Rapid Fast Field-Cycling Imaging using the Keyhole Technique

P. James Ross and David J. Lurie
Aberdeen Biomedical Imaging Centre, University of Aberdeen, AB25 2ZD, Scotland

Purpose

Fast Field-Cycling MRI (FFC-MRI)[1] is an emerging technique that adds a new dimension to conventional MRI by making it possible to rapidly vary B_0 during a pulse sequence. By doing this it is possible to observe how the NMR relaxation rates of biological tissues vary with magnetic field strength - information which can be employed as a useful contrast mechanism. In this work we have made use of the keyhole MRI technique[2] in order to speed up FFC-MRI.

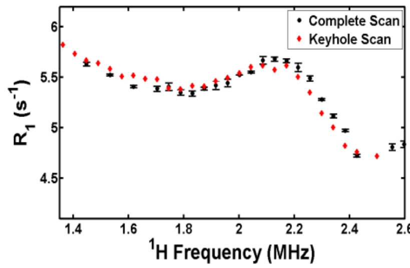

Figure 1: Dispersion curves for a phantom of cross-linked BSA obtained using the keyhole method (red diamonds) show good agreement with results obtained using a conventional field-cycling spin-echo sequence (black circles).

Methods

Imaging was carried out on a home-built, whole-body, field-cycling imager with a 59 mT detection field[3]. Images were constructed by combining an initially-acquired full resolution k-space with a set of low resolution k-space matrices acquired at each evolution field, requiring a scan time of 25% compared to conventional imaging. The technique was used to derive R_1 dispersion curves from a phantom consisting of cross-linked bovine serum albumin (BSA) across a field range of 32 mT to 59 mT (proton Larmor frequencies of 1.4 MHz to 2.5 MHz). Brain images were also collected from a volunteer (Fig 2A) in order to validate that the method generated artefact free images *in vivo*. Images were collected for evolution fields of 49 mT and 59 mT (2.1 MHz and 2.5 MHz) and from these images R_1 maps were derived.

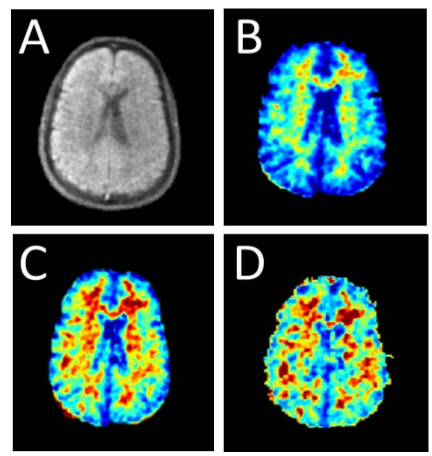

Figure 2: A: Brain image collected from a volunteer at 59 mT
B: Keyhole R_1 map collected at 59 mT
C: Keyhole R_1 map collected at 49 mT
D: ΔR_1 map generated from the subtraction of B from C.
Image parameters: matrix size = 128x128, FOV = 280 mm, THK = 15 mm, NEX = 6, TE = 30 ms, TR = 1500 ms, evolution time = 200 ms, field-cycling ramp time = 30 ms.

Results and Discussion

R_1 dispersion curves derived from BSA using the technique show excellent agreement with results obtained using a conventional scan. (Fig.1). The R_1 maps (Fig. 2B and 2C) generated from brain images show an increase in R_1 at 49 mT, which was used to generate a ΔR_1 map (Fig. 2D) which shows a higher increase in R_1 in predominately white matter regions.

Conclusions

This work has demonstrated that the keyhole technique can readily be applied to FFC-MRI and used to obtain a 4-fold or greater speed up in scan times while still retaining the same contrast as standard FFC-MRI methods. The rich ΔR_1 contrast present in brain images indicates that FFC-MRI has potential application in the characterization of neurodegenerative conditions where subtle changes in R_1, which may not be visible on conventional T_1-weighted imaging, could be used as an early marker of disease. The reduction in scan time achieved by use of the keyhole technique will significantly improve the applicability of FFC-MRI in volunteer and clinical studies, which we are currently working towards.

References

[1] Lurie D.J. *et al*. Fast field-cycling magnetic resonance imaging. C.R.Phys. 2010;11:136–148.
[2] van Vaals J.J. *et al.* “Keyhole” method for accelerating imaging of contrast agent uptake. J. Magn. Reson. Imaging 3:671–5.
[3] Lurie D.J., Foster M.A., Yeung D., Hutchison J.M. Design, construction and use of a large-sample field-cycled PEDRI imager. Phys. Med. Biol. 1998;43:1877–86.