Carotid Artery Imaging at 3T: More Signal from 3D Imaging using a New 4-element Coil

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Introduction Atherosclerotic plaque's vulnerability to rupture is related to plaque composition and morphology [1-3], and is best depicted by MRI. 3T MR imaging of carotid artery disease would improve plaque detection and characterization [4]. SNR gain with 2D TSE at 3T was 60~70% compared to 1.5T [5]. This can be used for either spatial resolution improvement or scan time reduction (but insufficient for both). With 2D TSE, anisotropic voxels are still limiting plaque morphology visualization. Recently, 3D imaging of carotid vessel walls proposed on 1.5T [6, 7] showed improved voxel isotropy and anatomic coverage. Equipped with appropriately designed coils, 3D carotid artery imaging at 3T may be more promising than with 2D TSE. In this study, we explored potential advantages of 3D carotid artery imaging at 3T using a dedicated 4-element phase array coil. Specifically, we evaluated if dark blood, T2 weighted 3D TSE (aka SPACE) imaging of carotid artery at 3T using the coil would provide additional benefit over 2D dark blood TSE.

Method Coil: The unilateral coil has 4 elements arranged in a 2x2 matrix (~15cm x 9cm). The circuit was mounted on a plastic foam substrate. It was flexible and fitted well to the neck and lower jaw. A 4-channel preamplifier connected the coil to the scanner.
Sequence: T2 weighted dark blood 2D TSE (or 2D TSE) and SPACE were compared. The SPACE based on [7] was used. The 2D TSE used was similar to that of [5] without interleaving. Imaging parameters for SPACE were: TR =1.5s with restore pulse, TE=166ms, ETL=66 (variable flip angles for refocusing pulses), fat saturation (fatsat), parallel acquisition technique (PAT) used (rate 2) NEX=2, 56 slices, bandwidth=445Hz/pixel, voxel size: $(0.7\text{mm})^3$, 3D interpolated to $(0.35\text{mm})^3$, scan time ~4.2 min. Parameters for 2D TSE were: TR=3RR (ECG triggered), TE=91ms, ETL=19, flip angle=155^o, dark blood preparation, fatsat, PAT2, NEX=3, bandwidth=130Hz/pixel, voxel size: $(0.47\text{mm})^2$ x 3mm, 2D interpolated to $(0.23\text{mm})^2$ x 3mm offline, scan time ~ 1.2min/slice.
Imaging: Imaging was performed with the dedicated coil on a 3T clinical scanner (Tim TRIO, Siemens, Erlangen, Germany). The IRB approved study included 5 healthy volunteers. For each volunteer, scouting was performed by 2D FLASH, followed by SPACE acquired in the coronal plane. In 4 volunteers, 2D TSE (1 slice) was acquired axially at the carotid bifurcation for comparison.
Evaluation: The 2D axial slice from SPACE corresponding to the 2D TSE image was obtained by MPR. True SNR measurement is difficult with PAT. "Apparent" SNRs (aSNRs) were measured in two ways for sternocleidomastoid muscle and vessel wall: (1) mean / standard deviation (SD) at ROI (aSNR1); (2) ratio of mean at ROI to noise SD measured in region free of signal and artifact (aSNR2). The values from 4 volunteers were averaged. Blood suppression was visually assessed due to the very low signal in the lumen.

Results Acquisitions were successful in all subjects. All images were artifact free. Table 1 showed the averaged aSNRs. Both aSNRs from two tissues were higher in SPACE than in 2D TSE though the later has two times the voxel size that of the former (0.34mm^3 in 3D vs 0.66mm^3 in 2D). Fig 1 showed a comparison of the 2D image and the corresponding axial slice from SPACE. The two other views in Fig 1 showed the superior anatomical coverage of the new coil – good signal sensitivity over 100mm (important for plaque morphology assessment along the artery's long axis). In all 5 cases, blood nulling along the artery in SPACE was comparable to 2D TSE. At the bifurcation, slow flowing blood gives similar appearance in both cases (Fig 2). Slab positioning for SPACE was very easy.

		Muscle	Vessel Wall
aSNR1	2D TSE	5.74	5.20
	SPACE	7.69	5.90
aSNR2	2D TSE	14.12	16.20
	SPACE	17.57	20.10

Table 1: Averaged "apparent" SNRs of carotid vessel wall and sternocleidomastoid muscle in 2D TSE and SPACE in 4 healthy volunteers.

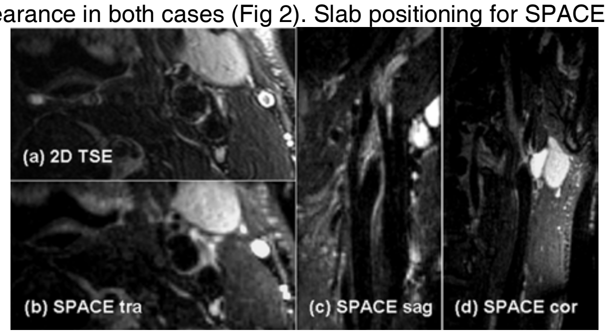

Fig 1: Images from 2D TSE (a) and SPACE (b-d).

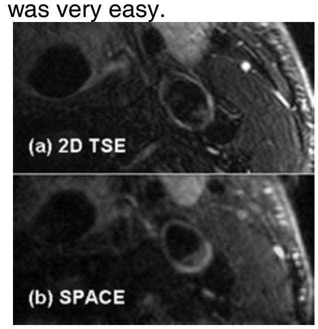

Fig 2: Residual blood in 2D TSE and SPACE.

Discussion The consistently higher aSNRs in SPACE compared to 2D TSE despite the smaller voxel volume in SPACE implies a notable SNR advantage of SPACE over 2D TSE. The voxel size with SPACE is the smallest attainable with 2D TSE in [5]. This SNR gain may come from the synergetic effects of improved coil design and intrinsic higher SNR with 3D acquisition. 3D acquisition benefits more from the improved coil design than 2D imaging because more coil elements are covering the imaging volume. The short scan time minimized subject related motion artifact, improving image quality too. When two coils are used for bilateral carotid imaging, PAT may be used in both phase and partition direction. Scan time reduction and improved isotropic resolution on the same scan may be possible.

Conclusion This preliminary study showed that 3D imaging with an appropriately designed carotid coil give both SNR and spatial resolution improvement within clinically practical scan time. Carotid vessel wall imaging at 3T is more advantageous with SPACE than with 2D TSE regarding SNR gain. The technique may have important applications in serial studies and plaque volume measurements.

References [1] Fayad & Fuster, Neuroimaging Clin N. Am, 12(3), 2002. [2] Rothwell et al., Stroke, 31:615-21, 2000. [3] Hatsukami et al., Stroke, 28:95-100, 1997. [4] Cury RC et al., Invest Radiol, 41(2):112-15, 2006. [5] Yarnykh et al., JMRI, 23:691-8, 2006. [6] Koktzoglou et al., Proc. 14th ISMRM, p.652, 2006. [7] Chung et al., Proc. 14th ISMRM, p.653, 2006.