Fast high resolution imaging of the mouse brain using a cryogenic 2x2 Phased Array coil at 9.4T

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INTRODUCTION

Mouse structural and functional imaging is confronted with high demands on spatial resolution and correspondingly high sensitivity. Recently, the advantages of cryogenic RF coils, linear [1] as well as quadrature coils [2] operating in transmit/receive mode, providing SNR gains of a factor 2 to 3 have been reported. This gain in sensitivity can be invested for improving spatial resolution or reducing scan time. Progress in coil technology and electronics has now made it possible to realize a receive-only array coil operating under cryogenic conditions. Here, we show the first mouse brain images obtained with this setup. We have evaluated the coil performance using standard T2 and T2* weighted MRI pulse sequences. Moreover, we have demonstrated the potential of the cryogenic phased array coil for accelerating data acquisition using GRAPPA [3].

METHODS

The four-element receive-only cryogenic phased array surface coil (2x2 geometry, overall coil size 20x27mm^2) operating at 30K (Bruker BioSpin AG, Fällanden, Switzerland) was used in combination with a linearly polarized 72mm ID room temperature volume resonator for transmission. All experiments were performed on a 9.4T animal MR system (BioSpec 94/30, Bruker BioSpin MRI GmbH, Ettlingen, Germany). Coil sensitivity profiles were acquired on phantom measurements (T9660, Bruker BioSpin MRI GmbH, Ettlingen, Germany) using a FLASH sequence. For *in vivo* measurements mice were anesthetized using 1.5% isoflurane in an oxygen/air (20% / 80%) mixture, intubated and artificially ventilated. The experiments were carried out in strict adherence with the Swiss law for animal protection. The following MRI sequences were performed: 2D TURBO-RARE coronal (FOV: 1.96*2.54cm^2; matrix: 512*512; res.: 38*50µm^2; slice: 300µm, TE: 46.3ms; TR: 3500ms; in 60min); 2D FLASH coronal (FOV: 1.6*1.6cm^2; matrix: 384*384; res.: 42*42µm^2; slice: 150µm; TE: 5.5ms; TR: 400ms; in 25min); 2D TURBO-RARE sagittal (FOV: 2*2cm^2; matrix: 384*384; res.: 52*52µm^2; slice: 500µm, TE: 38ms; TR: 1900ms; in 6 min); 2D FLASH axial (FOV: 1.7*1.7cm^2; matrix: 384*384; res.: 44*44µm^2; slice: 300µm; TE: 5.5ms; TR: 400ms; in 25 min). The usability for parallel imaging was tested using a coronal 3D FLASH sequence with and without GRAPPA (FOV: 1.7*1.3*0.3cm^3; matrix: 285*216*50; res.: 603µm^3; TE: 9ms; TR: 250ms; in 45 min and 29min, respectively (acceleration factor: 2; reference lines: 64).

RESULTS

The coil signal profiles of the four individual coil elements in a coronal plane of a phantom (FLASH) together with the root-sum-of-squares (RSOS) reconstruction are shown in Fig. 1. The dark side lobes of the coil element profiles are inherent to RF coils parallel to the B_0 field and appear not to be disturbed by the presence or potential coupling of the other coil elements. The homogeneous excitation combined with the superior sensitivity provided by the phased array coil allows visualizing structures of the whole brain with a good SNR. In particular, deeply located regions (e.g. brain stem) can be imaged with high resolution and SNR (Fig. 2). Fine structures such as the choroid plexus in the ventricles, white matter tracts within the caudate putamen, the Ammon's horn of the hippocampus, or spinal tracts entering brain stem structures can be readily identified (Fig. 2a,b). This is also illustrated by the sagittal (Fig. 2c) and axial views (Fig. 2d). Furthermore, the multiple receiver acquisition allows applying acceleration of data acquisition using parallel imaging strategies such as GRAPPA or SENSE, e.g. in the acquisition of 3D high-resolution images. Fig. 3 shows the comparison of two coronal cross-sections through the mouse brain from a high resolution (60µm)^3 3D FLASH dataset recorded without acceleration (a) and with an acceleration factor of 2 and GRAPPA reconstruction (b).

DISCUSSION

We have demonstrated the performance of a new cryogenic phased-array receiver probe operating in cross coil mode and show the first *in vivo* images of the mouse brain acquired with this setup. The basic tests using a phantom revealed the functionality of the 2x2 array system at low temperature with excellent decoupling of the individual coil elements. Due to the high sensitivity and uniform excitation, the coil setup serves the application of high-resolution structural whole brain imaging, in particular enabling mapping deep lying brain structures including the brain stem with high SNR. The phased-array design allows for accelerated image acquisition using parallel imaging strategies. The cryogenic setup is also attractive for functional MRI and spectroscopic imaging, which critically depend on high SNR values.

REFERENCES

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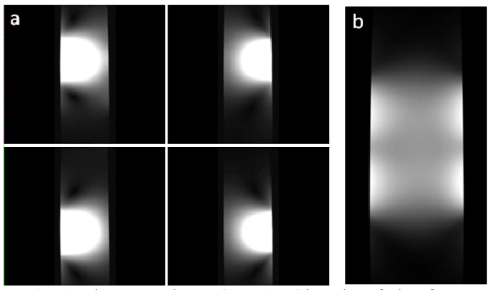

Fig. 1 Phantom data, GE. **(a)** Signals of the four individual coil elements. **(b)** RSOS reconstruction (all images processed with high contrast to show the delicate low-level signals)

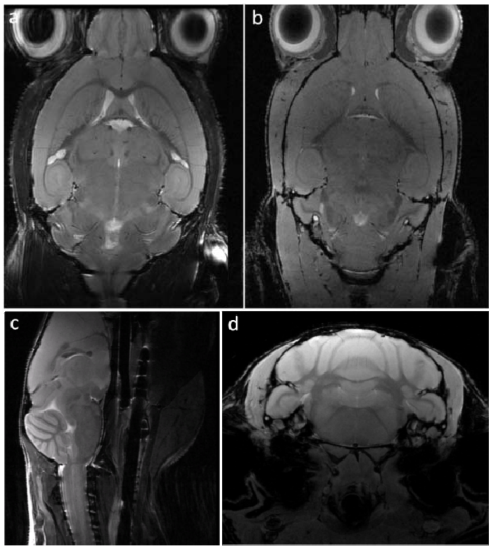

Fig. 2 *In vivo* high-resolution images. Coronal mouse brain sections acquired in 60min using a RARE sequence **(a)** and in 25min using a FLASH sequence **(b)**. Sagittal mouse brain section acquired in 6min using a RARE sequence **(c)** and axial section of the mouse brain stem acquired in 20min using a FLASH sequence **(d)**.

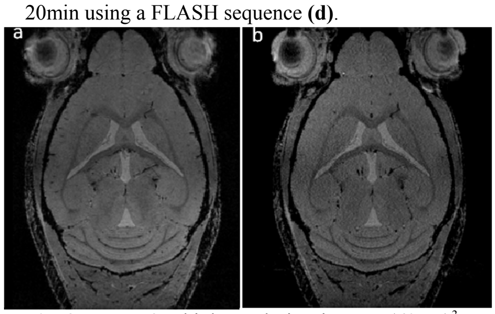

Fig. 3 *In vivo* 3D high-resolution images (60µm)^3, GE. **(a)** Acquisition time: 45min. **(b)** Acquisition time: 29min, GRAPPA acceleration factor 2.