Initial Human Imaging Experience with a Head-only Gradient System Utilizing 80 mT/m and 500 T/m/s

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Target audience: Clinicians and researchers interested in high performance neuroimaging systems.

Introduction: A second generation asymmetric head gradient coil has been developed as part of a program to build a compact 3T head only imaging system. The first generation coil included a 42 cm inner diameter and a distortion correctible FOV of 26 cm [1,2] . The goals of the program are to create an imager that is lightweight, requires a minimal amount of cryogens and has high performance capabilities. The expected total weight of the system is less than 2 tons, approximately a third to quarter of the weight of a standard whole body 3T system. Only 12 liters of helium will be required for magnet cooling compared with 2,000 liters typically needed for a whole body system. The gradient performance is targeted to achieve 85 mT/m and 700 T/m/s slew rate simultaneously, and for this test was run at 80 mT/m 500 T/m/s while minimizing peripheral nerve stimulation (PNS). Compared with the first generation coil [3] all hollow conductors have been incorporated allowing 25kW continuous cooling. A particular challenge for this gradient system is correction of gradient nonlinearity (GNL) induced geometrical distortion. Previous study has shown that the standard GNL correction method introduces blurring and loss of resolution in corrected images. In this work, we show that a recently developed integrated, non-uniform fast Fourier transform (NUFFT)-based gradient nonlinearity (GNL) correction strategy [4] is able to improve in vivo images acquired with this head-only high performance gradient system.

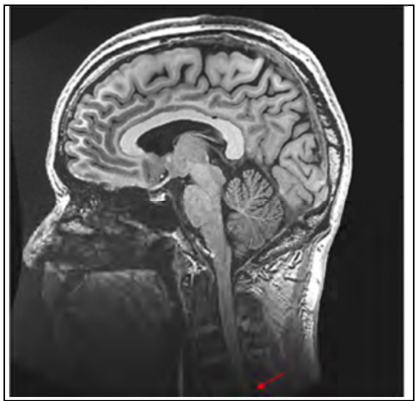

Figure 1. Sagittal T1 3D-SPGR with coverage to the C4-5 interspace (arrow).

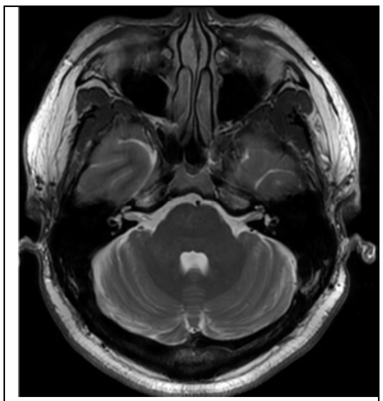

Figure 2. Axial T2 FSE brain images visualizing the inner ear structures.

Methods: The asymmetric head gradient coil was mounted inside a whole-body 3T scanner (MR750w, GE Healthcare, Waukesha, WI) and was interfaced with the scanner's systems. Within a 37-cm inner-diameter birdcage T/R coil a Nova 32-channel head receiver array (Nova Medical Inc. Wilmington, MA) was positioned.

In-vivo Scans. Healthy volunteers were scanned under an IRB-approved protocol with several standard clinical sequences. The scan parameters included sagittal T1 IR-prepped 3D-SPGR (i.e., MPRAGE): TI = 900 ms, TR = 6.2 ms, TE = 2.6 ms, flip = 10^o, FOV = 26 cm, matrix = 256 × 256, 1.2 mm sections; axial T2 2D fast-recovery FSE: TR = 5160 ms, TE = 104 ms, matrix = 256 × 256, 4 mm section, sagittal 3D MPRAGE: TR = 6.2 ms, TE = 2.6 ms, flip = 8^o, TI = 900 ms, FOV = 26 × 24.5 cm^2, matrix = 256 × 242, slice number = 168, slice thickness = 1.2 mm. For all acquisitions the gradients were operated at 80 mT/m and 500 T/m/s simultaneously. The volunteers were instructed to report any sensation suggestive of peripheral nerve stimulation or excessive noise. Standard image-domain GNL correction available on scanner was applied to all the acquired images. The 3D MPRAGE data was also corrected with the integrated GNL correction approach based on NUFFT, and was compared with the images obtained with the standard GNL correction.

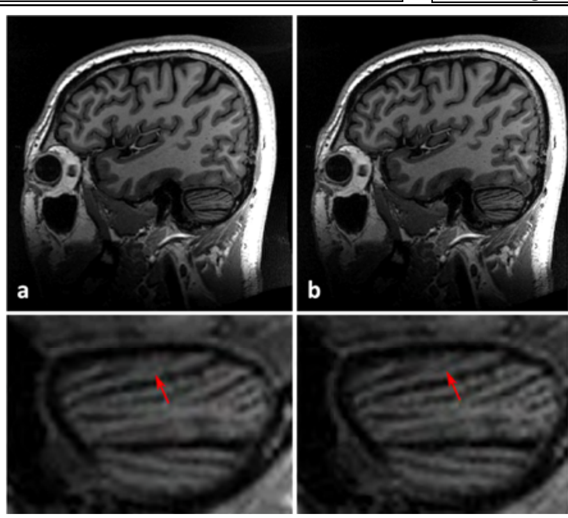

Figure 3. MPRAGE images after gradient nonlinearity correction with (a) standard image-domain correction method and (b) integrated, NUFFT based strategy.

Results and Discussion: Previous work has demonstrated that the PNS threshold with this asymmetric gradient coil design is much higher than a state-of-the-art body-size neuroscanner gradient coil [3]. None of the subjects reported PNS and with use of ear plugs the noise level was acceptable. Fig. 1 shows whole head coverage with visualization of the C4-5 interspace. Fig. 2 demonstrates high excellent image quality at the skull base with visualization of the cranial nerves within the internal auditory canal. Fig. 3 illustrates examples of the MPRAGE images corrected with: (a) standard GNL correction method and (b) integrated NUFFT-based GNL correction. Comparison between Fig. 3a and 3b shows improved cerebellar clarity in the results after the integrated NUFFT-based GNL correction.

Conclusion: This gradient coil is part of a project to develop a high performance brain imager with lower costs, that is easier to site and is more accessible than standard whole body systems. These results showed that our proposed design is able to achieve large (24-26 cm) FOVs with coverage into the upper cervical spine. In addition, the integrated gradient nonlinearity correction can improve in vivo images acquired with this head only system. We anticipate that the imager will serve as an ideal platform for advanced imaging of the brain and brain function.

Acknowledgment: This work was supported in part by the NIH grant 5R01EB010065. **References:** [1] Mathieu et al., ISMRM 20 (2012), 2588 [2] Mathieu et al., ISMRM 21 (2013), 2708 [3] Lee et al., ISMRM 22 (2014), 310 [4] Tao et al., MRM 2014, doi: 10.1002/mrm.25487.