PERSPECTIVES ON (f)MRI IMAGING AT ULTRAHIGH FIELD

Trieste - Italy, September 21st 2015

International School of Advanced Studies (SISSA) Via Bonomea, 265, Trieste - Italy
Meeting Room 7th floor

www.sissa.it cnc.unipd.it

Workshop Abstracts

Abstract:

As investigators consider approaching the challenge of MR imaging at field strengths above 3T, do they follow the same paradigm, and continue to work around the same problems they have encountered thus far at 3T, or do they explore other ways of answering the research questions more effectively and more comprehensively? The most immediate problems of imaging at ultrahigh field strength are not unfamiliar, as many of them are still pressing issues at 3T: radiofrequency coils, B1 homogeneity, specific absorption rate, safety, B0 field homogeneity, alterations in tissue contrast, and chemical shift. In this symposium, these issues will be briefly addressed in terms of how they may affect image quality at field strengths beyond 3T. Various approaches to overcoming the challenges will be discussed as well as potential applications of ultrahigh field MR imaging as it applies to the cognitive neuroscience domain.

Program:

9:30 **Welcome Address by Prof Guido Martinelli - Director of SISSA**

9:45 **Magnetic Resonance at 7 Tesla: Technological Developments and Applications**

Dr Alessandra Retico - National Institute for Nuclear Physics, Pisa Division

Abstract: Magnetic Resonance (MR) has become a standard medical diagnostic tool and a precious instrument for neuroscience research, thanks to the multiple information it can provide (e.g. structural, functional, metabolic) in healthy and pathological conditions, and to its non-invasive nature. Ultra-high-field (UHF) MR scanners, operating at 7 Tesla or higher field strengths, are becoming available worldwide. The use of a high static magnetic field (B0) can provide a substantial increase in the Signal to Noise Ratio (SNR) and a consequent reduction in scan time or improved spatial resolution, due to the increased polarization of the sample. However, the frequency of the B1 radio-frequency (RF) excitation field increases proportionally to B0, thus reducing the RF wavelength to dimensions comparable to the sample sizes (order 0.1 m). The shortening of the wavelength in tissues leads to a number of challenges, especially in human head and body imaging, such as inhomogeneity of the B1+ transmit field and of the flip angle, decreased power efficiency, and increased Specific Absorption Rate (SAR). Technical advanced solutions to these issues are under study.

Despite these challenges, UHF MR already demonstrated enhanced capabilities in imaging and spectroscopy of several body districts. In particular, advantages have already been achieved for in vivo imaging of the brain and of the musculoskeletal system, and for imaging and spectroscopy of nuclei other than 1H, which become accessible only at UHF. The Italian experience in this field started in 2012 at the IMAGO7 Foundation (Pisa). The technological research activities of the center include developments carried out in the RF laboratory [1,2], pulse sequence design and optimization [3], and assessment of patients' safety issues through electromagnetic-field simulations [4]. The clinical research topics are especially focused on neurodegenerative disease diagnosis [5,6], brain tumor and dysplastic lesion assessment [7], and the study of the musculoskeletal system [8].

[1] Stara, R et al., Validation of numerical approaches for electromagnetic characterization of magnetic resonance radiofrequency coils, Progress In Electromagnetics Research M 29:121-136 (2013)

[2] Stara, R et al., Quadrature birdcage coil with distributed capacitors for 7.0 T magnetic resonance data acquisition of small animals, Concepts in Magnetic Resonance Part B, 2015 Mar 23, doi: 10.1002/cmr.b.21271

[3] Toncelli, A et al., STEAM-MiTiS: An MR spectroscopy method for the detection of scalar-coupled metabolites and its application to glutamate at 7 T, Magn Reson Med, 2014 Dec 22, doi: 10.1002/mrm.25556

[4] Tiberi, G et al., Investigation of the maximum local Specific Absorption Rate in 7.0T Magnetic Resonance with respect to load size by the use of Electromagnetic simulations, Bioelectromagnetics, 2015 Mar 21, doi: 10.1002/bem.21907

[5] Cosottini, M et al., MR imaging of the substantia nigra at 7 T enables diagnosis of Parkinson disease, Radiology 271:831-8 (2014)

[6] Cosottini, M et al., Comparison of 3T and 7T Susceptibility-Weighted Angiography of the Substantia Nigra in Diagnosing Parkinson Disease. AJNR Am J Neuroradiol. 36(3):461-6 (2015)

[7] De Ciantis, A et al., Ultra-High-Field MR Imaging in Polymicrogyria and Epilepsy, AJNR Am J Neuroradiol. 36(2):309-16 (2015)

[8] Retico, A et al., Non-Invasive Assessment of Neuromuscular Disorders by 7 Tesla Magnetic Resonance Imaging and Spectroscopy: Dedicated Radio-Frequency Coil Development, IEEE Conference Record of Medical Measurements and Applications (MeMeA 2015), May 7-9, 2015, Torino, Italy.

10:45 Coffee Break

11:15 **Non-invasive mapping of the human primary somatosensory cortex using 7T fMRI**

Dr Roberto Martuzzi - École Polytechnique Fédérale de Lausanne

Abstract: In my talk I will present the way we used ultra-high field fMRI to investigate the organization of the primary somatosensory cortex, focusing on the representation of the fingers. Exploiting the high BOLD sensitivity and spatial resolution at 7T, we found that each finger is represented within three subregions of S1 in the postcentral gyrus. Within each of these three areas, the fingers are sequentially organized (from D1 to D5) in a somatotopic manner. Therefore, these finger representations likely reflect distinct activations of BAs 3b, 1, and 2, similar to those described in electrophysiological work in non-human primates. Quantitative analysis of the local BOLD responses revealed that within BA3b, each finger representation is specific to its own stimulation without any cross-finger responsiveness. This finger response selectivity was less prominent in BA 1 and in BA 2. I will also show how these precise body representations can be used to investigate the role of S1 in establishing illusory body ownership, demonstrating the degree of somatosensory specialization in S1 extends to bodily self-consciousness.

12:15 Lunch Break

14:00 **Challenges for ultra-high field fMRI**

Dr Christian Windischberger - MR Center of Excellence Center for Medical Physics and Biomedical Engineering, Medical University of Vienna

Abstract: Over the last years, functional MRI has evolved to become the prime method for non-invasive brain mapping. While the overwhelming number of fMRI studies are currently performed at magnetic field strengths of up to 3 Tesla, the next generation of MR scanners with field strengths of 7 Tesla and more has already shown great potential. Shifting to ultra-high field fMRI not only increases sensitivity and specificity but also poses new challenges as the fMRI signal decays faster and the impacts of various artefacts are more severe. I will show

several approaches to improve fMRI data quality at ultra-high fields to reduce image distortions, minimize physiological artefacts, and increase temporal and spatial resolution to ultimately reduce non-neural signal components. Also, I will show how this gain in data quality can be used to assess brain function on a network level via effective connectivity estimation using Dynamic Causal Modelling (DCM).

15:00 **Opportunities for Cognitive Neuroimaging at 7T**

Prof David G Norris Radboud - University Donders Institute for Brain Cognition and Behaviour, Radboud University Nijmegen

Abstract: Recent methodological advances have greatly increased the range and power of the techniques available for the neuroscientist at 7 T. Early scanners had enormous magnets, a limited range of RF coils, were plagued by inhomogeneities in both the static magnetic field and the radio-frequency (RF) field, and were severely hindered by the limits on RF power deposition. Over the last decade the MR community has worked assiduously to alleviate these problems with the result that today's 7T systems are vastly more potent than their predecessors. It is hence relevant to ask what use we should put 7 T systems to, and whether 7 T offers fundamentally different insights when compared to 3 T scanners?

In this talk I shall offer a brief overview of the current state of the art with respect to both acquisition methodology, and BOLD contrast at 7T. I shall show how the widespread availability of multi-channel receive coils has led to an impressive increase in acquisition speed, and potentially to a reduction in RF power deposition. The consequences for anatomical, functional and diffusion-weighted imaging will be examined, with an emphasis on techniques developed or extensively used in Nijmegen (3D-EPI, multiband, multi-echo, PINS RF-pulses).

In the last part of my talk I shall present recent developments in our attempts to perform high resolution fMRI at the level of the cortical layers. I shall argue that 3D-EPI represents an ideal tool for examining extended regions of the brain at the level of the cortical laminae, and that gradually the data analysis tools (in the form of advanced registration techniques) and anatomical insights (in the form of the Bok principle) are being developed to make laminar fMRI a reality. I will show models of the laminar hemodynamic response function. At the conclusion I will present a recent combined EEG and layer specific fMRI study that shows a localisation of the BOLD response in line with predictions from animal physiology, and models of the HRF.

16:00 **General Discussion**

Organizers:

Prof. Raffaella Rumiati http://www.sissa.it/cns/iNSuLa/index.html

Prof. Umberto Castiello http://www.nemolaboratory.com http://www.cnc.unipd.it