Modelling and measuring molecular dynamics to enhance Fast Field-Cycling MRI

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Fast field-cycling Nuclear Magnetic Resonance (FFC-NMR) is a widely used technique for the study of molecular dynamical processes in the timescales of 10^{-3} to 10^{-7} seconds [1]. It has been found that FFC-NMR measurements can provide unique insight into the behaviour of molecules, for example in polymers, by measuring NMR relaxation times over a wide range of magnetic field strengths.

There is a clear clinical benefit in applying the same methodology to model and measure disease processes, especially in light of the development of FFC-MRI techniques as demonstrated by our group [2]. However, relaxation phenomena in biological tissues are complex and not well understood, even though considerable work has been carried out to model specific molecular dynamics. A better understanding of these phenomena could help in predicting which areas of medicine would benefit most from the use of FFC-MRI and how this technique could then be applied to diagnose specific diseases. This project will involve developing models of relaxation phenomena and using the results to improve the methodology of FFC-MRI to enhance its sensitivity to disease-induced changes.

Work on the project will include: reviewing existing models of molecular dynamics and relaxation processes; identifying molecular dynamics relevant to specific disease states and adapting the model to describe the phenomena; developing tissue-mimicking phantoms and test materials and conducting FFC-NMR and FFC-MRI experiments to validate the models; developing and optimising new FFC pulse sequences to enhance their sensitivity to changes in molecular dynamics; testing the enhanced pulse sequences using biological material.

This work will make use of the state-of-the-art FFC-NMR and FFC-MRI facilities at the University of Aberdeen. The modelling work will be performed using MATLAB or similar environments and will be validated on test objects using an FFC-NMR benchtop relaxometer and locally-constructed FFC-MRI scanners. Biological samples obtained from the adjacent teaching hospital will also be used in order to validate the work on patient tissues and to generate pilot data for further studies. Depending on the results obtained, FFC-MRI studies on patients may be included towards the end of the project.

[1]Kimmich and Anoardo, Prog in Nucl Magn Reson Spect, 44 (2004) 257-320

[2]Lurie et al, C R Physique, 11, 136-148 (2010)

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