In-Vivo Multiple Mouse MRI using Parallel Receive-Only Coils on a 3.0 T Clinical Scanner for Molecular Imaging Research

M. Bernardo1,2, H. Kobayashi2, G. Metzger3,4, Y. Koyama2, C. Shaw1,2, D. Thomasson2, P. Choyke2

1SAIC-Frederick, Frederick, MD, United States, 2Molecular Imaging Program, National Cancer Institute, Bethesda, MD, United States, 3Philips Medical Systems, Bethesda, MD, United States, 4Center for Magnetic Resonance Research, University of Minnesota, Minneapolis, MN, United States, 2Clinical Center, National Institute of Health, Bethesda, MD, United States

Introduction: In-vivo multiple mouse MRI (MMMRI) has the potential to accelerate the development and preclinical testing of novel molecular imaging agents for the diagnosis and monitoring of cancer in patients. Clinical scanners have been used effectively to image mice in preclinical research, and its use facilitates easy translation of imaging protocols to clinical research. With their large volume of homogenous magnetic field, clinical scanners can also provide a suitable platform for MMMRI without the need for software or hardware modifications when equipped with parallel imaging capabilities. Clinical scanners are now available with up to 16 parallel receiver channels and soon up to 32 channels, providing the potential for up to a 32-fold increase in mouse imaging throughput. One way to realize this potential is to utilize a parallel receiver coil array comprised of multiple close-fitting coils around each mouse. A multiple mouse handling and support system which reduces stress on the animals and shortens the preparation time is equally important for increased throughput in dynamic MRI, targeted contrast screening and longitudinal studies. We report here the construction and performance of a 2-coil and 4-coil MMMRI parallel coil array for simultaneously imaging two and four mice in a 3.0 T clinical scanner along with an animal support system using non-conducting leads to eliminate RF interference for in-vivo imaging. A dual mouse MRA dynamic imaging with a G6 dendrimer agent is shown to demonstrate the system.

Methods: Each identical coil element was built using a simplified split-half turn (SHT) saddle coil design, a modification of the Alderman-Grant resonator, constructed with 1/8” 3M copper foil tape on a 38 mm OD cylindrical acrylic tube with an optimal size for full mouse imaging (77 mm length). Coupling between receiver elements was reduced by lowering the impedance measured at the end of each ¼ wavelength transmission line to 10 ohm. Each element was tuned to the frequency of the scanner (127.8 MHz) with a load in place. When used for in-vivo mouse imaging, the coils are tuned with a representative mouse load once and used without further adjustments. Anesthesia was applied either by IP injection, or using an isoflurane gas vaporizer through a 6-way flow splitter and vacuum scavenger. The mouse acquisitions unit (Biopac, Goleta, CA) with multiple differential transducers and amplifiers. Heating was provided by circulating heated Fluorinert FC-77 (3M, St. Paul, MN) through tubing wrapped around the coils. Gd-dendrimer contrast agents were administered through tail IV injection at a dose of 0.05 mmole/kg either manually or with a PHD-2000 multiple-syringe injector (Harvard Apparatus, Boston, MA).

Imaging was performed on a Philips Intera 3.0 T clinical scanner (Philips Medical Systems, Best, The Netherlands). Relative sensitivity and element isolation of the 2- and 4-coil arrays were measured from 2D T1-weighed FFE images on Gd-doped water phantoms. SENSE performance of the 4-coil array was measured on fixed samples using a simplified split-half turn (SHT) saddle coil design, a modification of the Alderman-Grant resonator, constructed with 1/8” 3M copper foil tape on a 38 mm OD cylindrical acrylic tube with an optimal size for full mouse imaging (77 mm length). Coupling between adjacent elements was tuned to the frequency of the scanner (127.8 MHz) with a load in place. When used for in-vivo mouse imaging, the coils are tuned with a representative mouse load once and used without further adjustments. Anesthesia was applied either by IP injection, or using an isoflurane gas vaporizer through a 6-way flow splitter and vacuum scavenger. The mouse acquisitions unit (Biopac, Goleta, CA) with multiple differential transducers and amplifiers. Heating was provided by circulating heated Fluorinert FC-77 (3M, St. Paul, MN) through tubing wrapped around the coils. Gd-dendrimer contrast agents were administered through tail IV injection at a dose of 0.05 mmole/kg either manually or with a PHD-2000 multiple-syringe injector (Harvard Apparatus, Boston, MA).

Imaging was performed on a Philips Intera 3.0 T clinical scanner (Philips Medical Systems, Best, The Netherlands). Relative sensitivity and element isolation of the 2- and 4-coil arrays were measured from 2D T1-weighed FFE images on Gd-doped water phantoms. SENSE performance of the 4-coil array was measured on fixed samples. Images of Gd-doped water phantom obtained from each coil showed a relative signal to noise ratio (SNR) of 0.80 in the 2-coil array, and 0.76 in the 4-coil compared to images from an isolated coil. This translates to a factor of 1.79 and 3.45 increased imaging throughput for the 2-coil and 4-coil arrays, respectively, in order to obtain the same SNR as in the single coil image. The isolation between elements in the 2-coil array was ~17 to ~24 dB while those for the 4-coil array were slightly reduced at ~14 to ~20 dB between adjacent coils and ~8 to ~14 dB between diagonal elements. To prevent ghosting, it is necessary to increase FOV and matrix size when imaging multiple mice versus single mice resulting in longer scan times. To maintain the same temporal resolution as in the single mouse, SENSE can be used to reduce the phase and slice encoding steps or the NSA can be reduced. Figure 1 shows slices from a 3D T1-weighed FFE acquire with SENSE factor of 3 in the slice direction. Dynamic MRA acquired with the 2-coil array (Figure 2) with NSA of 1 demonstrates performance that closely matches that of a single mouse coil with NSA of 2. Further improvement in temporal resolution can be achieved with SENSE but the effect of motion artifacts is yet to be determined.