Parallel Imaging for Mouse Phenotyping

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INTRODUCTION:

Parallel MRI for human imaging is usually thought of as the use of parallel receiver coils to achieve increases in signal-to-noise ratio (SNR) or more frequently, increases in imaging speed. A complimentary idea is to use parallel MRI with multiple coils for multiple samples. The SNR and acquisition time remain identical to that obtained on a single sample, but the throughput is increased. We have used this second concept of parallel imaging to develop a multiple mouse MR imaging system for anatomical screening of up to 19 mice in parallel.

METHODS:

Using a 7 Tesla, 40 cm magnet with a single gradient, we have developed an array of 19 transmit and receive Millipede[1] coils[2]. The parallel coils are arranged in a hexagonal array as in Figure 1 and are permanently mounted in the magnet system. Currently, we have four parallel receivers in a Varian spectrometer that acquire data from 16 mice simultaneously by four-fold parallel acquisition and four-fold multiplexing. We are presently developing 19 independent receiver channels to service all coils simultaneously.

Figure 1

The coils are well shielded from each other by long cylindrical shields of copper foil. The diameter of the Millipede coil is 35 mm and the shield diameter is 50 mm. The shielding reduces the coupling between coils by better than 51dB. This allows acquisition of simultaneous images of multiple mice for which the overlapping ghosts do not exceed 0.3% as shown in Figure 2. If the decoupling had been worse, we could still have corrected for ghosts using a form of SENSE[3] in which the sensitivity matrix was homogeneous over each mouse image. In this particular degenerate case, the algebraic SENSE correction is simple and there is no SNR penalty.

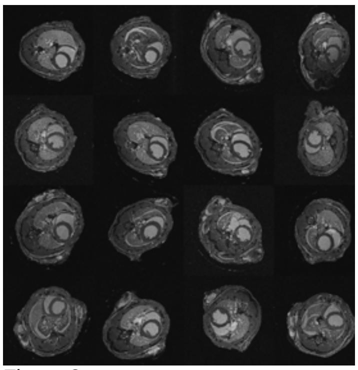

Figure 2

Parallel imaging of multiple mice does not allow for prospective gating. However by acquiring a free running data acquisition and simultaneously measuring the cardiac and respiratory signal from each mouse, it is possible to generate retrospectively gated abdominal images from slightly oversampled data.

APPLICATION:

Multiple mouse MRI (MMMRI) enables serious biological experiments with significant numbers of mice[4]. As illustrations, we have:

1. generated 3D brain atlases of several strains and have compared the intra- and inter-strain variation[5],
2. compared knockout (KO) mice with WT mice to look for phenotypic changes, such as the Sonic hedgehog mutant which results in several brain abnormalities, Figure 3.

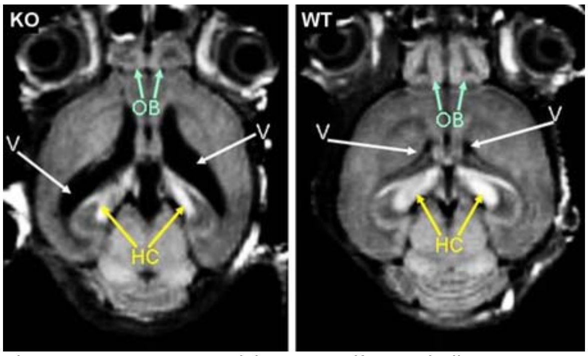

Figure 3: V=Larger Ventricles, OB=Olfactory bulbs, HC=Hippocampus

3. conducted brain tumor studies of 20 mice imaged every week for 10 weeks watching the growth curve of an implanted brain tumor[6]. These studies would have required the full time use of the imaging system for 2½ months if they were attempted without MMMRI.

In the future, we can already anticipate multiple receiver coils on each mouse in an MMMRI that could readily result in a system with a hundred independent receiver channels requiring novel designs based on low cost parallel inputs such as USB or wireless. Multiple sample imaging has been used successfully in the human context for two breasts or dual knee imaging. However, the use of parallel MRI for multiple patients is unlikely to be a profitable direction for research.

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