Fluorine and Sodium MRI on 0.5 T Clinical Scanner

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Typical MR scanners are focused on the detection of proton (^{1}H). Detection of other nuclei provides additional diagnostic information – about the state of tissues, cellular processes, etc. Sodium is of considerable interest – the natural abundance of the ^{23}Na isotope is 100%, and the gyromagnetic ratio is 3.8 times lower than of proton. However, the sodium content in living tissues is 2-3 orders of magnitude lower than that of hydrogen, which determines the low sensitivity of the method. The detection of fluorine signals is also of interest in MRI. The ^{19}F isotope has 100% natural abundance and its gyromagnetic ratio is only 6% less than of proton. So, ^{1}H and ^{19}F MRI are comparable in sensitivity. The content of fluorine in living tissues is extremely low, therefore, it is very productive to detect signals from fluorine-containing substance injected into the body, for example, a drug, as well as from gases in the lungs, since there is no background from normal tissues in the images. The use of strong fields – from 3 T and more increases the sensitivity of multinuclear methods. However, such fields are unattainable with open-type magnets and compact portable MRI systems. Therefore, it is of interest to evaluate the productivity of multinuclear research on low-field equipment. We carried out these studies on a 0.5T clinical scanner Bruker Tomikon S50 (1H NMR frequency is 21.1 MHz). The technical rework concerned only the coils, which were used as modified proprietary prototypes, originally intended for the detection of protons [1, 2].

In experiments on ^{19}F MRI (19.8 MHz) of human lungs, we used octafluorocyclobutane gas C_4F_8 [1]. The patient inhaled a gas mixture (80% C_4F_8 + 20% O_2) and during the breath holding, scanning was performed. Since this gas has $T_1 \sim 50$ ms, we use FSE method (TE_{min} = 8 ms, ETL = 4). There were 2D FSE in 3 projections (TR = 69 ms, NA = 30, in-plane resolution of 1×1 cm^2, no slice selection, scan time of one projection of 20 s), SNR up to 43) and 3D FSE (TR = 42 ms, NA = 4, voxel size = 1×1×1 cm^3, scan time = 33 s, SNR up to 11). Measurements were carried out on 6 volunteers: females – 23 and 27 y.o. and males – 23, 23, 40 and 71 y.o. The 3D scan data were used to calculate the volumes of lung lobes and their volumetric reconstructions. Real-time studies of lung filling during inhalation and exhalation have also been conducted. For this, 2D scans (TR = 45 ms) were carried out 16÷30 times every 5÷7 seconds, NA = 16÷20. 2D scan data was used also to create maps of T1, ventilation and perfusion.

^{23}Na MRI (5.6 MHz) was done using 3D GRE technique (TR/TE = 44.7/12 ms, FA = 45°, NA = 1, voxel size = 6×6×6 mm^3, scan time = 24.5 min) [2, 3].

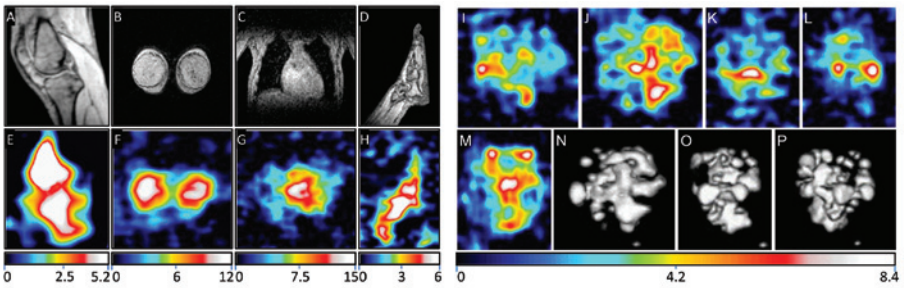

Fig. 1. MR images of different human organs: ^{1}H (A-D) and ^{23}Na (E-O).

To increase the SNR by an order of magnitude, the k-space data were exponentially apodized. To eliminate external RF interference, scans were performed at specific times of the day, and pulse noise bursts detected in k-space were edited [4]. Fig.1 shows examples of MRI of different human organs. Images A,E, I-M were obtained using a saddle coil and B-D, F-H using a solenoid coil. These coils are optimized for extremities and breast studies, respectively. For assignment of anatomical structures on ^{23}Na images E (knee, sagittal), F (breast, coronal), G (heart, coronal), H (foot, sagittal), corresponding ^{1}H images are shown: A-D. The right panel shows MRI of the head – separate slices: I,J (sagittal), K,L (coronal), M(axial), as well as 3D reconstruction – rendering at different azimuthal angles: –90°(N), 0°(O), 10°(P). The brightness scale corresponds to the SNR values. Optimization of the transceiver path can increase the SNR by more than 2 times [3].

^{19}F MRI on a 0.5 T clinical scanner is easy to implement. ^{23}Na MRI on it is also possible, but it is necessary to pay attention to the design of the coils and setting up the transceiver path.

The presented research was supported by the Russian Foundation for Basic Research (grants 19-29-10015, 20-52-10004) and by the Interdisciplinary Scientific and Educational School of Moscow State University “Photonic and Quantum Technologies. Digital Medicine”.

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