A practical sodium imaging method at 7T

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Generally, sodium is the second most abundant element in the biological system after hydrogen. Under normal conditions the concentration of sodium in human tissue is approximately 15mM intracelluarily, while 145mM extracellularily. And, this large ionic concentration gradient across the cellular membrane is maintained dynamically by the Na-K pump on the cell membrane that consumes ATP. The failure of the Na-K pump as result of any impaired ATP production during an ischemia event will inevitably lead to a significant increase in the intracelluar sodium concentration and then total tissue sodium content locally. For the same reason, the tissue sodium concentration can be an important indicator of its pathological status as well as a potential predictor of its fate during an ischemic event or degeneration or other pathological development (1-2). In the case of myocardial infraction (MI) or brain stroke, a quantitative sodium imaging can provide an important piece of information regarding to the physiology of an underlying pathology, which can be more specific and quantitative in monitoring its evolution than the routine MRI examination.

We have implemented a sodium imaging technique at 7 Tesla, which was based on a volumetric gradient-echo (GE) acquisition scheme. And, in the sequence a short RF pulse was used to minimize unwanted magnetization relaxation processes during imaging. Furthermore, an optimized k-space averaging scheme was used to shorten total data acquisition time. Also, a circularly polarized TEM cavity resonator (tuned to 78.5MHz with lamped capacitors) was used as a volume probe in imaging studies. An efficient head-insert gradient coil set was used. We have obtained brain sodium images from human subjects with the following scan parameters: TR/TE=50/1.5msec, flip angle<90, NSA=8. The spatial resolution parameters of the volumetric image set were: matrix of 64x48x16 corresponding to field of views of 25.6x19.2x12.8cm3. All imaging experiments were performed on a 7T whole body scanner with Varian console, Siemens gradient amplifier and 4kW CPC RF amplifier.

3D sodium MR images of the brain of human subject were obtained at 7 Tesla in about 8 min. Representative brain sodium images are shown below. Also, the transverse relaxation time (T2) was measured using a multiple echo version of the same imaging sequence. Since the sodium magnetization relaxation times of the brain tissue are significantly shorter than those of proton, its imaging can be performed more rapidly than the hydrogen imaging. However, caution should be taken when sequence repetition time is short. When TR was 50msec, the worst case SAR was found to be 2.225w/kg. This experimental result clearly suggests the potential of 7Tesla MR scanner for high field imaging applications using nuclei with relatively low gyromagnetic ratio. Furthermore, the added SNR at 7 Tesla allows a possibility of achieving high resolution imaging with voxel volume as small as 0.128 cc in reasonable scan duration. The sodium MR imaging provides information on total tissue sodium concentration, which is a physiological parameter for characterizing pathological tissue in a disease process. Considering the potential usefulness and the quality of images and the scan time required, the non-invasive sodium imaging can be both feasible and practical for diagnostic imaging applications of human at 7T.

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