Feasibility of in vivo microimaging of the mouse in a conventional 1.5 T body scanner equipped with a 12 mm HTS surface coil

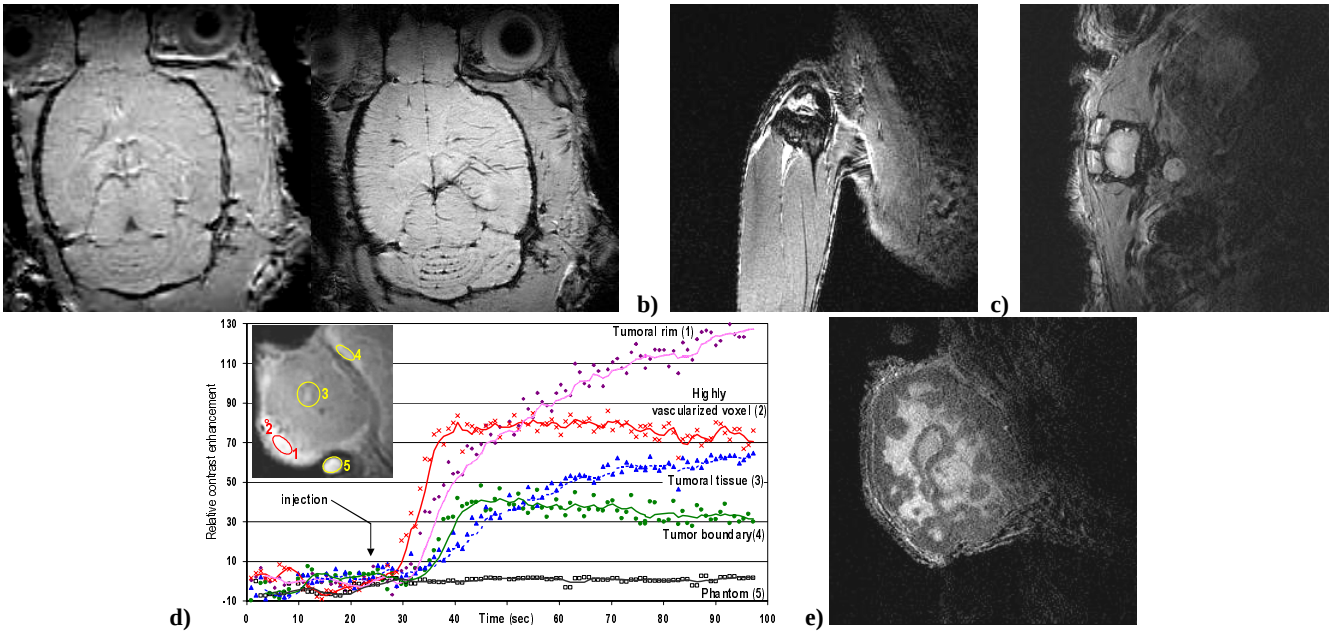
M. POIRIER-QUINOT[1], J-C. GINEFRI[1], P. ROBERT[2], L. DARRASSE[1]

[1]Universite Paris Sud, U2R2M CNRS UMR8081, Orsay, France, [2]Guerbet Research, Aulnay-Sous-Bois, France

Purpose Using animal models of human diseases is a rapidly expanding field [1], allowing to better understand pathological processes such as tumors, neurodegeneration, atherosclerosis, osteoporororosis and arthritis, and to develop suited therapeutic means. Smallest mammals such as mice are attractive since most investigations involve very expensive chemical substances. In addition animal management is easier and ethical acceptance could be less problematic than for larger animals. Investigations by MRI usually require dedicated scanners operating at a few Tesla and achieving voxels of less than 10^{-3} mm^3 within acquisition times of a few minutes. Conventional human body scanners have sufficient gradient encoding power to reach such a resolution, but suffer from a critical SNR-based limitation at the current field strength of 1.5 T. We explore here the spatial and time resolution performance accessible in different anatomical areas of the mouse using a 1.5 T body scanner (SIGNA, GE), equipped with a 12 mm surface coil [2] made of high temperature superconductor (HTS) to provide the needed sensitivity.

Materials and Methods The HTS surface coil was operated at 77 K using the standard scanner electronics in transmit/receive mode, with a unloaded Q factor of 11,000 inside the MR magnet [2]. A few normal mice of about 30 grams were investigated under anesthesia by intra-peritoneal injection of 200 µL of diluted (1/5) pentobarbital (Sanofi Laboratory) with a 2 mm distance between the coil and tissues. 3DFT gradient-echo sequences (SPGR) with total acquisition bandwidth of 15.6 kHz were applied to image the head (T1-weighted contrast, TR/TE 100/8 ms, matrix 256x128x124, FOV 30x15x14.5 mm^3, T_{acq} 27.3 min and T2*-weighted contrast, TR/TE 150/25 ms, matrix 512x256x60, FOV 30x15x18 mm^3, T_{acq} 41 min), the back (TR/TE 200/25 ms, matrix 512x256x60, FOV 30x15x15 mm^3, T_{acq} 54.6 min), and the knee (T1-weighted contrast, TR/TE 50/15 ms, matrix 512x384x60, FOV 30x22.5x18 mm^3, T_{acq} 41 min). A subcutaneous tumor model (MDA-MB-435) was also explored in high spatial-resolution mode with 3D isotropic voxels of 60 µm^3 (T1-weighted contrast, TR/TE 57/14 ms, matrix 512x256x60, FOV 30x15x3.6 mm^3, T_{acq} 15.6 min). Both knee and tumor images were acquired pre- and post-injection of 0.3 mmol/kg GD-DOTA (Dotarem ® Guerbet France). In addition the contrast uptake inside the tumor was followed up at high time resolution with a 2D GRASS sequence (T1-weighted contrast, TR/TE 13.9/4.8 ms, matrix 128x64, FOV 30x15 mm^2, slice 2 mm, T_{acq} 0.9 s). The loaded Q factor of the HTS coil was 7200 about the head, 2700 about the back, 7200 about the knee and 9000 about the tumor. Comparison to a room-temperature copper-coil mimic was done about the head (unloaded/loaded Q of about 120/110) using same imaging parameters. SNR performance was predicted [2] from the Q measurements and compared to actual image SNR.

Results Some images are shown below after systematic 2D cropping by a factor 2. T1- (left) and T2*- (right) weighted images of the head (Fig. a) show nicely detailed brain structures. A SNR of about 56 was measured in the T1-weighted image at the center of the brain, as compared to 12 for the copper-coil mimic image (not shown here). The articular fluid and synovial membrane are well visible on the post-injection image of the knee (Fig. b). A relatively deep penetration is demonstrated on the back image (Fig. c) despite the quite low loaded Q and transmit/receive coil operation. The perfusion phase of the tumor is analyzed with a SNR of about 110 from the high time-resolution images (Fig. d), allowing to characterize the contrast-enhancement kinetics between different internal areas. The high spatial resolution image (Fig. e) reveals many well-defined structural heterogeneities within the tumor such as a central necrotic lake, which has been confirmed by histology.



Discussion and conclusion We have demonstrated high-quality microscopic imaging in mice with a conventional 1.5 T body scanner. The HTS coil brings enough sensitivity for either high time- or space- resolution, voxels of 0.22 10^{-3} mm^3 being defined in less than one hour. A SNR gain of 4.5x as compared to the equivalent room-temperature copper coil is already observed. Moreover large extra sensitivity improvement can still be expected as indicated by the unloaded/loaded Q values. Full mouse-body coverage would be feasible using HTS coil arrays. Using current field strength rather than a high field may have some advantages such as reduced artifacts, better clinical relevance, lower cost and eased environmental appliance.

1. Benveniste H., Blackband S., Progress in Neurobiology **67**, 393-420 (2002).2. Ginefri JC, Darrasse L, Crozat, . Magn. Reson. Med. **45**, 376-82 (2001).

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