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Editorial: *In Vivo* Magnetic Resonance at Ultra High Field

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Editorial on the Research Topic

In Vivo Magnetic Resonance at Ultra High Field

This Special Research Topic includes a representative collection of the topics outlined in the overview. With the editorial, we aim to set the stage for these excellent articles. We also emphasize our view that biomedical imaging continues to be the frontier of science and engineering today. The Brain Research through Advancing Innovative Neurotechnologies (BRAIN) initiative in the US [1], for example, is regarded as the highest priority of the nation. It is often referred to as the "Apollo project of the brain" and the basic approach is best described as "reverse engineering the brain" [2]. Similarly, the EU has launched its Human Brain Project, a H2020 FET flagship project "*which strives to accelerate the fields of neuroscience, computing and brain-related medicine*"[1]. In both efforts, neuroimaging serves as a natural foundation because seeing it is the first step of figuring out how it works. This principal applies to the entire body and differs in the specific challenges of an imaging method. It can be low sensitivity of molecular imaging, motion in cardiac imaging or inhomogeneous magnetic fields at ultra high fields and frequencies. In general, discoveries in biomedical sciences can be expected when the technology of the tools moves forward.

A frugal collection of articles cover a particularly broad range of topics. In a review focused on the history of NMR magnet technology Moser et al. addressed the driving issue of this topic that is the motivation for higher and higher magnetic fields. This review summarizes the magnet development since its early commercial availability in the 1950s in analytical NMR, up to now at 7 T or above for clinical (human) and preclinical (animal) purposes. To establish the background, the article first explained the behaviors of signal and noise versus field strengths [3]. The development in the following 60 plus years was chronicled in different stages (resistive, permanent, and superconducting magnets) to what is available today. Here we should note that Dr. Lauterbur actually never received a patent for his idea to employ NMR for imaging (which he dubbed "zeugmatography"), as in 1971 his university did not believe this was worthwhile. Concerning the current state of clinical UHF MRI, Siemens obtained CE-labeling for its 7 T Terra system in August of 2017, whereas FDA approval is still pending (M. Blasche, personal communication). The second review in this collection is focused on RF decoupling methods of ^{13}C spectroscopy (Li et al.). In contrast to the broad scope of the first one, this review goes deep into details on a small topic in NMR [4]. However, we expect to see this topic grow larger than it is because ^{13}C spectroscopy allows detection of many important organic compounds. Since the 90's, a few groups have performed ^{13}C experiments from 2.1 T to 14.1 T. One example of these efforts is to distinguish glutamate (Glu) and glutamine (Gln)in the brain [5, 6]. As Glu-Gln cycling accounts for up to 80% of the energy consumption, it is essential in understanding the brain in the clinic or in the lab [7].

The first research article by Miller et al. describes a series of unique experiments of ^{13}C spectroscopy on glucose and glycogen. The goal was to investigate the modulation effect of glucagon on glycogen and glucose in the liver [8]. ^{13}C spectroscopy was first performed on a preclinical platform at 11.7 T on perfused mouse liver. Then the same experiments were

[1] www.humanbrainproject.eu/en/

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performed on non-human primates (NHP) at 7 T. Similar dynamics of glucose and glycogen concentrations were measured *ex vivo* and *in vivo* as proof of concept as well as validation. ^{1}H spectroscopy is perhaps the hallmark application at UHF as it can be included with regular although appropriately adapted MRI protocols without special hardware. An article by Li et al. [9] demonstrates this advantage in MRI guided single voxel MRS with GABA editing in the brain [10]. They applied the special editing scheme to suppress macromolecules, i.e., acquiring GABA instead of GABA+ [11]. More importantly, the placements of the voxels were automatically generated using MRI images with segmentation and registration. This procedure addresses a long-standing issue of single voxel MRS that is the inconsistency of human interpretation of brain structures and manually placing voxels. Their algorithm achieved spatial variations of approximately 1 mm or less.

We are delighted to include an article on cardiac MRI because of its difficulty [12] and worthy alternative in CT [13]. Huelnhagen et al. present a comprehensive report on the potential and challenge of myocardial T_2* mapping using 7 T MRI. All aspects are discussed from signal mechanism, hardware requirement, available sequences to post processing and clinical merit. What is particularly valuable is the theoretical and experimental analysis of the dependence of T_2* on spatial resolution and B_0 inhomogeneity. This framework will benefit all gradient echo based sequences on 7 T as they are the workhorse due to RF restrictions. Last but not least, Orzada et al. present an analysis of an integrated 8-channel Tx/Rx body array as a body coil on 7 T MRI [14]. Due to the high frequency, and thus decreasing wavelength in tissue, whole-body Tx/Rx coils remain a challenge. The integrated 8-channel array was compared to a local 8-channel array. The bigger and wider integrated body coil demonstrates the inherent advantage of producing a more homogeneous excitation profile while similar SAR may be achieved with future optimization.

A typical scientist or engineer in biomedical research would not sensibly compare our own profession to the moon landing. Now as the analogy appears in the media for the general public, we are happy to use the APOLLO project to articulate our point. There was no real significance in putting two people on the moon for a walk. Nevertheless, it is regarded as a historic achievement because the pursuit led to new science and technology that changed the world. On a smaller scale, the pursue in imaging technology will bring progress to various biomedical fields [15]. We proposed this topic to express this view and we hope this collection shows that our aspirations resonate with fellow researchers.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

NOTE

In August 21, 2017, i.e., after the Editorial was accepted, the National High Magnetic Field Laboratory, Tallahassee, Florida State University, USA, reached 41.4 T with a dc resistive magnet (M.D. Bird, private communication). This clearly surpasses the former record of 38.5 T in Hefei, China.

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