High resolution carotid plaque MRI using a custom gradient coil insert

J. P. Hulet[1], S-E. Kim[2,3], J. A. Roberts[2,3], D. R. Nightingale[4], G. S. Treiman[5,6], and D. L. Parker[2,3]

[1]Department of Biomedical Informatics, University of Utah, Salt Lake City, Ut, United States, [2]Utah Center for Advanced Imaging Research, Salt Lake City, Ut, [3]Department of Radiology, University of Utah, [4]VA Salt Lake City Health Care System, [5]Surgical Service, VA Salt Lake City Health Care System, [6]Department of Surgery, University of Utah, School of Medicine

Introduction

MRI has been used in both in-vivo and ex-vivo experiments to image and classify carotid plaques[1,2]. One major goal of carotid MRI has been to improve image quality and thereby improve the use of MRI in the characterization of carotid plaques. While ex-vivo experiments benefit from the high image quality of small bore specimen scanners, in-vivo experiments are limited by a variety of factors associated with clinical scanners, one such factor being limited spatial resolution. We hypothesize that increased gradient performance in a high field (3T), clinical MRI scanner could significantly improve plaque image resolution and, ultimately, the diagnostic utility of in-vivo carotid MRI. To test this hypothesis we performed several experiments in a whole body MRI scanner using a novel gradient system. This gradient system consists of a gradient coil insert which can be used in conjunction with the whole-body gradient system of a clinical scanner to increase image resolution[3]. We scanned excised carotid plaques with and without the gradient coil insert and compared the quality of the images.

Methods

Carotid plaque specimens were obtained from patients undergoing endarterectomy and immersed in a saline solution to reduce susceptibility effects caused by air. Imaging was performed on the Siemens 3T TIM Trio scanner (Siemens Medical, Erlangen Germany) using a transmit/receive RF wrist coil. The standard system was augmented with a gradient coil insert (Figure 1) having three additional gradient amplifiers and waveform generators. These additional gradient coils are controlled by a second host computer operating as a slave to the master host computer. The control hardware and software were developed and provided by Siemens. For all experiments, the master and slave computers executed identical pulse sequences, with the master controlling the system body gradient coils and the slave controlling the amplifier currents in the gradient coil insert[3]. Although this gradient coil insert has efficiencies of roughly 0.4 mT/m/A and is therefore capable of very large gradients, it was operated with gradient strength identical to the body gradient coils for these initial experiments.

Results

For the specimen shown in Figure 2, five sets of images with different MR contrast were obtained: T1w (TE/TR=12/600 ms), T2w (TE/TR=65/1500 ms), PDw (TE/TR=12/1500 ms), 3D MPRAGE with inversion recovery (TI/TE/TR=700/2.31/1500ms), and diffusion weighted rFOV EPI (b=1000 s/mm^2). The slice thickness was 0.5mm for both gradient modes and in-plane image resolution was 500x500 μm^2 with the body gradient only (Figure 2a) and 250x250 μm^2 with the dual gradient system (Figure 2b). Figure 2 illustrates the increased image resolution obtained using the dual gradient system. Plaque features such as calcification are more clearly delineated in the higher resolution Figure 2b. Using as a reference the corresponding micro-CT image (Figure 2c) it can be noted that internal regions of fibrous tissue which are surrounded by calcium, are more clearly represented in the image obtained using the dual gradient system.

Discussion

Our intent has been to evaluate the potential improvement in plaque detail that can be obtained using a high performance gradient coil insert in conjunction with the whole body gradient coils of a clinical MR scanner. We have scanned a number of excised carotid plaques and demonstrated that the increased gradient performance of this dual gradient system results in higher resolution plaque images. These comparisons are ongoing but the carotid specimens scanned to date give evidence that the dual gradient system may be used to overcome some of the spatial resolution limitations of clinical whole body scanners. This unique system could be used to improve human carotid MR studies by providing the means for high resolution imaging using clinical whole body scanners.

Acknowledgements

We would like to thank Craig Goodrich and Anne Haroldsen for their contributions to this work. This research is supported in part by a Clinical Merit Review Grant from the Veterans Administration Health Care System.

References

[1] Yuan C, Oikawa M, Miller Z, Hatsukami T. MRI of carotid atherosclerosis. J Nucl Cardiol 2008;15(2):266-75

[2] Clarke SE, Beletsky V, Hammond RR, Hegele RA, Rutt BK. Validation of automatically classified magnetic resonance images for carotid plaque compositional analysis. Stroke 2006;37(1):93-97

[3] Chronik BA, Alejski A, Rutt BK. Design and fabrication of a three-axis edge RUO head and neck gradient coil. Magn Reson Med. 2000;44(6):955-63

Figure 1: Gradient coil insert with RF wrist coil.

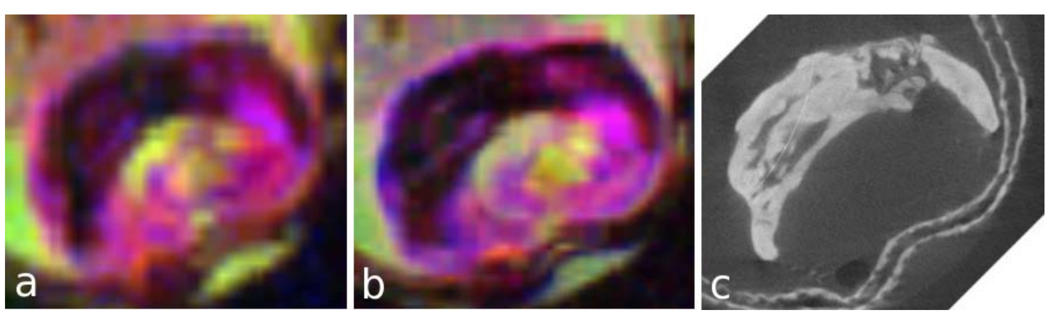

Figure 2: RGB (T1, T2, MPRAGE) images of carotid specimen imaged using a) only the body gradient coils and using b) the composite gradient system and c) a micro-CT scan showing calcification at the same location