High Field Parallel Imaging in Small Rodents

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INTRODUCTION

Parallel imaging (PI) is now routine in clinical MRI, however application to animal studies has been limited. Nevertheless this field would also benefit greatly from the features of PI, such as scan-time reduction, which could help imaging large numbers of animals in pharmaceutical studies, resolution enhancement, artefact suppression and SAR reduction [1].
Furthermore, it has recently been shown [2] that PI in humans benefits strongly from high field strengths due to the higher SNR obtained and the concomitant wavelength effects. This could be an important aspect for animal PI, too, since the involved field strengths are typically much higher than in clinical MRI. On the other hand this positive effect will be partially or even totally neutralized by the much smaller geometries typically occurring in animal MRI.
In this study the feasibility of PI in small rodents will be demonstrated and examples illustrating the performance of small animal PI will be shown.

METHODS

A 4.7 T, 40 cm bore, *BioSpec*® 4-channel system (Bruker BioSpin MRI GmbH, Ettlingen, Germany) was used for experiments with two 4-element coil arrays designed and optimized for high-field head imaging in rats and mice, respectively [3]. The design of the coil was developed to be scaleable for both rat and mouse head geometries. The arrays were built with four overlapping square elements (Fig. 1). In the rat coil the elements have a side length of 15 mm, whereas the mouse coil elements measure only 10 mm. Special attention has been paid to the effects of inductive coupling and dielectric resonances. The overall mutual decoupling of the rat coil elements is approximately -30 dB which has been achieved using enhanced geometrical decoupling and novel Bruker-built low-impedance preamplifiers with approx. zero Ohm input impedance. Similar electrical features are expected for the mouse coil, which has still to be verified in detail.
The phased arrays operate as receive only coils in combination with a standard actively decoupled transmit coil. The coil has all the electronics integrated into the casing, and fits optimally to standard Bruker animal beds.
Standard spin echo and RARE images were acquired from anesthetised Fisher rats and Quackenbush mice. For unaccelerated imaging the single element images were combined using a sum of squares. For accelerated imaging a GRAPPA (**G**ene**R**alized **A**utocalibrating **P**artially **P**arallel **A**cquisitions) [4] algorithm was implemented in MATLAB (The MathWorks Inc., Natick, MA, USA) and used for image reconstruction.

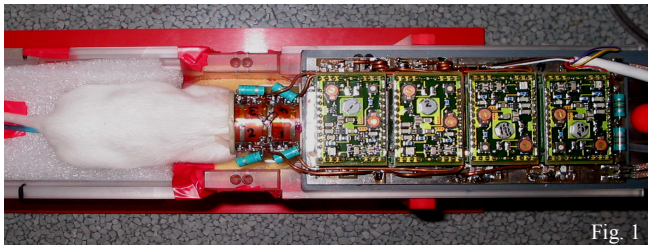

Fig. 1

RESULTS

A SNR comparison of the rat array to a standard quadrature rat brain coil shows that a considerable increase of the SNR can be achieved throughout the rat brain. Figure 2 shows the SNR for both coils along the AP direction in the centre of an axial slice. The evaluation has been performed using a standard gradient echo sequence (TE=5.2 ms, TR=1000 ms) and a cylindrical loading phantom equivalent to the load of a rat head.

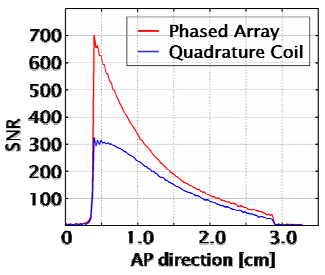

Fig. 2

Figures 3-6 show axial spin-echo (TE=18.0 ms, TR=3495 ms) and coronal RARE (TE=14.0 ms, TR=5000 ms) images from a rat brain with a matrix size of 256x256. The left images are fully sampled while the right ones are sampled with an acceleration factor of 2 and 24 reference lines.

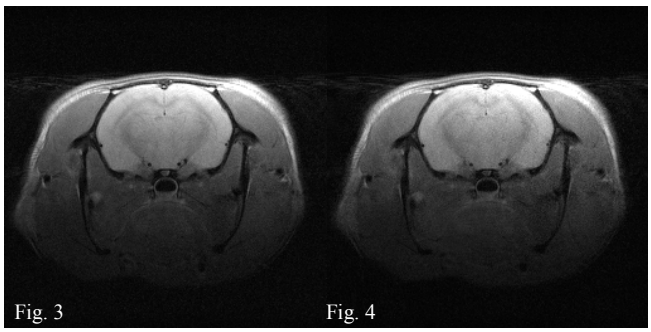

Fig. 3 Fig. 4

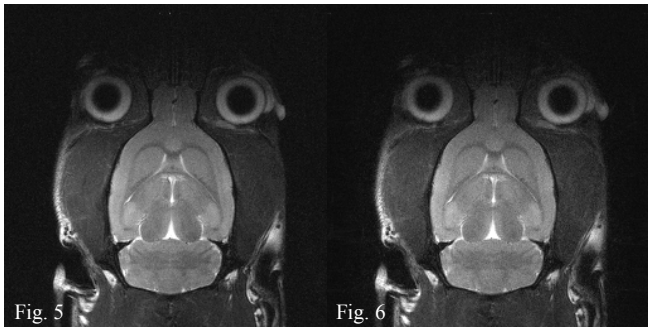

Fig. 5 Fig. 6

Figures 7-8 show a fully sampled and an accelerated (factor 2) spin-echo image from a mouse brain (TE=28.3 ms, TR=3014 ms). The image matrix of these images is 512x512, which together with a FOV of 3x2 cm, results in an inplane resolution of only 39x59 microns (the read direction is not entirely displayed).

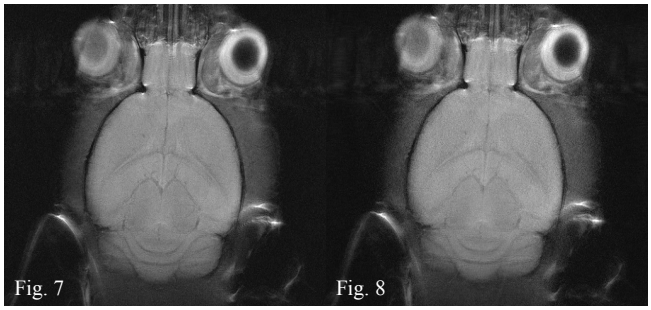

Fig. 7 Fig. 8

DISCUSSION

In this study images have been acquired up to a reduction factor of 4. For an acceleration factor of 2 the image quality is very good. There is almost no difference visible compared to the fully sampled images. The apparent SNR is also nearly maintained in the accelerated images. This is due to the signal-contribution of the GRAPPA calibration lines which have been integrated in the reconstruction and which compensate the loss of SNR from undersampling and g-factor properties. A quantitative SNR analysis is problematic because of the local noise amplification and suppression inherent in the GRAPPA reconstruction. This could be a subject of further investigation.
The study demonstrates that parallel imaging has successfully been implemented for imaging in small rodents and that the coil design employed is well suited for rat and mouse brain imaging at 4.7 T. First investigations with the rat array show that there is also a SNR benefit compared to standard quadrature coils. However, this has yet to be verified for the mouse array, which will be the subject of further studies together with a detailed performance analysis of the coils for PI focusing mainly on g-factor properties and the comparison with alternative designs.

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