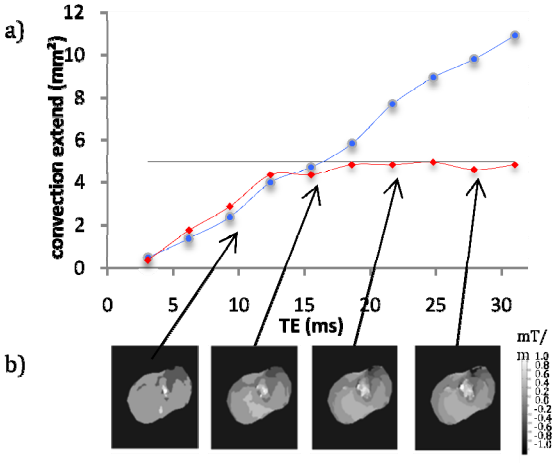

Figure 2 : *In vivo* quantitative evaluation of the area infused by SPIO-loaded nanocapsules using convection-enhanced drug delivery in a rat brain: (a) Convection extent on SIRMA images (–), T2*weighted images (–) and histological *post-mortem* Perl's staining image (–) as function of TE. (**b**) Corresponding representative SIRMA maps.

CONCLUSION :

The proposed method is a promising technique for a wide range of applications especially in molecular or cellular imaging with respect to its quantitative nature and its computational simplicity.

REFERENCES :

[1]H. Dahnke et al., Magn Reson Med **60**, 595-603 (2008).[2]J.R. Reichenbachet al., J Magn Reson Imaging **7**, 266-279 (1997).[3]C.J. Bakker et al., Magn Reson Med **55**, 92-97 (2006).