Carotid Artery Imaging at 7T: SNR Improvements using Anatomically Tailored Surface Coils.

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Introduction: Blood vessel shape, blood flow, and wall shear stress (WSS) are important indicators of vascular function. WSS is directly related to spatial velocity gradients at the vessel wall and has been linked to the progression of atherosclerotic plaques. Since phase contrast imaging is relatively independent of B_1 inhomogeneities, the technique seems well suited for application at 7T field strength [1], without suffering from B_1-related artifacts to a large extent. Imaging of the carotid artery bifurcation at 7T has been limited so far mainly by the lack of suitable coils.
In this work a 7T receive-only, double surface coil [2] was built to optimize imaging of the carotid region [3]. The geometry of the coil was chosen such that it optimally conforms to the average adult's anatomy surrounding the bifurcation. First results of high resolution phase-contrast angiography and flow measurements of the carotid bifurcation with the dedicated coil are presented and compared to images obtained with a commercial volume T/R coil.

Methods:
Carotid coil: The coil support was constructed of a 1 mm polycarbonate thermoplastic, which was heat-formed to fit to the neck and lower jaw anatomy while allowing clearance for the pinna. The two coil elements were made of 6.5 mm copper tape and adapted to the anatomy for optimal viewing of the carotid bifurcation. The overlap was adjusted to minimize mutual inductance between the loops. Foam padding 5 mm in thickness separated the coil from the skin for comfort and safety. A common ground for both elements allows the coils to be relatively insensitive to geometric positioning, a considerable challenge at 7T (298 MHz). The common ground also allows a single bazooka cable trap to be used around both signal coaxial cables, which were wrapped in plastic sleeving to form a single unit exiting the detunable volume transmit/receive coil (Nova Medical, USA). The matching circuit employed a standard PIN diode circuit for active detuning during transmission. Cables' lengths were chosen to be an odd multiple of $\lambda/4$ and connected to low-input impedance preamplifiers to provide preamp decoupling [4].
Imaging: Phase-contrast angiographic and 7D quantitative flow data were acquired from two healthy subjects on a human 7T MRI system (Philips Medical Systems, Best, The Netherlands) receiving a) with the volume transmit/receive coil and b) with the carotid coil while using the volume coil in transmission mode .
The following sequences were used: 3D T1-weighted gradient echo imaging with FOV 150x150x56mm^3 (sagittal), scan matrix 256 x163x113,venc (FH-RL-AP) 50cm/s, TE/TR 4/7.3 ms, scan duration: 4.10 min; 7D time-resolved T1-weighted turbo-gradient echo quantitative flow imaging with FOV 150x150x30mm^3 (sagittal), scan matrix 150 x97x15,venc (FH-RL-AP) (50-80-50) cm/s, 30 cardiac phases, TE/TR 3.8/5.5ms, scan duration: 12:10 min. The flow data were visualized using the GTFlow package (GyroTools Ltd., Zurich, Switzerland).

Results: The carotid array comfortably fits different anatomies and was easy to use. Excellent transmit detuning was confirmed by transmitting and receiving with the volume coil and noting little effect of the carotid array on transmit field uniformity. As expected, coupling between the elements was minimal as confirmed by the only minor overlap of the elements' sensitivity maps. The SNR of the angiography data was drastically improved when using the dedicated coil in comparison to the volume head coil (Figure 2). Narrow branching vessels are visible and, in addition to the carotid artery, the vertebral artery was clearly depicted. The flow measurements showed flow patterns in accordance with angiographic data, and flow in narrow branching vessels was correctly tracked (Figure 2c).

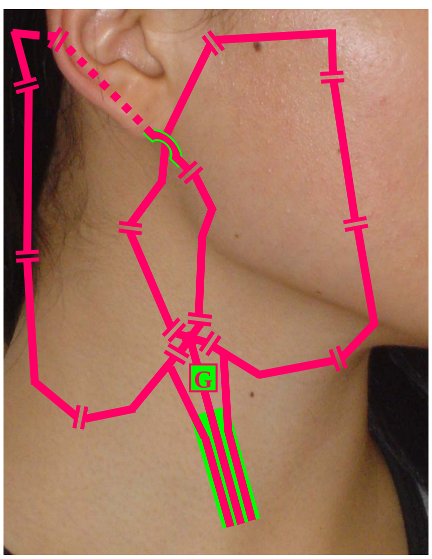

Figure 1: *Schematic of the 2-element carotid coil. The plastic support of the coil is fitted to the neck and lower jaw. The letter G marks the common ground. The two output coaxial cables share a common cable trap (green).*

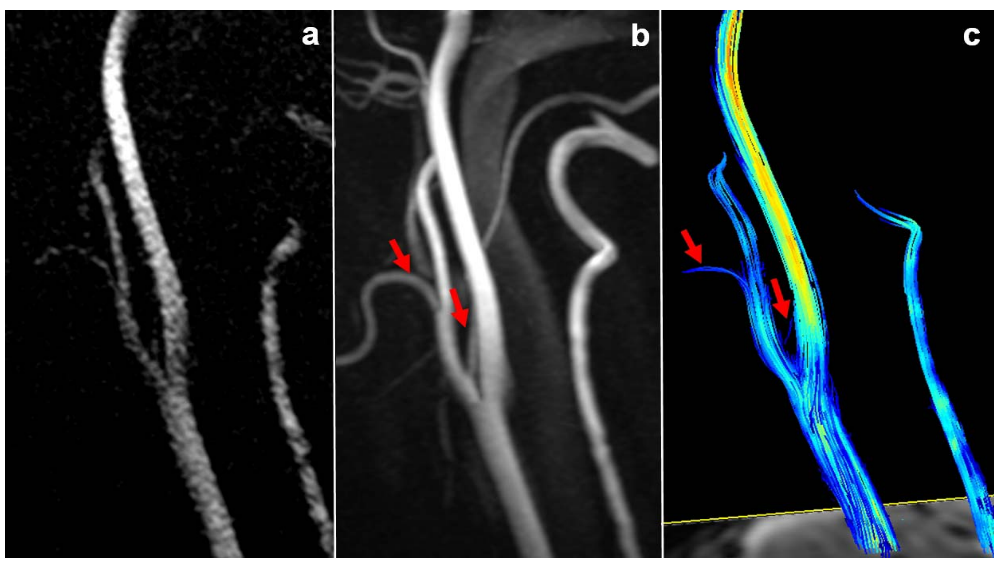

Figure 2: *Maximum intensity projection of the carotid bifurcation obtained from 3D PC angiographic data* **a)** *acquired with the volume T/R head coil and* **b)** *with the carotid coil. Particle traces derived from 7D quantitative flow data acquired with the carotid coil are depicted in* **c)**. *The arrows indicated flow branching off the carotid artery. The colors reflect peak velocities with the axis of the internal carotid artery lying in the imaging plane displayed (high flow). The axis of the common carotid artery is slightly out of plane hence yielding lower velocities in the display.*

Conclusion: This work has demonstrated that the use of anatomically shaped receive-only surface coils realizes the SNR potential of 7T thereby making high resolution carotid bifurcation angiography and flow imaging a promising application. Phase contrast imaging methods are especially suitable due to their insensitivity to B_1 inhomogeneities, which are often considered to be a severe limitation at 7T.

References: [1] Van de Moortele PF, et al. MRM 54 p1503 (2005) [2] Stensgaard A, JMR 125 p84 (1996) [3] Hayes CE, et al. JMRI 6 p109 (1996) [4] Romer PB, et al. MRM 16 p192 (1990)