Traveling Wave MRI for the Acquisition of Reference Images for Parallel Imaging at the Carotid Artery at 7T - Proof of Concept

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Introduction: MRI of the carotid artery and specifically of plaque formation near its bifurcation, is important to asses plaque composition and the associated risk of stroke [1]. Imaging these plaques at 7T may result in higher resolution and in better qualification and risk assessment of the different plaque components, compared to 1.5T and 3T. Dedicated surface coils that can be positioned close to the carotids have been used in phased array for reception of RF signal with maximal efficiency. Undersampling of k-space can then be applied using techniques based on k-space reconstruction (SMASH, GRAPPA) or on image-based reconstruction (SENSE). For most of these methods good sensitivity profiles of the individual coils are needed, which can be obtained by dividing each individual coil image by an additional reference image acquired with uniform spatial sensitivity either using RF body coils or using a virtual body coil by a fixed combination of the images obtained with the receiver coils. In the absence of a uniform B_1-field (i.e. at high field strength like 7T), transceivers are applied that can be used for excitation and optimal reception. However, optimal reception requires closely positioned RF coils at the expense of uniformity. Specifically at body parts that vary substantially between subjects, like the human neck, uniformity may be substantially compromised because of the use of small surface coils, which eliminates the possibility of using such setup for reference images. Therefore, we propose to use travelling wave MRI [2] for the acquisition of uniform reference images. As such antennas have a low efficiency, the carotid array was used for transmitting. This reference scan can also be used to correct images for image inhomongeneity by dividing them by this reference image (CLEAR). This abstract shows a proof of concept by means of experimental results on a volunteer subject.

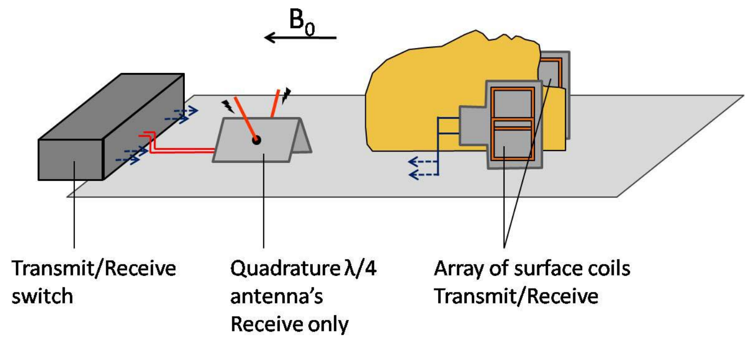

Fig. 1 Schematic overview of the setup. Two pairs of decoupled RF transceive coils are used for imaging. Two perpendicular λ/4 antenna's are used for quadrature reception of a reference acquisition.

Methods An array of four dedicated transceive coils for optimal sensitivity of signals from the carotid arteries was used, consisting of two pairs of decoupled surface coils (Machnet B.V., Maarn, Netherlands). Two home built perpendicular oriented shortened λ/4 antenna's were added to the setup to enable traveling wave acquisition, as shown in Fig. 1. All elements were interfaced to a whole body 7T MR system (Philips, Cleveland, USA) using home built transmit receive switches and preamplifiers. For the coil sensitivity maps two datasets were acquired: individual gradient echo (GE) images of each coil (Tx and Rx: surface coil) and an additionally acquired GE reference scan (Tx: surface coils, Rx: antenna). These individual images of the coils were divided by the reference scan resulting in coil sensitivity maps. These maps will also be used for CLEAR inhomogeneity correction. As a comparison, transverse images of the neck were acquired in two different ways: (1) T2 weighted Turbo Spin Echo (TSE), transmitted (Tx) and received (Rx) with the carotid coils, FOV: 200x200 mm^2, slice thickness: 2 mm, voxel: 0.80x0.80 mm^2, T_R/T_E = 4000/40 ms, TSE factor 7, ES 10.0 ms, duration 4:48 min, and (2): identical scan, but k-space undersampled with factor 2, duration 2:32 min, coil profiles and reference scan were used to reconstruct full FOV image (SENSE) and correct for inhomogeneity (CLEAR). To illustrate uniformity of the travelling wave antennas, gradient echo images were obtained using the antenna both as (low power) transmitter and receiver.

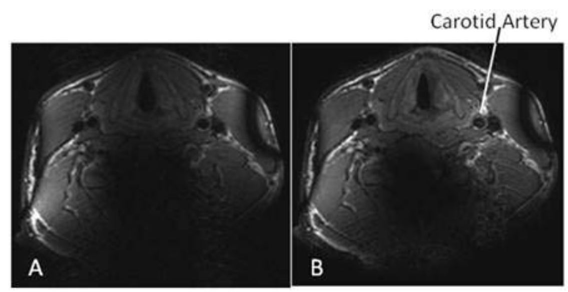

Figure 2: Transverse T2 weighted TSE images of the neck (A) without acceleration and (B) antenna reference scan used to enable CLEAR and SENSE with acceleration factor 2 reducing scantime with factor 2.

Results Figure 2 shows the TSE images acquired (2a) without and (2b) with SENSE. In (2b), the reference scan obtained for SENSE, is also used to correct for image inhomogeneity using CLEAR. Visually, it can already be confirmed that the full FOV image has successfully been reconstructed using SENSE with acceleration factor 2, reducing the scantime by a half. In addition, as non uniformity can be corrected as well (using CLEAR), a more homogeneous image can be generated as can bee seen in Fig. 2b. In the middle area a signal void remains present, as this area is located outside the sensitivity region of any of the carotid coils. Figure 3 is the GE image acquired by the antenna alone (Tx and Rx), which shows a relative uniform transversal image of the neck.

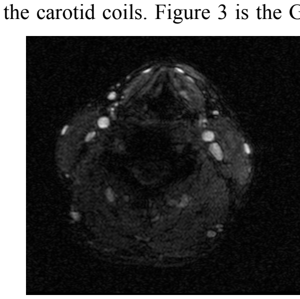

Figure 3: transversal GE image of a (different) slice of the neck acquired with the antenna for both transmitting and receiving shows relative high uniformity.

Conclusion Traveling wave MRI can be applied for the acquisition of reference images. This enables acceleration with parallel imaging even with RF coil setups that are optimized for sensitivity only, as demonstrated in the carotids, where accurate reference scans are difficult to obtain otherwise. This enables acceleration of the sequences with SENSE and improvement of image homogeneity with CLEAR.

[1] Oppenheim et al, J Radiol 2008; 89:293-301
[2] Brunner et al, Nature 2009; 457:994-998