Multiple-Animal MR Imaging Performed using a 3-Tesla Whole-body Scanner: A Feasibility Study using a 16-Channel Array Coil

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Introduction: There is an increasing demand for molecular imaging techniques such as MR imaging, bioluminescence imaging, and nuclear medicine imaging to study small-animal models of human diseases. In MR imaging, lesions can be visualized utilizing the intrinsic contrast between tissues, and this visualization can be performed without the incorporation of reporter genes or administration of radiolabeled compounds. In addition, translation of the study results from the bench to the bed is easily possible, especially by using a whole-body MRI scanner. However, this approach requires long acquisition times to compensate the inherent low sensitivity, thereby preventing a high-throughput examination when the animals are scanned individually. Therefore, we aim to construct a multiple-animal MRI system that employs a 3-T whole-body scanner for high-throughput MR imaging of a large number of animals.

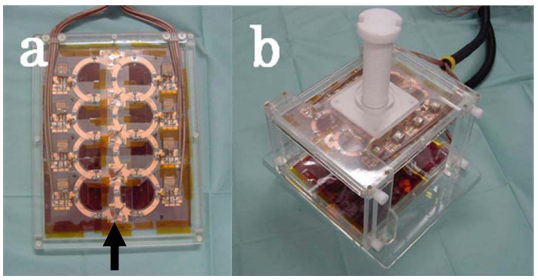

Fig.1. Sixteen-channel coil dedicated for small animal MRI. An array comprises 8 5-cm-circular coils (a). The 16-channel coil has 2 sets of 8-array coils in the upper and lower parts (b). A white bar on the top is used to adjust the distance between the upper and lower coils.

Materials and methods:

Construction of the 16-channel array coil: We constructed a 4 × 2 array comprising 8 circular coils (Each coil was fixed onto a 0.2-mm-thick FR-4 plate with a 0.018-mm-thick copper on; the trace width and diameter were 6 mm and 50 mm, respectively) that were tuned to 127.7 MHz for the 3-T scanner. The circular coils had additional quadrille patterns (arrow in Fig.1 a) to adjust the distance between neighboring coils, particularly, the diagonally opposite coils, and to eliminate mutual inductance among all contiguous coils. A BALUN was inserted into the feeding port of each coil to reduce the shield current of the coaxial cables. Two sets of 8-channel array coils (length, 25 cm; width, 20 cm) were set opposite to each other on an acrylic holder (Fig. 1b). These array coils were connected to 16 low-input impedance preamplifiers and receivers of a 3-T whole-body scanner (Sigma HDx; GE, Milwaukee, WI).

Animal experiments: All animal experiments were approved by the institutional animal experimental committee. Four rats and 16 mice were anesthetized using isoflurane, O_2, and N_2O. Two rats and 8 mice were placed on the lower coils, and the other animals were placed on the upper coils in the prone position. MRI of the whole body were simultaneously obtained using a fast spin echo (FSE) sequence (TR/TE_{eff} = 4000/16–24 ms; echo train length (ETL) = 8; FOV = 16−20 cm; matrix = 256 × 160 (ZIP 512); slice thickness = 2 mm; and 4 accumulations). Signal intensity correction was performed using in-house built software according to a previously reported method [1]: Two image data sets of the same object were obtained using 3-dimensional FSE sequence (TE/TE_{eff} = 2000/16.8 ms; acquisition time = 5 min) with the 16-channel and body coils as receivers. After normalization of the signal intensities, the image from the 16-channel coil was divided by that from the body coil on the pixel-by-pixel basis to determine the sensitivity map of the 16-channel coil. Finally, the original image was divided by the sensitivity map to yield the corrected image.

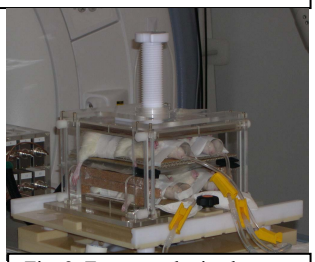

Fig. 2. Four anesthetized rats were placed on the 16-channel coil and the 3-T whole-body scanner.

Comparison between simultaneous and individual imaging of rats: A group of 4 rats was individually examined using a solenoid coil [inner diameter (ID) = 5 cm] and another group of 4 rats was simultaneously examined using the 16-channel coil. T_2*-, T_1-, and T_2-weighted and proton-density images of the livers of these rats (voxel sizes: 0.313 × 0.5 × 2 mm^3 for the solenoid coil and 0.625 × 1 × 2 mm^3 for the 16-channel coil) were obtained. The signal-to-noise ratios (SNRs) of the liver on proton-density images were compared between the two groups. We also compared the total acquisition times.

Results and Discussion: We succeeded in performing simultaneous MRI for 4 rats (Fig. 3) and 16 mice. Although we used 16 close-fitting circular coils, we were able to obtain homogeneous images of the entire bodies of these rats and mice using our intensity-correction method. However, while the abdominal organs and vessels were clearly visualized in rats, they were not clearly visualized in mice because of the lack of spatial resolution. Therefore, the spatial resolution and the number of mice that can be simultaneously scanned should be further optimized to improve visualization. These results indicate that the combination of a high-SNR-surface coil array and post-processing intensity correction is useful for multiple-animal 3-T imaging with good homogeneity, which has been a critical issue in this procedure [2] [3]. The liver SNRs obtained using the 16-channel array coil were comparable with those obtained using the solenoid coils [211 ± 77 and 190 ± 33, respectively (average ± SD, in arbitrary units; not significant (NS) in *t* test), but the former SNRs were obtained at the expense of a 4-fold increase in voxel sizes. The total image-acquisition time for the 4 rats in simultaneous imaging was 55% (56 min) of the corresponding value for individual imaging (101 min). The expected 25% reduction in total acquisition time could not be achieved because of the additional scanning that was performed to determine the sensitivity map.

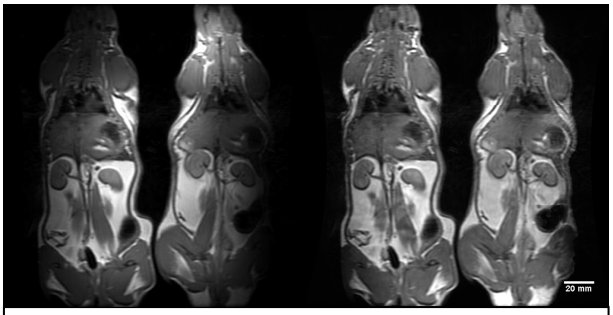

Fig. 3. A coronal proton-density image of the bodies of 2 rats before (left) and after (right) signal intensity correction. The images of the other 2 rats were simultaneously obtained and were of comparable quality (not shown).

Conclusion: The multiple-animal MRI system using a 3-T whole-body scanner may facilitate high-throughput examination in rats; however, further investigations are required to assess its feasibility in mice.

References: [1] Med. Phys. 1988; 15:241–245, [2] Proc ISMRM 2006; 14:2604, [3] Proc ISMRM 2006; 14:2601