[SY11] IBS CNIR-KSMRM Joint Symposium

SY11-01

Anatomical and functional imaging of the human brain at 7T

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Human MRI at ultra-high magnetic field strengths has had a major impact on the NeuroImage community. Ultra-high field MRI, or UHF-MRI, defined as imaging with magnetic fields ≥ 7 Tesla, is an enabling technology that is increasingly utilized by both researchers and clinicians for human neuroimaging to ask novel questions about brain structure and function. Although this technology has been in use for nearly 20 years, UHF- MRI has seen tremendous growth in the past few years, as more institutions witness both the maturity of the technology and the exciting new opportunities it creates. UHF-MRI has long been a platform for MR technology and instrumentation development as well as for MR physics and fMRI research, but is increasingly falling into the hands of cognitive neuroscientists, neurologists, and radiologists who are developing new applications that utilize the boost in sensitivity and specificity afforded by these higher field strengths. Thus, UHF-MRI has, in the last years, rapidly grown from a niche technology primarily used by MRI physicist and engineers, to a widely used imaging approach to study brain structure and cognitive function.

In this talk, I will present the expected theoretical gains of human brain 7 Tesla MRI compared with standard clinical magnetic field strengths of 1.5 and 3T and describe the challenges to achieve these gains. I will focus on MRI method developments for anatomical and functional MRI at 7T, in particular on: a) MRI sequences for high-resolution functional MRI; b) accelerated imaging for whole brain functional & anatomical MRI; c) arterial spin labeling measuring cerebral blood flow, not yet standard at 7 Tesla; and d) quantitative anatomical imaging (T1 and T2*), allowing for accurate longitudinal studies and inter-subject comparison beyond the limits of standard qualitative approaches. In addition, I will present advanced clinical and basic neuroscience applications (e.g. MELAS, type-II Diabetes, motor symptoms & DBS, Alzheimer’s Disease).

Keywords : Functional MRI, Anatomical MRI, Ultra-high field, Cognitive Neuroscience, Clinical Applications

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SY11-03

7 Tesla MRI Research at SKKU: Promise and Prospect

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In 2018, Sungkyunkwan University (SKKU) became the first institute in Asia to install a human 7T MRI system with limited clinical use approval by the United States and European Union. The system, Siemens Magnetom Terra, was subsequently approved for human clinical use by the Korean government, for head and limb imaging as provided by the manufacturer. The system is also capable of research-mode (contingent on case-based approval) imaging of human volunteers with independently controlled multi-channel radio frequency coils (parallel transmit, pTx). Since the successful commissioning of the system in July, the SKKU MRI team has obtained high-resolution clinical-mode images on healthy volunteers, enhanced functional activation maps from non-human primates, and high-resolution ex-vivo monkey brain images at multiple orientations.

Our initial assessment of the system indicates good temporal stability for phantom and ex-vivo imaging, high spatial resolutions as expected from a 7T system (compared to 3T), and very good functional sensitivity for anesthetized animals. Currently, as expected, the biggest challenge appears to be B1 inhomogeneity in human whole brain imaging when imaged with the vendor-provided single channel transmit RF head coil. Work is under way to improve and push the B1 homogeneity in the clinical (non-pTx) mode operation first, by employing $CaTiO_3$ dielectric padding and a custom-designed phased-array RF head coil.

The human 7T system is currently operated by the IBS Center for Neuroscience Imaging Research (CNIR, Director: Seong-Gi Kim), and mainly supports its mission to advance image-based human and animal neuroscience research by providing high-resolution structural and functional images. At the same time, the system is also available for use by external researchers; the scan time priority is given to projects with high potential for research collaboration with CNIR. Currently, three main research directions are envisioned. They are: (1) compilation of high-resolution multi-contrast whole brain image database of healthy Korean volunteers, (2) layer-specific functional imaging for humans and non-human primates, and (3) methodological developments for high-speed and high-quality imaging. Synergetic use of the system in conjunction with the existing 3T human MRI and ultra-high field (9.4T, 15.2T) MRI systems would also enable field-dependence studies for MR physics and biophysics research. Finally, significant interest exists in using the 7T system for clinical research, in the fields of disease biomarkers for neurodegeneration and chronic pain. Currently, discussion is under way to translate existing 3T clinical research collaborations with Samsung Medical Center to 7T. Priorities for different research directions will be set based on available human resources and more detailed system performance assessments. It is expected that in the next few years, the 7T MRI system at SKKU will become a major facility supporting internationally leading neuroscience research in Korea.

Keywords : 7T, Ultrahigh field, Neuro

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SY11-04

Preliminary Study on Development of Multi-Parametric Imaging Biomarker of Senile Brain Disease

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We present our recent preliminary study on senile brain disease, including Alzheimer's and Parkinson's disease (AD, PD), by integrating quantitative and qualitative information using 7T MRI system. The key objective of this study is development of multi parametric fusion diagnosis of AD and PD. Alterations of quantitative susceptibility values, glutamate level changes of CEST imaging, and CSF volume changes were considered as the ingredients of this multi-parametric fusion diagnosis of AD and PD. 7T MRI system was employed for this study since the sensitivity of susceptibility related information can be empathized at higher field strength, so that we included the QSM for this study. On the other hand, 7T MRI environment also enhances CEST effect of glutamate than lower field strength mainly because of slow-to-intermediate exchange rate. Volume changes in CSF were also monitored using 3D T1 weighted images of brain because the larger CSF volume size tends to be observed at the severer AD cases at a number of related studies. Finally, we also tried to include the phase shift information at cortical area. Based on those multi-parametric information, we planned to establish the fusion diagnosis of AD and/or PD using non-human primate. Since our ultimate concern is establishment of translational research platform of senile brain disease, so that the non-human primate would be the best resource for the case of preclinical tries. Seven monkeys (1 Rhesus, 6 Cynomolgus) were prepared as control, AD and PD models for this initial experimental phase. QSM, glutamate CEST, 3D T1w, and phase shift were measured at 7T human MRI system (Philips Achieva). We observed notable susceptibility and glutamate level changes at the related anatomical locations. The CSF volume changes were also observed which increased at AD models comparing to the controls. In addition to the MR imaging, designing the RF coil was also performed for the susceptibility related protocols because we assumed that the RF coil itself would be rotated at several orientations within the magnet bore for the case of COSMOS which is the QSM reconstruction method based on multiple orientations. In summary, development of comprehensive diagnosis of senile brain disease based on the multi-parametric information are currently underway at 7T human MRI environment with non-human primate.

Keywords : Sneile brain disease, High field MRI, Non-human primate, Translational research