P3: Ekosi Tesla Initiative for Human Brain Studies at 20 Tesla

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One year ago, a group of magnet and magnetic resonance scientists and engineers started an initiative to explore the human brain, in vivo, at fields of 14 T to 20 T. This initiative followed a recommendation from a U.S. National Research Council report developed by some of the participants listed herein ("High Magnetic Field Science and its Application in the United States" NRC 2013). The recommendation was to conduct an engineering feasibility study for appropriate magnet design, RF strategies, gradient coils and power supplies that will enable MRI and MRS at 20T (cf. Mark Bird et al. poster at this Symposium). The initiative includes experiments on current small bore magnets at the National High Magnetic Field Laboratory in Tallahassee, Florida supported by the U.S. National Science Foundation, and the McKnight Brain Research Institute, University of Florida, Gainesville, Florida. Five other universities throughout the U.S.A. are involved in feasibility experiments led by experimenters whose current programs anticipate MR capabilities beyond the currently available field strengths for human studies (e.g., the Univ. of Minnesota, Massachusetts General Hospital and MIT, and the University of Illinois, Chicago).

The principal motivations include the fact that sensitivity, spectral dispersion and relaxation time changes will allow investigations of metabolites in vivo that cannot be observed by any other methods. A further horizon opened by 20 T is that of imaging nuclei other than 1H such as ^{13}C, ^{15}N, ^{17}O, ^{23}Na, ^{31}P, ^{35}Cl, ^{39}K and even ^{7}Li, ^{85}Rb, and possibly ^{63}Cu. Other horizons opened by the high field are the potential for biochemical kinetic studies as well as further polarization of carbon and nitrogen substrates to achieve studies without enzyme saturation artifacts that plague injected hyperpolarization studies. A significant potential is that ^{31}P CEST could resolve all ATP, ADP and AMP signals. ^{13}C-CEST has the potential to redefine metabolic pathway phenotypes in human beings. In addition, 20 T will allow measurement of pH, redox, metabolite levels, temperature, ROS, singlet oxygen, etc., through the use of PARACEST agents that have exchange rates too fast at lower fields. The ability to perform multiple quantum studies on Na, K, and Cl leads to the promise that the electrical properties of the brain can be discerned from the gradients of these ions based on their intra- and extra-cellular regional concentrations. The B1 field distortions, also, can lead to assessments of the distribution of dielectric and conductivity properties.

The success of this endeavor depends on the broad range of expertise and participation of the 28 individuals who have joined the effort, the results of engineering design studies, the planned enabling experiments and funding (i.e., 100 million US). Some of the enabling for low gamma nuclei at fields of 17.6 T and 21.1 T as well as the physiological effects evaluations will be presented in the poster.

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