Optimization of a Phased-Array Coil for High-Resolution MR of the Carotid Arteries

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100 WORD ABSTRACT

The geometry of a phased-array coil for high-resolution imaging of carotid artery walls was optimized concerning signal-to-noise ratio (SNR). Simulations of SNR for various coil geometries were performed. The coil with the most favorable geometry was implemented and SNR measurements in a phantom were performed to verify the simulations. The capability of the developed phased-array coil for high-resolution imaging of carotid artery walls and evaluation of atherosclerotic plaque was demonstrated in in vivo measurements.

INTRODUCTION

Noninvasive imaging of carotid arterial walls, particularly the bifurcation, and characterization of possible plaque is of high neurological interest: The turbulent blood flow at the bifurcation promotes the formation of plaque which might endanger brain perfusion. A high resolution of about 100-300 µm in-plane is required. To achieve a high SNR in voxels $\Delta V \leq 10^{-2}$ mm^3, the utilization of surface coils is essential. The carotid arteries are situated superficial at a depth of $y = 3$-4 cm. To ensure adequate longitudinal coverage, including the bifurcation, they should be imaged over a length of about $\Delta z_K = 8$ cm. The penetration depth of a surface coil is approximately restricted to its smallest geometrical dimension. To enhance the SNR while maintaining anatomical coverage, phased-arrays are used. Phased-arrays consist of several individual coils, which are arranged with an optimized overlap. Phased-arrays achieve a higher SNR than single coils with the same surface coverage. This is not the first application of a phased-array coil for high-resolution MR of the carotid arteries. Hayes et al. [1] developed an array consisting of two square elements with overall dimensions of $\Delta x \times \Delta z =$ 10.8 cm x 6.4 cm. The goal of the present work is the optimization of the geometry of the elements to further enhance the SNR, while maintaining an anatomical coverage (5 cm x 8 cm) which avoids the necessity for frequent repositioning of the coil in a clinical situation.

METHODS

A simulation tool was developed to determine SNR/ΔV for coils with various geometries. The geometry was optimized for SNR over the required sensitive region. The optimized geometry was compared to the geometry used by Hayes [1] and implemented for a Siemens Sonata 1.5 T. Comparative SNR measurements with a 2.0 l saline solution phantom were performed. The SNR of the new phased-array coil (ref. to as 'PA') and two commercial coils, 'CP Neck Coil' and 'LP Flex Loop Small' (ref. to as 'Loop S', ∅ 4 cm), were compared. The pulse sequence was a 2D fast spin echo. The signal and noise were determined by the mean and difference of two successive images. These measured SNRs were compared to the simulated SNR of the PA, the Loop S and a 5 cm x 8 cm single coil. Additionally, in vivo measurements of 5 healthy volunteers and 8 patients with known carotid artery stenosis were performed with the PA (TSE-sequence, FOV 5 cm, matrix 512 x 512 interpolated, 256 x 256 acquired, slice thickness 1.5 mm sagittal / 2 mm axial)

RESULTS

For the required sensitive area of $\Delta x_s \times \Delta z_s = 5$ cm x 8 cm at a depth of $y = 3$-4 cm, a two-element PA with the same overall xz-dimensions came out on top concerning SNR. The PA consists of two single elements, each with $\Delta x_{S1,2} \times \Delta z_{S1,2} =$ 3 cm x 8 cm, overlapping 1 cm in the x-direction. Figure 1 shows the simulated (a, b) and measured (c, d) SNR-profiles: SNR($x = 0, y, z = 0$) (a, c) and SNR($x = 0, |y| = 30$ mm, z) (b, d).

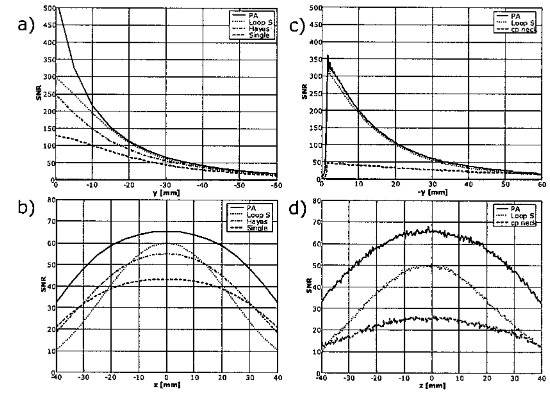

Fig. 1: SNR-profiles: a), b): simulations, c), d) measurements; a), c) SNR($x = 0$, y, $z = 0$), b), d) SNR($x = 0$, $|y| = 30$ mm, z)

The simulations show an SNR enhancement of the PA in comparison to the single coil and Hayes' design. The 'Loop S' achieves an SNR similar to the PA but with significantly restricted coverage in z. The 'CP Neck' yields a homogeneous but relatively low SNR. The simulations for the 'Loop S' and the PA match the measurements. The measured y-profiles of SNR for both coils are nearly identical. At the depth $y = 3$ cm, the PA yields 1.3-times higher SNR than the 'Loop S' at $x = z = 0$, and —because of the rapid decrease in SNR of the 'Loop S' in the z-direction— a 3-fold higher SNR at $\Delta z = \pm 40$ mm. The in vivo measurements (Fig. 2) performed with the PA are of excellent quality. The arterial wall and plaque are clearly identifiable.

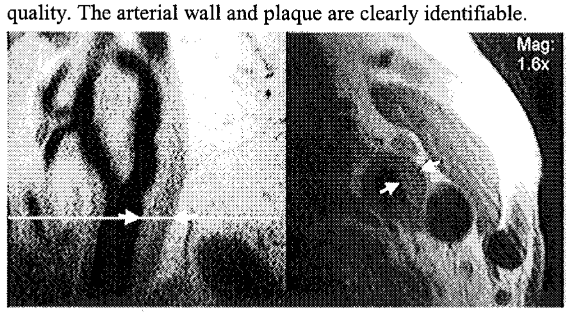

Fig 2: sagittal and axial slices of a patient with stenosis of the left common carotid artery, arrow heads: plaque

CONCLUSIONS AND FUTURE WORK

Both the SNR simulations and measurements demonstrate how the optimized phased-array coil (PA) leads to an excellent compromise between SNR and sensitive area for the high-resolution evaluation of atherosclerotic disease. The commercial coil 'Loop S' is not suitable for clinical imaging of the carotid arteries due to its limited sensitive extent in z. The 'CP Neck' yields a homogeneous but overall low SNR. The Hayes' coil design [1] is currently being implemented for our scanner, and comparative measurements are planned to verify the simulations.

REFERENCES

[1] Hayes, C.E. et al.: Surface coil phased arrays for high-resolution imaging of the carotid arteries, JMRI 6, 109-112, 1996