Molecular-based image contrast using Fast Field-Cycling MRI

Lionel Broche, Saadiya Ismail, Nuala A. Booth,
Henning Wackerhage and David J. Lurie
School of Medical Sciences, University of Aberdeen, Scotland, UK
http://www.ffc-mri.org

Conventional MRI is performed at a fixed, high magnetic field in order to obtain high signal-to-noise ratio. Fields such as 3T or even 7T are common nowadays. However, proton MRI at such magnetic strengths is known to give results related mostly to free water, hence providing little information about water-protein interactions. One way to solve this issue is to use a scanner with the ability to change its main magnetic field and collect information at a range of fields: this is the principle of fast field-cycling MRI (FFC-MRI).

Our work consists of developing a fast field-cycling MRI scanner together with new techniques to create protein-dependent contrast in MRI images. In particular, we are investigating the use of the ^{1}H-^{14}N quadrupolar cross-relaxation process, which occurs when a sufficiently immobilised NH entity is in contact with low-mobility water molecules. Under such conditions, a magnetisation transfer occurs between the bulk water and the ^{14}N nuclei, which act as a sink. This generates bell-like features in the dispersion curve (R_1 versus magnetic field), called 'quadrupolar peaks', at well-defined field strengths (16, 49 and 65 mT) where the ^{14}N nuclear quadrupole resonance and ^{1}H NMR frequencies coincide.

A preliminary validation was conducted using FFC-NMR relaxometry on the fibrinogen/fibrin (blood clotting) system *in vitro*. We have measured the amplitude of the quadrupolar peaks at different fibrin concentrations and have shown that the peak amplitude increases linearly with fibrin concentration, as expected. It was also shown that soluble and thus mobile fibrinogen did not exhibit a quadrupolar signal.

Proof-of-concept FFC-MRI experiments have been conducted on volunteers' legs to detect the quadrupolar relaxation *in vivo*. This relaxation process was used to create protein-dependent contrast using the NH_2 groups from actin/myosin filaments in the muscles. A series of images was obtained at different magnetic fields using a field-cycling pulse sequence, which successfully provided an image with a linear, muscle-dependant contrast.

This technique can potentially lead to a novel way to measure changes in the concentration of immobilised muscle protein possibly during hypertrophy/atrophy and muscle damage/injury, and is likely to be used for the detection of other types of tissue and protein gels and agglomerates. Furthermore, FFC-MRI used with tailored contrast agents can significantly increase detection sensitivity.