Ultra High Resolution (156-micron) Black-blood Carotid Artery MRI at 3T

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Introduction

High-resolution black-blood carotid artery MR imaging has great potential for visualizing and characterizing atherosclerotic plaques. However, due to aliasing artifacts in MRI, the field-of-view (FOV) along the phase-encoding direction must, in general, be larger than the total anatomy size in that direction. This introduces an inherent inefficiency in spatial resolution and scan time, particularly when high-resolution imaging is only required for either the left carotid artery or the right carotid artery, and not for both sides. The use of the inner volume technique[1,2] with double-inversion fast-spin-echo (DIR-FSE), together with the use of a high-field, 3T, MRI system for signal-to-noise ratio (SNR) advantages, presents a scheme to perform ultra high-resolution black-blood FSE carotid artery MRI.

Methods

Nine healthy subjects (5 males, 4 females; age 19-41 yr., avg. 31.4 yr.) underwent this Institutional Review Board approved study, after signing an informed consent. All studies were performed on a 3T whole-body short-bore TwinSpeed MR scanner (GE Healthcare, Waukesha WI, USA), with a maximum gradient strength of 40 mT/m and a maximum gradient slew rate of 150 T/m/s. The RF coil used was a custom-made 6-element carotid phased-array coil (Fig. 1), designed to give the optimal SNR at the desired penetration level for carotid bifurcation, which is about 3-4 cm away from the surface of the human neck[3]. With inner volume sequences, wrap-around artifacts are not a concern, and therefore the FOV can be reduced in order to “zoom” into the anatomy/pathology of interest. In our studies, a FOV of 8×4 cm^2 was used, centered on either the left carotid artery or the right carotid artery, with a matrix size of 512×256, resulting in an in-plane resolution of 156×156 µm^2. The slice thickness was 2 mm, the receiver bandwidth was ±62.5 kHz, the echo train length = 16, and cardiac gating was used, with an interval of 2 heartbeats between slices (i.e., TR=2R-R). Effective TE = 10 ms, and 8 averages were acquired. Double inversion pulses were used at an appropriate delay time before the excitation pulse in order to produce black-blood images. Depending on the heart rate, the total scan time per slice ranged from 2.5 to 4.8 min. For data analysis, since the FOV was too small to include any background region, it was, therefore, not possible to measure the standard deviation of the background noise in order to calculate SNR and contrast-to-noise ratio.

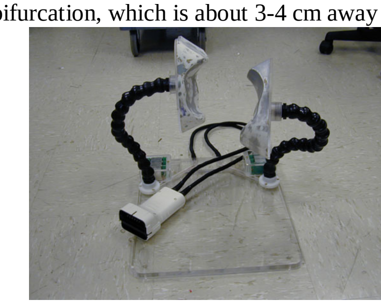

Fig. 1 6-element carotid phased array

Results

Fig. 2 shows two examples of inner volume DIR-FSE black-blood carotid artery images, slightly superior to the bifurcation, obtained from two volunteers. Fig. 3 shows, on the same volunteer and the same imaging slice as Fig. 2b, a DIR-FSE image obtained in the same total scan time without using inner volume - with a FOV of 10×10 cm^2, wrap-around artifacts can be seen.

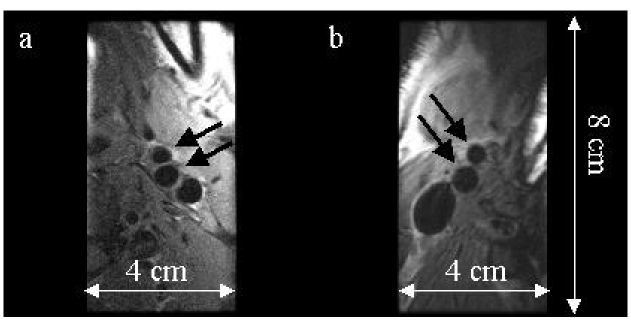

Fig. 2 Inner volume black-blood images of (a) the left carotid arteries (arrows) on a 26 yr healthy female volunteer (scan time = 3.5 min), and (b) the right carotid arteries (arrows) on a 34 yr healthy male volunteer (scan time = 4.3 min). Both images have a 156-micron^2 in-plane resolution, 2 mm slice thickness, 8×4 cm^2 FOV, and 8 averages.

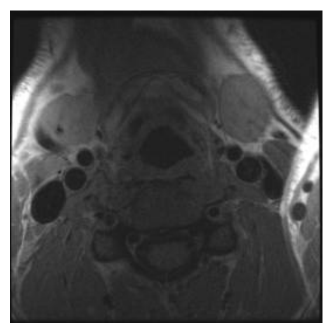

Fig. 3 A regular black-blood image acquired without using inner volume, on the same volunteer and the same imaging slice as Fig. 2b, with FOV = 10×10 cm^2, matrix size 512×512, 2 mm slice thickness, 4 averages, and the same scan time of 4.3 min. Wrap-around artifacts can be seen.

Conclusions

We have demonstrated the feasibility of acquiring ultra high-resolution (156-micron) black-blood images of the carotid arteries using inner volume DIR-FSE at 3T, within a reasonable scan time. This technique may prove to have a great potential in characterizing vascular stenosis and atherosclerotic plaques. Improvement in the SNR, by optimizing the pulse sequence, scan protocol and coil design, will help further reduce the scan time and/or increase the spatial resolution. The use of a non-gated and/or multi-slice version of the sequence will be explored, which can also significantly reduce the scan time and improve coverage.

References: 1. D.A. Feinberg, *et al.*, *Radiology* **156**, 743-747 (1985); 2. B.S.Y. Li, *et al.*, *ISMRM* Abstracts, p. 2598 (2003); 3. S. Mathew, *et al.*, *ISMRM* Abstracts, p. 1550 (2004)

This work was supported in part by NIH grant HL60708.