Fast Field-Cycling Magnetic Resonance Imaging

David J. Lurie, Changhoon Choi, Gareth R. Davies,
Dara O'Hogain, Kerrin J. Pine
*Bio-Medical Physics, School of Medical Sciences, University of Aberdeen,
Foresterhill, Aberdeen AB25 2ZD, UK*

Fast field-cycling (FFC) nuclear magnetic resonance (NMR) relaxometry of small samples has been in use for several decades, using commercially-available and home-built equipment. In FFC NMR the field is switched rapidly, so that the nuclear spins evolve at a chosen magnetic field strength, with signal detection at a different, fixed field. Thus, a single instrument can be used to measure a sample's NMR relaxation times (T_1 and T_2) over a wide range of magnetic field strengths. However, the use of fast field-cycling in magnetic resonance *imaging* (MRI) has been limited to only a few laboratories.

Previous uses of FFC in MRI include: (a) Earth's Magnetic Field MRI [1]. Since the Boltzmann magnetisation at the Earth's field is naturally very small, field-cycling is used to boost the initial magnetisation, for subsequent detection in the Earth's field; (b) Pre-Polarised MRI [2]. This uses a strong, inhomogeneous magnetic field to boost the initial magnetisation, and hence improve the SNR; (c) Relaxometric MRI [3]. This is used to obtain spatially-resolved T_1 versus magnetic field data by collecting images at a range of evolution field strengths.

In our laboratory we have developed Field-Cycled PEDRI free radical imaging, using the Overhauser effect [4]. Irradiation of the free radical's electron spin resonance (ESR) at low field causes a transfer of polarisation from electron spins to coupled nuclear spins, resulting in a change in image intensity in parts of the sample containing free radicals (signals detected at a higher field).

We are currently engaged in a project to develop new FFC-MRI hardware and to optimise the pulse sequences and data analysis. In particular, information on protein concentration can be obtained non-invasively, by virtue of the "quadrupole dip" effect, whereby the proton T_1 is reduced significantly at field strengths where resonance crossings of the proton NMR and N^{14} nuclear quadrupole resonance (NQR) occur (16, 49 and 65 mT) [5].

Fast Field-cycling MRI is a developing area, which offers significant extra information compared to conventional MRI. Due to the necessity to switch the magnetic field rapidly (in a few tens of milliseconds), it requires special magnets, power supplies, control hardware and software. All of these present significant technical challenges, which we are investigating.

[1] Stepisnik J., Erzen V. and Kos M., Magn.Reson.Med. 15, 386-391 (1990).
[2] Macovski A. and Conolly S., Magn.Reson.Med. 30, 221-230 (1993).
[3] Carlson J.W., Goldhaber D.M., et al., Radiology 184, 635-639 (1992).
[4] Lurie D.J., Davies G.R., et al., Magn.Reson.Imaging 23, 175-181 (2005).
[5] Davies G.R. and Lurie D.J., Proc. ISMRM 13th Meeting, p2187 (2005).