Improving whole brain coverage and Signal-to-Noise ratio using novel intra-oral and over head surface coil array in rat under 9.4T

R. Li[1], P. Bishop[2], A. Jesmanowicz[2], A. Nencka[2], J. Stephenson IV[3], C. Pawela[2], J-G. Yan[3], A. G. Hudetz[4], H. Matloub[3], and J. S. Hyde[1]
[1]Biophysics, Medical College of Wisconsin, Milwaukee, WI, United States, [2]Biophysics, Medical College of Wisconsin, [3]Plastic Surgery, Medical College of Wisconsin, [4]Anesthesiology, Medical College of Wisconsin

Introduction

In small-animal fMRI/fcMRI studies, whole-brain coverage and better signal-to-noise ratio (SNR) remain core issues that affect experimental results, especially in rats. Whole-brain coverage, particularly of deep brain structures, is hard to obtain using conventional methods. With the rat in the prone position, good access to the brain is provided for surface coils on top of head, but the jaws, mouth, and throat greatly restrict access to the lower side of the brain, and the massive masseter muscle restricts lateral access. A birdcage head coil can fix this problem to some degree, but due to the great susceptibility effects from the extensive tissue surrounding the brain, signal dropoff remains significant. A more sensitive approach to image acquisition of the rat whole-brain is described here. This approach consists of an array of coils on top of the head combined with an intra-oral coil supported by a bite bar. The surface of the intra-oral coil is in direct contact with the upper palate. This novel coil array voids tissue interference from the side and bottom of the rat brain and minimizes signal dropoff. This two-coil array also improves SNR. This design could be used in other small-animal studies.

Materials and Methods

Animal preparation: One Sprague-Dawley rat (weighing 400 g) was used to demonstrate the effects of the new coil array. All surgeries were performed under 1.4% Isoflurane anesthesia. A tracheotomy was performed before the experiment to provide ventilation during the scan. PE-50 tubing was placed in both the right femoral artery and vein to provide arterial blood pressure monitoring and anesthesia drug delivery. After the rat was transferred into the scanner, Isoflurane was tapered off. A mixture of Dexdomitor (0.1 mg/kg/hr) and pancuronium bromide (2 mg/kg/hr) was pumped into the venous line for maintenance of anesthesia. The rat was ventilated using 30-70% O_2/N_2. During the experiment, all physiological parameters, including blood pressure, arterial blood gases, respiratory rate, body temperature, and pulse oximetry, were monitored and maintained at a steady state. **Coil management:** A commercial one-turn Bruker surface coil was used on the top of the rat head. The brain coverage available from this coil is shown in Figure 1. This surface coil does not cover the whole brain or focus with sufficient intensity in cortical regions. A self-designed and manufactured bite-bar coil made of G10 fiber glass was used with the rat's front teeth as anatomical marker. The coils were first used individually, then combined to form a coil array. Figure 2 shows a photo of the novel bite-bar coil and conveys the idea of synergic acquisition using this two-channel coil array during scanning. **fMRI parameters and data analysis:** MRI data were acquired using fast low-angle-shot MRI (FLASH) on a 9.4 Tesla Bruker animal scanner (parameters as follows: FOV = 3.5 cm, TR = 500 ms, TE = 9 ms, matrix size = 512 x 512, slice thickness 0.5 mm, slice number = 20, flip angle = 30 degrees). The image was reconstructed with the self-written software, which is especially designed for high-resolution and multiple-channel acquisition.

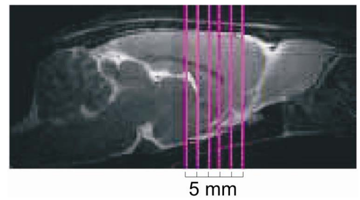

Figure 1: Midline rat brain sagittal "scout" image used for slice location.

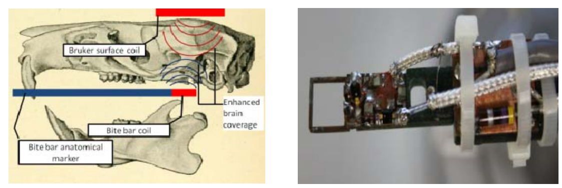

Figure 2: Left: Schematic design of bite-bar coil array. Right: Photo of completed bite bar with 9.4 T surface coil.

Results

The completed bite-bar surface coil with tune, match, and detune circuitry is shown in Figure 2. Tune and match are done within the mouth of the rat using varactors, but adjustments are done remotely. The coil is covered in PTFE tape to reduce dielectric loss of soft tissue and saliva before placement in the rat mouth. Initial results using the bite bar in a two-channel array are shown in Figure 3 in two slices. Improvement in whole-brain sensitivity is apparent. The results of Figure 3 are intriguing. Figure 3A uses a conventional Bruker surface coil only. Significant signal intensity drop-off can be seen as the scan depth increases. The detail of the deep brain structure is totally lost. Figure 3B uses an intra-oral bite-bar coil only. Due to the presence of the nasal cavity, the signal intensity was greatly diminished. However, the detail of the deep brain structure can still be observed. Images shown in Figure 3C use a combination of both coils They are better than the sum of images 3A and B. Signal drop-off was clearly reduced throughout the whole brain (even in the cortical surface directly below the Bruker surface coil). Furthermore, the detail of the deep brain structure is shown at a relatively high signal intensity.

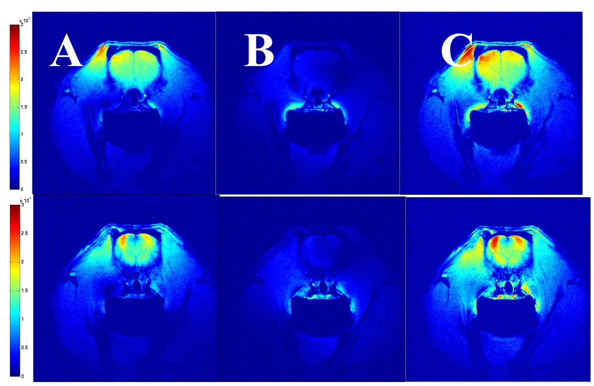

Figure 3: Initial results using Flash image acquisition using two channels. Channel 1 is (A) a commercial Bruker surface coil, channel 2 is (B) a bite-bar internal coil, and (C) is the summation showing whole-brain improvement at two slices.

Conclusion and Discussion

We have demonstrated that the combination of intra-oral bite-bar coil and conventional surface head coil could lead to improvement in whole-brain coverage and SNR. The intra-oral coil design greatly reduces signal drop-off from massive tissue surrounding the brain and minimizes the susceptibility effect. This design has never been used in previous animal studies. Many studies today involve the functional structure from the deep brain region (such as studies of Alzheimer's disease, the whole-brain Connectome, pain, etc.). Functional MRI/fcMRI studies of these animal models are a desirable way to carry out research of such diseases. However, due to the inability of functional MRI to image the deep brain structure, uses of these animal models are highly constricted. Our novel design has great potential to change the current situation. It also can be used, together with animal birdcage coils, to gain extra advantage in scan results. Lastly, the physical presence of two coils alters the distribution of RF flux because of the mutual inductance between the coils. This suggests a new direction for future development of RF coil assemblies.

Acknowledgements

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