MR engineering research at the Ghent University

Workgroup Quantitative Nuclear Magnetic Resonance in Medicine and Biology (QMRI) – Medical Image and Signal Processing (MEDISIP)

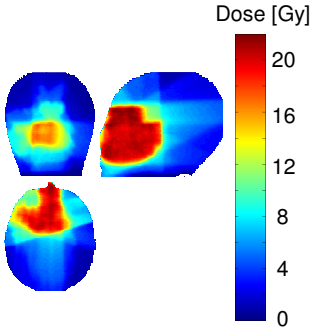
The MR engineering research unit of the Ghent University (QMRI-MEDISIP) has a focus on the development of innovative MR acquisition and image processing technologies for both diagnostics and treatment. The research group has a two fold mission: On the one hand the research group aims to come up with technical solutions for specific clinical needs as experienced within the Ghent University Hospital. At the other hand the research group performs several fundamental studies in order to obtain a better understanding of NMR measured physical properties. The MR engineering research group has expertise in both image acquisition and image processing. In the near future, the MR engineering research group will also play an increasing role in education of NMR physics and technology.

Current research projects are (ordered along starting time of the project):

Three dimensional radiation dosimetry using polymer gels and quantitative MRI

In order to simulate the deposition of ionizing irradiation dose in a patient during conformal radiotherapy, radiation sensitive polymer gel phantoms have been developed.

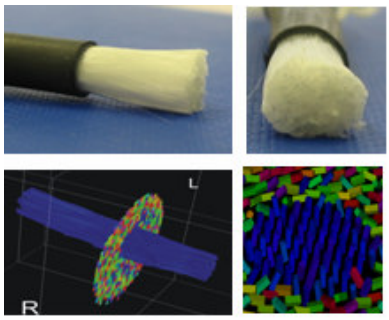
Upon irradiation a radiation induced polymerization reaction occurs within the polymer gel of which the degree of polymerization is proportional to the absorbed dose. The three-dimensional dose distribution absorbed in the irradiated polymer gel phantoms is read out by use of quantitative MRI with an accuracy of better than 2% standard deviation. Both T2 and magnetization transfer mapping have been used to acquire the quantitative dose maps. Several sources of artifacts that compromise the accuracy have been investigated and compensated such as eddy currents, B1 field inhomogeneity, susceptibility related distortions and temperature drift during scanning. This technique has been successfully adapted for the verification of intensity modulated radiotherapy treatments (IMRT) in soft-tissue organs and is currently extended to the lungs using a low-density polymer gel foam.

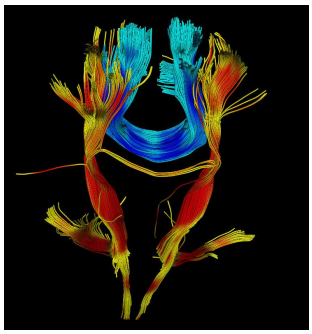


Principal investigators: Yves De Deene (and Koen Vergote)

Modeling of diffusion weighting in brain white matter

Diffusion weighted magnetic resonance imaging (DW-MRI) is a non-invasive tool to explore biological tissue in vivo, e.g. the three dimensional fiber of brain white matter (BWM). The quantization and validation of DW-MRI acquisition, fiber tractography algorithms and models for diffusion in BWM, crucial for application in clinic, are the major research topics. To determine the accuracy and precision of DW-MRI, anisotropic fiber phantoms are developed with a well-known structure. The diffusion behavior inside the fiber phantoms is modeled with Monte-Carlo simulations and verified against experimental data acquired with an NMR relaxometer and on a clinical MR-scanner. The constructed phantoms also serve as a model for the extra cellular space in BWM and can be used in combination with Monte-Carlo simulations, to validate diffusion models. Anatomically realistic, noise free data sets are generated to test the developed probabilistic fiber tracking and Q-ball algorithms.

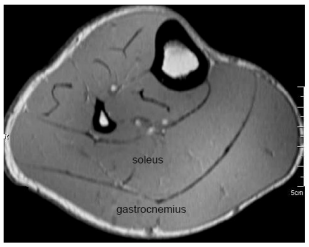




Principal investigators: Els Fieremans (and Steven Delputte)

Quantitative in vivo MR spectroscopy

In vivo MR spectroscopy is performed to achieve quantification of metabolites without water suppression. This requires additional approaches to deal with the sideband problem inherent in non-water-suppressed acquisition. To this end, two methods, modulus signal method and external reference signal method were investigated and evaluated in phantoms with respect to their performance to quantify metabolite concentrations. The feasibility of quantification without water suppression was shown. Additionally, the quantification of the metabolite carnosine (present in human muscle and brain) by in vivo MR spectroscopy as an alternative to muscle biopsy was demonstrated. The effect of B1 inhomogeneity was investigated using phantoms as well as in vivo during this study. Recent research is focusing on the accuracy of the technique for metabolic imaging of the prostate.



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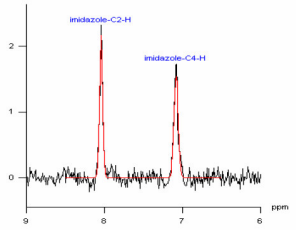
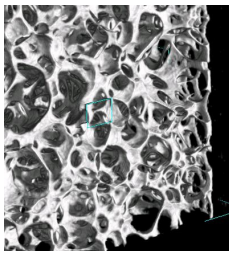


(b)

Principal investigator: Mahir Ozdemir

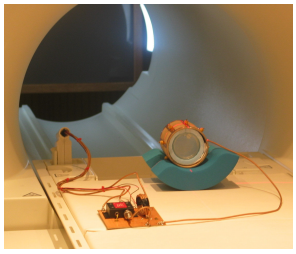
Quantitative microstructure analysis with NMR

In this study, the correlation between quantitative MR measurable properties (such as T1, T2, molecular self-diffusion and magnetization transfer) and tissue microstructure is investigated. In a first step, the MR properties of simple microscopic geometries such as randomly packed microspheres and hydrogel foams are investigated and described by use of physical models that are solved by numerical 'random walk' algorithms. In a second step, the degree of complexity is increased by including permeable membranes as they occur in liposomes. In a final stage, the findings will be translated towards more complex microstructures as they occur in human tissue.

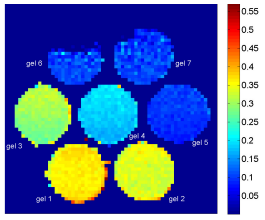


Principal investigators: Steven Baete and Yves De Deene

Measuring hypoxia by use of Fluor-19 NMR



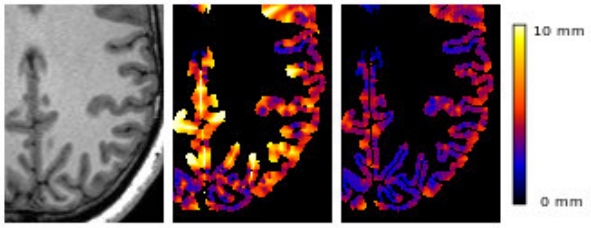
The aim of this study is to investigate the use of Fluor-19 NMR for measuring oxygen concentrations in vivo. The spin-lattice relaxation rate (1/T1) of Fluor-19 is proportional to the oxygen concentration and can thus be used to acquire oxygen maps. A home-build experimental Fluor-19 NMR coil has been interfaced with the MR scanner (Siemens Trio) and images have been acquired of Fluor-19 loaded liposomes. In this study, an emphasis is put on the quantitative aspects of the technique. Perfusion phantoms are constructed in which oxygen concentration gradients can be simulated. Alternatively, optical methods to acquire oxygen maps are developed.



Principal investigators: Steven Baete and Yves De Deene

Segmentation of gray and white brain matter

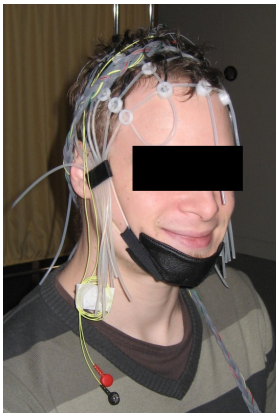
Quantitative tools to detect brain lesions with MRI are developed, especially for focal cortical dysplasia patients. In order to make statistical analysis on patient data by voxel-based morphometry approaches, feature maps are generated that display properties such as hyper-intense signal density, blurring transition across the white and gray matter and cortical thickness. Segmentation of the brain tissue and extraction of the white-gray matter interface and the cortical surface are some of the main challenging issues.



Deformable surface models and topological constraints are used for increasing the accuracy of the tissue segmentation and surface extraction methods. Developing optimal visualization of these features in clinical applications are also among the challenges of this study.

Principal investigator: Burak Ozkalayci

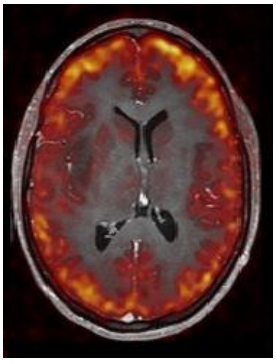
Acquiring EEG in the MR scanner



The electroencephalogram (EEG) is a standard technique to record and study brain activity with a high temporal resolution. Blood oxygenation level dependent functional magnetic resonance imaging (BOLD fMRI) is a non-invasive imaging method that allows the localization of activated brain regions with a high spatial resolution. The co-recording of these two complementary modalities can give new insights into how the brain functions. However, the interaction between the strong electromagnetic field (3T) of the MR scanner and the currents recorded by the electrodes placed on the scalp generates artefacts that obscure the EEG and diminish its readability. At this moment, the sources of the artefacts are investigated by measurements acquired in vivo and on phantoms.

Principal investigator: Sara Assecondi

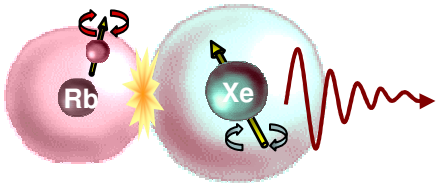
Investigative research for PET/MR multimodality imaging



The advantage of combining anatomical and functional information in one image is clear from the widespread use of PET/CT imaging in clinical practice. PET/MR additionally provides the possibility to acquire anatomical information without the ionizing radiation of a CT scan and the excellent soft-tissue contrast inherent to MRI. Through the use of avalanche photodiodes or silicon photomultipliers, the use of a PET scanner inside the magnet bore of an MR scanner has become possible. In this study we focus on two issues: First, the ability to use MR images for attenuation correction of PET acquired data is investigated. The approach that will be followed is to segment MR images into tissue types with different attenuation factors for positron annihilation photons (511 keV) bone, soft tissue and air. Secondly, MR compensation techniques will be developed to correct PET images for organ motion. Motion compensation can be performed based on MR motion detection techniques such as by navigator echoes.

Principal investigator: Vincent Keereman and Stefaan Vandenberghe

Hyperpolarized Xenon MRI



A hyperpolarizer for Xenon-129 will be constructed. The hyperpolarizer consisting of a laser diode array, a glass cell, a Helmholtz coil producing a static magnetic field and an oven will generate hyperpolarized Xenon-129 gas that will be inhaled by the subject. In a first step, the use of hyperpolarized Xenon gas for lung imaging will be exploited. The correlation between different contrast mechanisms and lung microstructure will be investigated. In a second step the use of hyperpolarized Xenon NMR for molecular imaging will be investigated.

Principal investigator: Yves De Deene
For this project there is an open position for a PhD student.

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