RF coil configuration study for 7T high resolution Na23 and H1 animal MRI

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Purpose: The advent of dual-tuned radiofrequency (RF) coil was crucial in terms of offering easy co-registration of spatial data acquired from two separate tuned frequencies without subject's repositioning issued from the use of two separate tuned RF coils [1-4]. Many researchers have used dual-tuned RF coils to research cancer therapies, neurodegenerative diseases and metabolic disorders in many different organs and tissues of humans. Although the dual-tuned coil causes signal-to-noise ratio (SNR) drop by adding trap circuits [3-4] or PIN diodes [5], it is still useful in human study. However, it is quite different in the case of small animals. Since the size of animal tissues is too small, SNR degradation is not excused. Therefore, we suggest a simple way of maintaining high SNR and resolving the issue about subject's relocation for animal study with a fixed couch to carry out animals and exchangeable RF coil.

Methods: For the proposed study, the animal couch was assembled with the cylindrical pipe which have identical diameter (90mm) with outer diameter of RF shielding pipe covering RF coil as shown Figure 2. The couch embedding animal moved into the isocenter of 7T magnet bore (inner diameter: 92mm) and fixed the position. RF coil was so exchangeable from the rear magnet that it could be linked with the cylindrical pipe nested on the isocenter (figure 2(a-b)). For precise MRI scan about the location of an anatomy, participated RF coils had identical dimensions (the diameter and location of RF coil and RF circuit pattern). The diameter and the length of coils were 5.0 cm and 4.8 cm, respectively. Assembled two single-tuned, high-pass birdcage coils and a dual-tuned, low-pass birdcage coil were tuned at 79 MHz and 299.01 MHz for 7T Na^{23} and H^1 resonance frequencies separately [6]. They were Tx/Rx (transmit/receive) and quadrature operational. The dual-tuned RF coil used the trap circuit, parallel LC resonance circuit, as used in a previous research by G.X.Shen et,al [3-4]. Dual cable balun traps tuned to the Na^{23} and H^1 frequencies were soldered at the each quad outputs of the dual-tuned birdcage coil. After the fine tuning, we scanned MR images with three different coils sequentially. For invivo imaging, hydrogen images were obtained using the following acquisition parameters: 3D gradient echo, TR/TE= 10ms/3ms, FOV= 64mm x 64mm x 64mm, acquired matrix = 256 x 256 x 64, recon matrix = 256 x 256 x 64, FA = 10°, NSA=2. Sodium imaging parameters were the following: 3D gradient echo, TR/TE = 150ms/2ms, FOV =64mm x 64mm, acquired matrix = 32 x 32 x 16, recon matrix = 256 x 256 x 64, FA = 90°, NSA=16. The SNR from the reconstructed image was calculated by the equation: [(signal average-noise average) / (noise standard deviation). To calculate noise, the standard deviation was measured from the background.

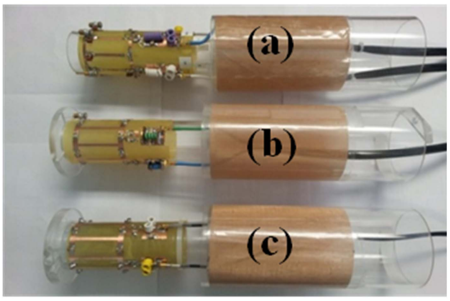

Figure. 1RF coils employed for the experiments. (a) Dual-tuned birdcage coil. (b) H^1 single-tuned birdcage coil. (c) Na^{23} single-tuned birdcage coil.

Results: With proposed concept, we successfully scanned the rat's brain with the single tuned coils without fine adjustment of image slice location as shown by Figure 3. From acquired rat's brain, a quantitative difference between single-tuned and dual-tuned RF coil was found. H^1 SNRs were 253.77 (single-tuned coil) and 205.55 (dual-tuned coil). Na^{23} SNRs were 34.18 (single-tuned coil) and 10.50 (dual-tuned coil).

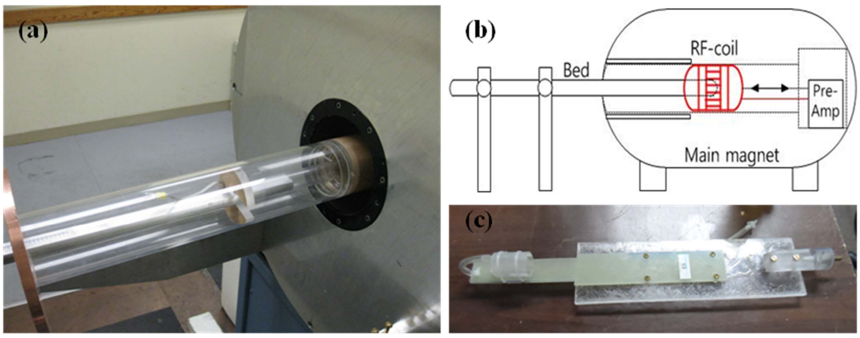

Figure 2. The fixed couch and changeable RF coil configuration for our 7T MRI experiment. (a) The aluminum bed support screwing the end of animal couch (c) moves toward into the isocenter of MRI. On the isocenter of MRI, the couch is constrained by knobs. In the picture, it is seen that RF coil linked with the end of acrylic pipe. (b) The block diagram of our scheme; the subject nested on the couch is located on the isocenter of magnet and the couch fastens up. RF coil can be changed from the rear of magnet. (c) The animal couch.

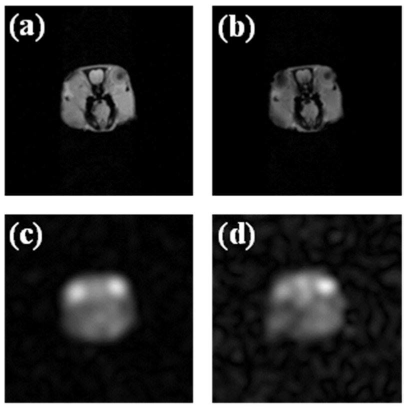

Figure 3. The rat's brain images acquired from different RF coil setup. (a) H1 image using single-tuned RF coil. (b) H1 image using dual-tuned RF coil. (c) Na23 image using single-tuned RF coil. (d) Na23 image using dual-tuned coil

Discussion: SNR of dual-tuned birdcage coil decreased up to 81% (H^1), and 31% (Na^{23}) compared to single-tuned birdcage coils. Although it may not overlook SNR degradation by high ESR (equivalent series resistance: >1.0Ω) of air inductor (about 61nH) used in trap circuit, deficient isolation (-18dB) and craftsmanship error, especially, enormous SNR drop of Na^{23} make usage of dual-tuned birdcage coil be re-considerable in animal study. Since a subject does not need to move during RF coils change, high resolution multinuclear MR animal images can be obtained with single-tuned birdcage coils preserving the inherent SNR. In this study, we used relatively long TE (2ms); however, the T2 relaxation is much faster in biological samples. Ultra short echo time (UTE) pulse sequences should be essential in order to achieve higher SNR [7]. We expect our study can offer an alternative choice in multinuclear animal MRI.

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Acknowledgements: This research was supported by the World Class University program through the National Research Foundation of Korea funded by the Ministry of Education, Science and Technology, Korea (grant no. R31-20004).