Accelerated Field-Cycling MRI using the Keyhole Technique

P. James Ross and David J. Lurie

Aberdeen Biomedical Imaging Centre, University of Aberdeen, AB25 2ZD, Scotland, UK
www.ffc-mri.org

Introduction

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. To date we have used FFC-MRI to perform spatially-selective relaxometry using an adapted PRESS sequence[2] and also relaxometric imaging (a set of R_1 images at a range of field strengths) using a gradient echo sequence. Relaxometric imaging collects more information than selected-volume relaxometry but its application is limited by lengthy scan times, since the entirety of k-space is acquired at each field strength. For high-resolution imaging, or where images are collected at multiple evolution fields, scan times can become unacceptably long. In this work we have made use of the keyhole MRI technique[3] in order to speed up FFC-MRI. By collecting data for the whole of k-space at the beginning of each scan and thereafter only updating the low spatial-frequency region of k-space with each subsequent field-cycling experiment, contrast derived from the FFC technique is maintained while the scan time is dramatically reduced.

Methods

Imaging was carried out on a home-built, whole-body, field-cycling imager with a 59 mT detection field and a coaxial resistive offset magnet which provides field-cycling capabilities[4]. The system uses a commercial console (MR Solutions, U.K.). For each experiment, reference saturation-recovery and inversion-recovery images were acquired at the detection field using a conventional gradient-echo sequence. Following this, for each evolution field of interest, the central portion of k-space was acquired using a field-cycling inversion-recovery gradient echo sequence. During the inversion recovery period B_0 was rapidly switched to a different evolution field and M_z was allowed to relax at that field for an evolution period, typically of the order of T_1. The field was then switched back to the detection field and the imaging sequence was performed. The data were then reconstructed by combining the initially-acquired high spatial-frequency part of k-space with the "keyhole" central portion of k-space, obtained at each evolution field value. In this way a full-resolution image was constructed at each evolution field value, requiring a scan time of approximately 15% per image, compared to conventional imaging.

Results

Comparison of field-cycling images obtained using conventional methods (i.e. collecting all of k-space) with those constructed using the keyhole method shows very little difference (Figure 1). The conventional scan took 128 seconds to collect, while the keyhole image took 20 seconds.

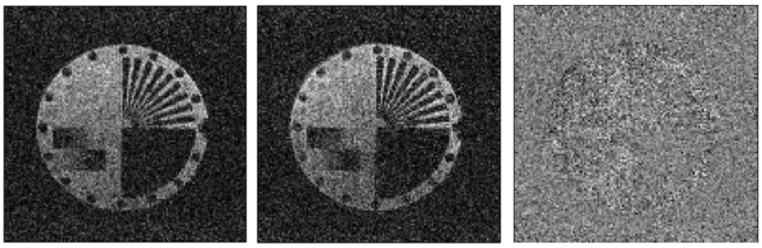

Figure 1: Left: a conventional field-cycling gradient echo 128x128 phantom image acquired using an evolution field of 40 mT. Middle: keyhole image of the same phantom acquired at the same evolution field. Right: The difference of the two images.

Conclusions

This work has demonstrated that the keyhole technique can readily be applied to FFC-MRI and used to obtain a 6-fold or greater speed up in scan times while still retaining the same contrast as standard FFC-MRI methods. The reduction in scan time 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.*, *C.R. Physique* 11, 136-148, 2010.
[2] Pine, K.J. *et al.*, *Magn Reson Med*, 63, 1698-1702, 2010.
[3] van Vaals J. *et al., JMRI* 3:671–5, 1993.
[4] Lurie, D.J. *et al.*, *Phys Med Biol*, 43, 1877-1886, 1998.

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