Long Segment Dark Blood Carotid Artery Imaging with Pencil-Beam-Excitation and Diffusion Preparation at 3T.

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Introduction

The increasing understanding of atherosclerosis as an important risk factor for the development of acute ischemic events like ischemic stroke has stimulated increasing interest in non-invasive assessment of the structure, composition and burden of plaque depositions in the carotid artery wall. This requires the coverage of larger volumes with blood suppression, which can often not be ensured by the conventional dual inversion recovery (DIR) 2D techniques. However, due to the prolonged image acquisition times 3D protocols are prone to severe motion artifacts, e.g. from swallowing and patient motion. Furthermore the DIR black blood effect is prone to fail in the larger volumes due to saturation effects.

The purpose of this work was to develop a time efficient and robust 3D black blood technique to visualize large segments of the carotid arteries, centred on the bifurcation, which are of special clinical interest for the assessment of atherosclerosis.

Methods

Carotid artery wall imaging was performed in 6 volunteers. All imaging was performed on a 3 T whole Body Scanner (Achieva, Philips Medical Systems, Netherlands) equipped with a high performance gradient system capable of a maximum gradient amplitude for imaging of 40 mT m^{-1} using a maximum slew rate of 200 T m^{-1} s^{-1}. All data was acquired with a dedicated two times two-element carotid artery coil sized 120 x 50 mm (Philips Research Europe) with one two-element coil located on either side of the neck. A 3D diffusion prepared, fat suppressed, segmented spoiled gradient echo sequence was developed (TE/TR 1.8/7.2 ms, TR per segment 1 s, acq. duration 290 ms , Flip 25°, FOV 150x50x50mm, resolution 1mm isotropic, parallel imaging factor 2 in AP direction, acquisition time 370 s). As reported previously by Koktzoglou [1], suppression of blood signal was accomplished by a motion sensitizing diffusion spin preparation. The preparation comprised a $90°_x$-$180°_y$-$90°_{-x}$–driven equilibrium technique with integrated magnetic field gradients for dephasing the spins of moving blood. Suppression of residual transversal magnetization was achieved by subsequently applied spoiler gradients. The duration of the preparation was 21.5 ms with a cumulated B-value in all three directions of 17.1 s mm^{-2} applying a 15 mT m^{-1} gradient amplitude for 4.5 ms. The preparation was applied once prior to the acquisition of each k-space segment. The local excitation was achieved by incorporation of a 2D spatially selective excitation pulse using variable density spirals for excitation k-space encoding. The pulse was optimized for an excitation of a specific field of view of 50 mm with minimal excitation duration of 3.8 ms by sacrificing a little excitation profile sharpness. Aliasing from residual side-loops was avoided by twofold oversampling in phase-encoding direction and 28% oversampling in slice-encoding direction, which turned out to sufficiently suppress backfolding artifacts. This approach was chosen to diminish possible motion artifacts from paroxysmal patient motion and swallowing as the pharynx is left out of the acquisition and not excited, thus the peril of motion artifacts is greatly reduced.

Figure 1: Reformatted image of the carotid artery.

Results

Figure 1 summarizes the obtainable image quality and coverage of the suggested technique. The carotid artery is shown as reformatted image. After reformatting, the vessel wall could be clearly depicted over a range of about 15 cm in either volunteer.

Discussion

With the suggested local excitation technique in combination with diffusion prepared black-blood imaging, high quality dark blood imaging of the carotid arteries over a large range appears feasible. This might enable fast overview scans for assessment of the plaque burden in atherosclerotic patients.

[1] Koktzoglou I, Li D. Diffusion-prepared segmented steady-state free precession: Application to 3D black-blood cardiovascular magnetic resonance of the thoracic aorta and carotid artery walls. J Cardiovasc Magn Reson. 2007;9(1):33-42.