Robust carotid atherosclerotic plaque imaging at 3.0T with black blood single shot EPI

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Introduction

Magnetic resonance imaging has a great potential to provide high resolution imaging of vessel wall for the detection and estimation of atherosclerotic plaque burden. Nonetheless, it has been relatively difficult to achieve the required robustness in-vivo for characterization because of many confounding problems. High resolution is usually associated with long imaging times even with specialized multi-channel reception to provide adequate signal-to-noise ratio (SNR) scans. Secondly, in many cases the appearance of slow flowing and stagnant blood contribute to confuse vessel wall and lumen boundaries. Problematic is also patient and inherent vessel motion (e.g., swallowing and vessel pulsation) during the examination, producing substantial image degradation in most cases and mismatch between different measurements.

Purpose

The best contrast possible for the detection of atherosclerotic plaque and characterization of the different plaque components has been carried out with proton density-, T2- and T1-weighted contrasts and a black-blood image sequence readout that can provide good contrast between vessel wall and lumen. In this work we assess a candidate alternative for T2-weighted black blood imaging at 3.0T, of lesser in-plane resolution than commonly acquired for these types of studies but with the potential to provide faster and robust volumetric imaging of the carotid arteries.

Methods

6 volunteers and 8 patients scheduled for carotid endarectamy were scanned at 3.0T (General Electric Healthcare, USA; software release 12). A 4-channel phased array carotid coil (2 receiver channels per side, Flick Engineering Solutions B.V., the Netherlands) was used to cover a 6 cm long carotid section centered at the level of each carotid bifurcation. An un-gated thin-multislice fat suppressed proton density weighted fast spin echo (PDw-FSE) scan was used for a high resolution morphological assessment of the vessel wall morphology. Imaging parameters were: TR/TE=4500/18 ms, ET=4, BW=19.2 KHz, slice=1.5 mm, FOV=18 cm^2, matrix=512x320, voxel=0.35x0.56x1.50 mm^3, NEX=1, scantime=6 min. The imaging volume consisted of 40 slices.

A single-shot T2-weighted black blood echo planar imaging (T2w-BBEPI) scan sensitized with diffusion gradients applied in all orthogonal axes was then acquired. The same slice positions and slice thickness were used as in the PDw-FSE scan. In volunteers the b-value was incremented between 10 and 100 s/mm^2 in steps of 20 to determine an "optimal" for blood signal suppression in the region of the carotid bulb. Multi-planar reconstructions were performed on each of the data sets for evaluation.

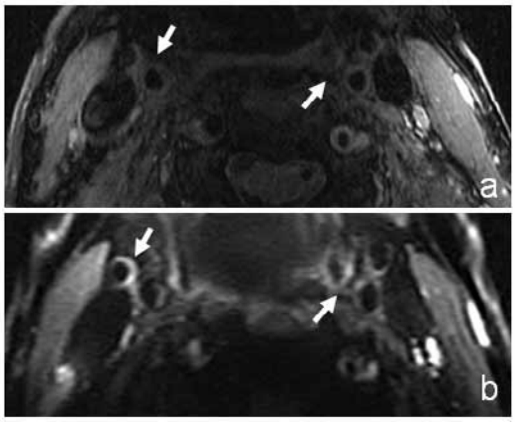

Figure 1: (a) Fat suppressed PDw-FSE scan; (b) T2w-BBEPI. Geometrical distortions in EPI can be seen, nonetheless, variations in signal intensity in the vessel wall are clearly distinguishable with a scanned voxel resolution of 1.25x0.90x1.50 mm^3. Arrows point at the region of interest (internal and external carotid arteries).

Results

After a qualitative assessment of the T2w-BBEPI on volunteers at the level of the carotid bulb a b-value of 50 s/mm^2 was chosen as the one that provided consistent blood suppression and kept signal dephasing from pulsatile motion in the region small. The imaging parameters for the resulting T2w-BBEPI chosen were: TR/TE=10500/53 ms, FOV=16 x 8 cm^2, matrix=128x180, voxel = 1.25x0.90x1.50 mm^3, NEX=6, scan time=4 minutes.

Geometrical distortions were not excessive with the EPI readout executed at the set resolution. Distortions were further reduced using a rectangular FOV with an aspect ratio of 0.5 and saturation bands placed anterior/posterior to eliminate fold-over artifacts and provide additional blood suppression by angulating the saturations bands over blood in the heart to further suppress its signal. Figure 1 and Figure 2 illustrate a comparison between PDw-FSE and T2w-BBEPI scans in two patients.

Discussion

The SNR in the T2w-BBEPI scans was adequate. Although the voxel resolution was not as high as what has been collected in other studies, T2w-BBEPI provided a robust display of the plaque morphology with well defined intensity variations in the diseased vessel wall. The findings in this scan can be used as base scans for a targeted higher resolution T2w-FSE acquisition. T2w-FSE scans were not acquired for comparison in patients to keep overall examination short as this study was part of a more complex protocol including contrast agents. Likewise, it was deemed that SNR was not good enough for T2w-FSE with the same voxel resolution as in PDw-FSE with the same imaging time.

The hyperintense structures observed in T2w-BBEPI in patients most likely corresponds to fibrous/collageneous tissue. The low intensity specks in the hyperintense structures are calcifications or lipid pools.

One advantage of the BBEPI module is that it permits scanning after the administration of contrast agents. This opens the possibility for the use of a T1w-BBEPI version with the same robustness and good blood suppression characteristics. Nonetheless, a b value of 50 s/mm^2 provides a TE that is presumably too long to follow positive signal intensity changes from the accumulation of contrast agents in plaque. A T1w-BBEPI scan will necessitate further investigation.

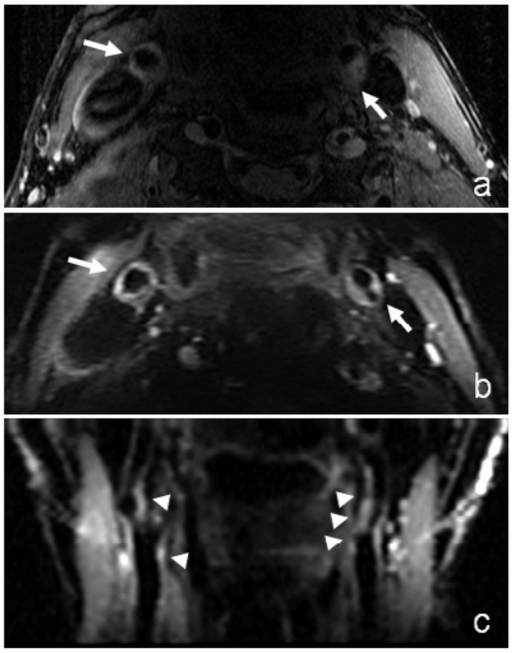

Figure 2: (a) Fat suppressed PDw-FSE scan; (b) T2w-BBEPI. The arrows point at the carotid arteries below the bifurcation. (c) Multi-planar reformat of the BBEPI data set illustrates bright spots (arrow heads), defining well the extent of the lesions seen in the acquired axial slices.

Conclusion

In this ongoing study, our experience on patients using T2w-BBEPI is very positive. The sequence provides a fast, robust approach to imaging atherosclerosis in the carotid arteries with quasi-isotropic resolution and high SNR. Diffusion sensitized scans provide consistent black blood suppression, reducing largely quantification problems with slower and stagnant blood. The results obtained are encouraging so far and the setup provides more flexibility, larger volume coverage and time efficiency.