C-13 Studies of Human Brain Metabolism

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^{13}C MRS (measured either directly or indirectly through the ^{1}H nucleus) is the only non invasive method for measuring brain metabolic pathways including cell type specific neuroenergetics, glutamate and GABA neurotransmitter cycling between neurons and glial cells, and anaplerosis. Although technically and experimentally challenging ^{13}C MRS has already provided important new information on the relationship between neuroenergetics and neuronal function, the energy cost of brain function, the high neuronal activity in the resting brain state, and how neuroenergetics and neurotransmitter cycling are altered in neurological and psychiatric disease. In this lecture the current state of ^{13}C MRS as it is applied to study neuroenergetics and neurotransmitter cycling in humans is reviewed. The lecture will begin with a brief introduction to ^{13}C MRS spectroscopy and the principles of tracing metabolic pathways using ^{13}C labeled compounds. An overview of a typical human ^{13}C study will then be given along with examples of the data obtained and how the data is fit and analyzed. The practical considerations of performing ^{13}C studies will also be discussed including personnel and costs. The focus of the remainder of the presentation will be on recent findings in humans in clinical research and in addressing basic neuroscience questions. Results from *in vivo* ^{13}C MRS studies in animals will also be discussed from the standpoint where they have helped understand brain metabolic and neurotransmitter pathways. We further touch upon different ^{13}C labeled substrates used to study brain metabolism, before reviewing a number of human brain diseases studied using ^{13}C MRS. Future technological developments are discussed that will help to overcome limitations of ^{13}C MRS with special attention on recent developments in hyperpolarized ^{13}C MRS.